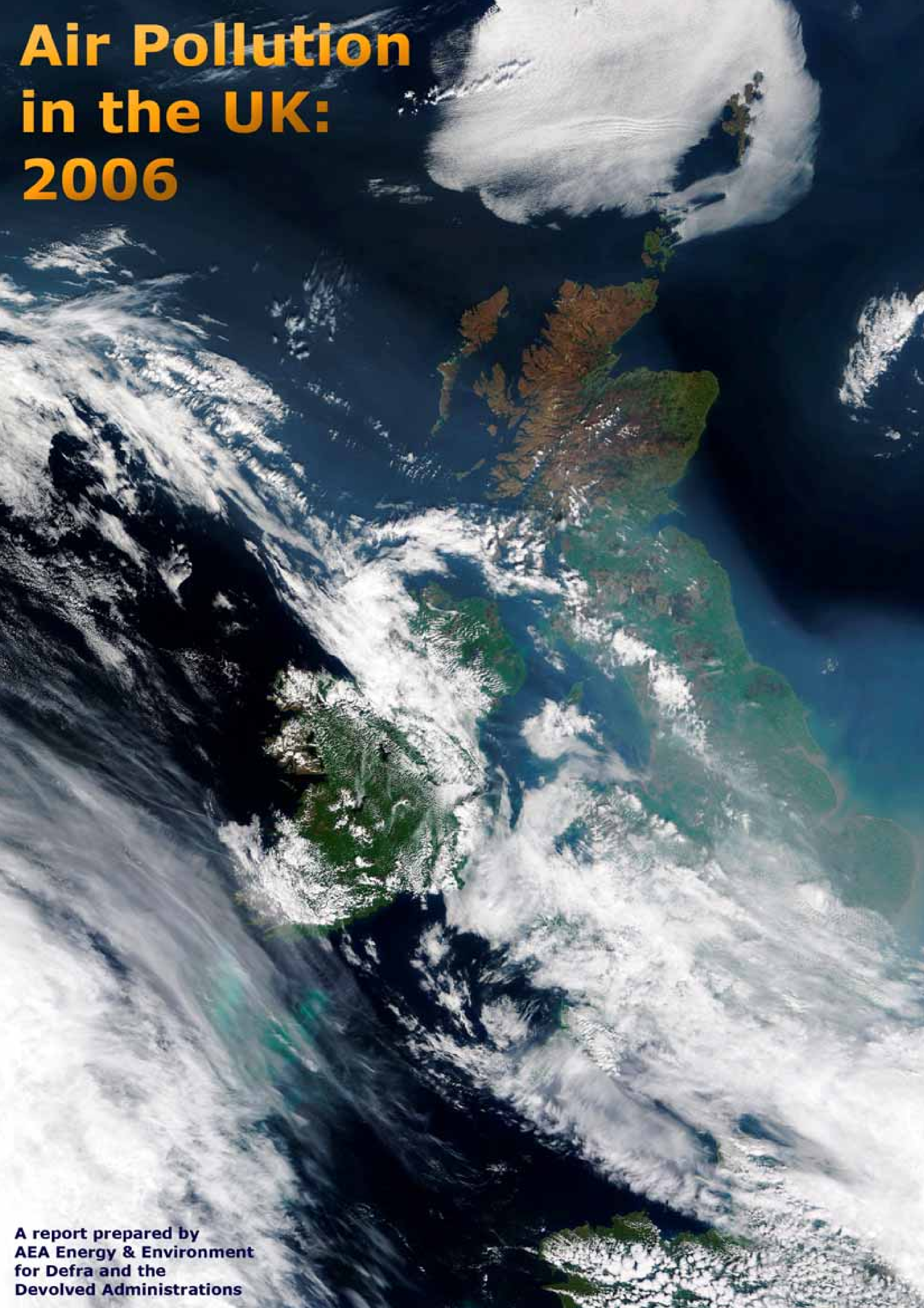
Air Pollution in the UK: 2006



A report prepared by AEA Energy & Environment for Defra and the Devolved Administrations

Front cover image

Satellite image of the May 2006 particle episode, courtesy of Dundee University and the National Environment Research Council (NERC)

Air Pollution in the UK: 2006

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, Geoff Broughton, John Stedman, Andrew Kent, Andy Cook, Jaume Targa, Andy Glynn, Paul Willis 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.

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Didcot power station cooling towers, emerging from a field of rapeseed
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Executive Summary

For those of you who are a bit short of time…

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 2006. The pollutants we summarise and analyse are:

- Ozone (O_3)
- Nitrogen oxides (NO_x = NO and NO_2)
- Sulphur dioxide (SO_2)
- Carbon Monoxide (CO)
- PM_{10} and $PM_{2.5}$ particles
- Benzene
- 1,3-butadiene

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

The measurements we report here were made in national automatic air monitoring networks, comprising 130 stations during 2006. These networks serve a variety 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 2006; we discuss the major developments.
2. ***Describe current UK air monitoring networks, their objectives and methodologies.*** Major continuing changes to these programmes are considered.
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.*** We go further than in previous years in examining these important national-scale patterns of pollution.
5. ***Examine major periods of elevated pollution*** (so called pollution 'episodes') that occurred during 2006. This year, we examine a summer photochemical smog event, together with an interesting particle episode involving long-range transport of pollutants from outside the UK.
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 sampler networks.*** In a first for the annual reports, we review over 40 years of monitoring of black smoke and SO_2 to highlight long-term changes in the UK's pollution climate.
8. ***Identify published, web and media sources for information*** on UK air quality. In particular, we provide details of new national air quality websites.
9. ***Consider how UK pollution levels compare with other parts of Europe*** In another first for this year's annual report, we seek to place the UK's pollution issues in a broader European context.

The report, together with the family of 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 UK's air pollution during 2006.

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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 (see Section 6), but has expanded massively in scope, coverage and sophistication since then. These developments to monitoring programmes continued apace during 2006.

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.

Monitoring air pollution in the UK has the following broad objectives:

- To provide a sound scientific basis for the development of cost-effective control policies and solutions under the UK Air Quality Strategy and Local Air Quality Management (LAQM)
- 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

Figure 1.1. The source-oriented automatic air monitoring station at Grangemouth, Scotland after a heavy storm (© Jon Bower)

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 current UK and European policy efforts and initiatives to tackle air pollution. This year, we highlight a number of significant developments in both areas *(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)*.
- Provide information on where and how to find out more about air pollution emissions, levels and effects in the UK. We also introduce important new web-based air quality information resources for Scotland, Wales and Northern Ireland, as well as important changes to the long-running UK national website *(Section 3).*
- Examine key episodes - major periods of elevated pollution - that occurred in 2006. We give particular prominence this year to a major particle episode in May, which involved the impact of fires from Russia; we also review a photochemical smog episode that extended from late June to early July. *(Section 4).*
- Investigate - through a series of detailed maps and analyses - how pollution levels vary across the UK *(Section 5).*
- Look back at over 40 years of sampler-based monitoring of black smoke and sulphur; we see how this monitoring has revealed long-term changes in UK's air quality *(Section 6)*
- Assess long-term pollution trends in order to see whether pollution levels are declining over time. (*Section 7).*
- Examine how air quality in the UK compares with that in other parts of the Europe *(Section 8).*

The **second part** of the report, from Sections 9 to 17, 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 2006. 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 series of Appendices provide:

- 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: 2006

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 also provide details of how to obtain more information about UK air quality, particularly from the World Wide Web.

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

In two new sections, we review the long-term history of air monitoring in the UK and assess our current pollution levels in a broader European context.

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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 drivers and factors related to air monitoring nationwide.

Over the past decade, air pollution has becoming an increasingly important focus of interest for UK, European and international policy makers. This has been prompted by increasing evidence that air pollution still poses significant risks to our health and amenity, as well as threatening our natural environment. In recognition of this, the European Union's Sixth Environment Action Programme - 'Environment 2010: Our future, Our choice' [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[B2,3], discussed later in this section.

Another factor in the increased attention paid to air pollution is emerging evidence of its 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 inter-linked with air pollution.

2.1 European background

2.1.1 Aspirations and Instruments

Air quality is an area in which Europe has been strongly proactive in recent years. The Community as a whole is acting at many levels to reduce exposure to air pollution, through:

- Established legislation such as the Air Quality Framework and Daughter Directives- discussed below
- Work at the wider international level aimed at reducing cross-border pollution
- Agreement with transport and industrial sectors responsible for air pollution, for example under the Auto Oil II umbrella
- Effective liaison with national, regional authorities and NGOs
- Research undertaken in its own or Member States' institutes and universities.
- Reducing emissions from large combustion plant and mobile sources
- Improving fuel quality and
- Integrating environmental protection requirements more fully into the transport and energy sectors.

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

- Established Limit and Target Values for key air pollutants and defined overall requirements for monitoring compliance with limit values and progress towards targets.
- Defined the monitoring, modelling and air quality management obligations of Member States
- Set targets for pollutant emissions in different types of industry as well as in the transport sector
- Confirmed the need to communicate information on air quality to the public at large.

In 1996, the Environment Council adopted Framework Directive 96/62/EC[B4] on ambient air quality assessment and management. This key Directive revised and harmonised pre-existing legislation for a range of air pollutants. It also extended the scope of legislation to cover an increased range of pollutants, and set a timetable for the development of Daughter Directives; these have specified the detailed Limit and Target Values, monitoring and assessment methods for:

1) Sulphur dioxide, nitrogen dioxide, lead and particulate matter (1st Daughter Directive)
2) Benzene and carbon monoxide (2nd Daughter Directive)
3) Ozone (3^{rd} Daughter Directive)
4) Arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons (4^{th} Daughter Directive)

A list of current EC Directive Limit and Target Values for air pollutants covered by the Directives 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 Open access to Information

The right of all citizens to information on the quality of the air we breathe is an important cornerstone of both UK and European air quality policy. In fact, the Daughter Directives impose important requirements on Member States to advise the public when Information and Alert Thresholds for specified pollutants are exceeded.

The Directives specify the detailed requirements for reporting measurements from national monitoring networks to the European Commission. In addition, a Community-wide procedure for the exchange of information and data on ambient air quality in the European Community has also been established by Council Decision 97/101/EC[B5]. The decision introduces a scheme for the reciprocal exchange of information and data relating to the networks and stations established in the Member States to measure air pollution, together with the air quality measurements from those stations.

The 1998 Århus Convention[B6] on environmental openness is another important instrument for ensuring an informed public; this is designed to guarantee citizens across the continent the right to information, public participation in decision-making and access to justice in environmental matters.

We identify throughout this report a series of information resources enabling UK technical, local authority and public end-users to obtain up-to-date information on local or national air quality; this report, in itself, represents one of the range of published, media and web resources intended for this purpose in the UK.

2.1.3 Development of the Thematic Strategy on Air Pollution

An important focus within the European Community for the next ten years will be implementation of air quality standards and increasing the coherency of all air legislation and related policy effort. The main frameworks and initiatives for achieving this are described here:

The Sixth Environment Action Programme (6^{th} EAP) is a wide-ranging programme of Community action on the environment with key objectives covering a period of ten years, 2002 to 2012. The priorities of the 6th EAP cover climate change, nature and biodiversity, environment, health and quality of life, and natural resources and waste.

The 6^{th} EAP introduced the concept of 'Thematic Strategies' - coherent and integrated policies addressing specific environmental issues. They are intended to modernize the European Union's environmental policy-making process; the policies adopt an integrated approach, which acknowledges that the effects of decisions in one policy area may impact on others. The 6th EAP calls for the development of seven thematic strategies, covering waste prevention and recycling, the marine environment, soil, pesticides, natural resources, the urban environment, and *air pollution*.

The development of the Thematic Strategy for air pollution was underpinned by **the CAFÉ (Clean Air For Europe)** [B7] **programme.** CAFE was set up in 2001 to develop, collect and validate scientific information about air pollution throughout Europe, with the aim of reviewing current policies and assessing progress towards long-term objectives. CAFÉ provided much of the technical analysis and consultation that was fed into the process of developing the Thematic Strategy.

CAFE sets out a long-term perspective for achieving cleaner air in Europe. It seeks to do this in a way that is cost-effective, as well as cconsistent with the objective of growth and employment (the Lisbon Strategy) and the EU Sustainable Development Strategy. The Strategy is a major policy initiative; it presents a coherent and integrated policy on air pollution which:

- Sets out priorities for future action;
- Reviews existing ambient air quality legislation with a view to reaching long-term environmental objectives; and
- Develops better systems for gathering information, modelling and forecasting air pollution.

The Thematic Strategy on Air Pollution was published in September 2005, and is available at
http://eur-lex.europa.eu/LexUriServ/site/en/com/2005/com2005_0446en01.pdf

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

1. Current legislation be modernised
2. Efforts should focus on the most serious pollutants and that
3. More should be done to integrate environmental concerns into other policies and programmes.

The Strategy is designed to substantially improve Europe's air quality over time. It aspires to prevent thousands of premature deaths from pollution-related illnesses and drastically reduce damage to crops, forests and other ecosystems. Although 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.

The Strategy represents a modern way of decision-making. It has been based on extensive research and consultation with stakeholders, and seeks to address the core issues in a holistic way that fully takes into account links with other problems and policy areas. At the same time, it involves an integrated assessment of different environmental and health effects, and aims to provide the most cost-effective solution for the chosen level of objectives.

2.1.4 Implementation of the Thematic Strategy on Air Pollution

The Strategy acknowledges that despite significant improvements in Europe's air quality - driven both by legislation and other factors- air pollution continues to have serious human health and environmental effects throughout Europe. It results in several hundreds of thousands of premature deaths each year, together with increased hospital admissions, extra medication, and millions of lost working days. The health and societal costs to the European Union are substantial. In addition to these impacts, there are also additional costs relating to environmental damage through acidification of ecosystems and damage to crops and forests; however, these are often notoriously difficult to quantify.

Even if all relevant technically feasible measures were applied irrespective of cost, it would not be possible by 2020 to meet the ambitious objective of the 6th Environment Action Programme to attain "*levels of air quality that do not give rise to significant negative impacts on, and risks to, human health and the environment*" . Therefore, policy decisions must be based on a full analysis of the costs and benefits associated with various possible measures.

While covering all major air pollutants, the Strategy pays special attention to particles and ground-level ozone pollution, because it has been conclusively demonstrated that these pose the greatest danger to human health, and no safe levels have yet been identified for either pollutant. Under the Strategy, the Commission is proposing for the first time to start regulating fine airborne particulates, known as $PM_{2.5}$, which penetrate deep into human lungs. This would require reductions in average $PM_{2.5}$ concentrations throughout each Member State and set a cap on concentrations in the most polluted areas. These developments are likely to have wide-ranging implications for the UK's national monitoring networks measuring particulate matter (see also Section 3).

The main actions proposed under the Thematic Strategy on Air Pollution are as follows:

1. To revise and streamline current air quality legislation.

As a result, the European Council is currently considering a proposal for a new Air Quality Directive, which would:

- Combine and streamline the Framework Directive, the first three of its four Daughter Directives, and the Exchange of Information Decision 97/101/EC in line with better regulation principles
- Confirm many of the existing directives' obligations, but introduce some flexibility in meeting those obligations under some circumstances:
    - The possibility to extend the attainment deadline for some limit values in exceptional circumstances
    - The ability to disregard the contribution to air pollution from natural sources – for example natural wind-blown dusts - when determining compliance with limit values
    - Greater clarity on where to assess air quality, so that the focus is on areas where members of the public could be exposed.
- Introduce controls on fine particulate, measured as $PM_{2.5}$, in the light of clear scientific evidence that fine particles are most hazardous to health.
- Introduce an "exposure reduction" approach, which would aim to improve air quality in areas where the greatest numbers of people are exposed, not just in areas that exceed a Limit Value.

A preliminary position was adopted in June 2006, and it is expected that the revised directive will be adopted in early 2008.

2. To revise the National Emissions Ceiling Directive.

The Commission also intends to propose a revision of the National Emissions Ceilings Directive, in order to bring its emissions ceilings into line with the objectives of the Strategy. This will ensure reduced emissions of a range of pollutants – SO_2, NO_x, primary particulate matter, VOCs and ammonia - in line with the interim objectives proposed in the strategy for 2020.

3. To integrate air quality concerns into other policy areas.

These include –

- Energy, in line with the EU's existing target of producing 21% of all energy, and 21% of electricity, from renewable sources by 2010. Measures to ensure more efficient use of energy are also included.
- Controls on smaller combustion plant, with the Commission to examine whether the IPPC Directive should be extended to sources below 50 MWth.
- Investigation of the scope for further reducing VOC emissions from petrol stations.
- Transport: encouraging shifts towards cleaner vehicles, alternative fuels, reducing congestion and other measures.
- Initiatives already in place to revitalise and integrate European rail systems, and measures to improve efficiency of inter-modal freight transport.
- A range of other possible measures will be examined, such as the introduction of new car emission standards and other initiatives in the energy, transport and agriculture sectors, the Structural Funds and international cooperation.

Fig 2.1 Cost benefit analysis- an important part of European Strategies

Some of the benefits expected as a result of the implementation of the Strategy are summarised below:

- It has been estimated that the Strategy will reduce the number of premature deaths across Europe that are related to fine particulate matter and ozone from 370,000 a year in 2000 to 230,000 in 2020. Without the Strategy, there would still be over 290,000 premature deaths a year in 2020.
- It has also been calculated that the Strategy will deliver health benefits worth at least €42 billion per year through fewer premature deaths, less sickness, fewer hospital admissions and improved labour productivity. This is more than five times higher than the cost of implementing the Strategy. This is estimated at around €7.1 billion per annum, or about 0.05% of EU-25 GDP in 2020.
- Although there is no agreed way to express damage to ecosystems in monetary terms, the environmental benefits of reduced air pollution are also significant. The Strategy will protect several hundred thousand square kilometres of forest and other sensitive ecosystems.
- Moreover, it is intended that European companies will gain competitive advantage by focusing research and development on less polluting technologies that other countries may eventually need to adopt.

2.2 The UK perspective

Although the lethal smogs in London and other cities caused by coal burning have now gone for good, air pollution remains a problem in the UK. Medical evidence shows that many thousands of people die prematurely every year because of the effects of air pollution. Air pollution from man-made particles is currently estimated to reduce the life expectancy of every person in the UK by an average of eight months. Many more become unwell or may require hospital treatment.

The health impacts of air pollution are estimated to cost the UK between £9.1 billion and £21.4 billion per year. The very young, old and infirm are often particularly affected, as well as people living in deprived areas. In addition, sensitive ecosystems are also affected. More than half of all natural and semi-natural habitats in Britain still have too high levels of harmful acidity and/or nutrient deposition.

As highlighted in the previous section, the UK - as a Member State of the European Community - has obligations to address air pollution issues. However, the UK also has its own Air Quality Strategy in place, and this is discussed below.

2.2.1 The UK Air Quality Strategy

The Air Quality Strategy for England, Scotland, Wales and Northern Ireland, first published in March 1997, and reviewed in 2000 and 2007, has established a strong framework for tackling air pollution over the coming years [B2,,B3]. The Strategy is available in full at www.defra.gov.uk/environment/airquality/strategy/. The continuing objectives of the Strategy are to:

- Map out future ambient air quality policy in the United Kingdom
- 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
- Provide a framework to help identify what we all can do to improve air quality.

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. In the majority of cases, these are incorporated into UK legislation for the purpose of Local Air Quality Management by means of the Air Quality Regulations 2000 and (Amendment) Regulations 2002 (although there are some exceptions for pollutants such as ozone which are in practice difficult to control by local action) [B9,B10].

The UK Air Quality Strategy's main focus is on protecting the health of the population at large; however, the Strategy has also established corresponding targets for the protection of vegetation, ecosystems and the natural environment. Air monitoring provides a key tool in assessing how far the health objectives and other environmental targets are being met throughout the UK.

As our knowledge of the health effects of these pollutants has deepened, the objectives have been progressively refined and strengthened. Objectives for a ninth pollutant, Polycyclic Aromatic Hydrocarbons (PAHs) were introduced in 2003.

However, despite overall improvements in UK's air quality, it had become clear that additional controls may be needed to meet the Strategy's objectives for particulate matter, nitrogen dioxide, ozone and polyaromatic hydrocarbons in some urban areas.

Also, emerging research has highlighted two important aspects relating to the health impacts of particulate pollution: firstly, the importance of the fine particulate fraction $PM_{2.5}$, and secondly, that there appears to be no 'threshold' below which exposure to particles has no effect on health. Air pollution also caused over half the UK's natural and semi-natural habitats to exceed harmful levels of acidity in 2003.

These concerns formed the basis for the next major review of the Strategy, which was carried out largely during 2006. The aim of the Air Quality Strategy review was to assess:

- The UK's predicted air quality to 2020
- Progress towards meeting the current AQS objectives
- Additional policy measures required to improve air quality
- The current AQS Objectives, and the case for new ones (in particular for $PM_{2.5}$)

Between April and July 2006, Defra undertook a thorough and detailed consultation exercise to seek stakeholders' views on a number of potential additional national policy measures designed to cut air pollution, reduce breaches of air quality objectives and improve human health. (Climate change and ecosystem protection were also taken into account). These measures covered transport, industry, fuel use and other areas. Detailed cost-benefit analyses were carried out on a range of potential policy options. Extensive use was made of modelling techniques, to assess the effectiveness of the various policy options in improving air quality.

A study by the Committee on the Medical Effects of Air Pollution (COMEAP) on the long-term effects of exposure to air pollution was carried out concurrently with the review, and its report published to coincide with the release of the new strategy.

The new Air Quality Strategy was released in July 2007[B11,B12]. All the previously existing Air Quality Strategy Objectives have been retained, apart from the provisional PM_{10} objectives originally proposed for 2010 in England, Wales and Northern Ireland, which have been replaced by 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.

The Strategy also introduces an exposure reduction approach for managing exposure to $PM_{2.5}$. There is clear evidence that there is no 'safe' level for exposure to fine particles – no "threshold" below which no health impacts are expected to occur. The Strategy therefore concludes that, for this pollutant, a policy based on achieving standards or objectives alone is not going to generate the maximum benefit in public health for the investment made; this is because such a policy would focus only on the areas where concentrations are highest, while in reality adverse effects on health are likely to be much more widespread.

The exposure reduction approach takes the view that the maximum benefit for the most people will be obtained cost-effectively by reducing pollutant levels across the whole urban area, rather that focussing action on 'hot-spot' areas exceeding Objectives. 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, as at present. These are referred to as a 'backstop' objective.
- 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. This is intended to generate further improvements over and above the protection afforded by the backstop objective.

These two aspects of the new approach are inseparable: the concept of the 'backstop objective' is an essential counterpart to the exposure reduction target. This ensures a minimum level of acceptable air quality for all – an essential aspect of social justice. The backstop objectives for annual mean $PM_{2.5}$, to be met by 2010, are 12µg m^{-3} in Scotland (where levels are typically lower) and 25 µg m^{-3} in the rest of the UK.

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.

The existing objectives for PAH (as benzo (a) pyrene) and for 15-minute mean SO_2 concentration, have been retained.

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 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.

As well as setting Air Quality Objectives, the review also considered specific measures to reduce pollutant emissions and improve ambient air quality. Policies to be considered include:

- Incentivising the early uptake of new tighter European vehicle emission standards (Euro 5 and Euro 6 for cars).
- Increasing uptake of low emission vehicles
- Reducing emissions from ships – reduction of sulphur content of marine fuels, and reducing emissions of NOx from ships' engines.
- National road use charging.
- Low emission zones, similar to that already being implemented in London from February 2008.
- Retrofitting catalyst-based diesel particulate filters to existing HGV vehicles, buses and coaches to bring them up to Euro 5 standards.
- Reducing emissions from small combustion plants (20 – 50 MW)

A summary of the current UK Air Quality Strategy Objectives is provided in Table 2.1a and b overleaf. The new objectives arising from the recent review of the Strategy are highlighted by shading.

Table 2.1a UK Air Quality Objectives for protection of human health, July 2007. New objectives highlighted 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 $\mu g\ m^{-3}$ 0.25 $\mu g\ m^{-3}$	Annual mean Annual mean	31.12.2004 31.12.2008
Nitrogen dioxide	200 $\mu g\ m^{-3}$ not to be exceeded more than 18 times a year 40 $\mu g\ m^{-3}$	1-hour mean Annual mean	31.12.2005 31.12.2005
Particles (PM_{10}) (gravimetric) All authorities	50 $\mu g\ m^{-3}$, not to be exceeded more than 35 times a year 40 $\mu g\ m^{-3}$	24-hour mean Annual mean	31.12.2004 31.12.2004
Scotland only	50 $\mu g\ m^{-3}$, not to be exceeded more than 7 times a year 18 $\mu g\ m^{-3}$	24-hour mean Annual mean	31.12.2010 31.12.2010
Particles ($PM_{2.5}$) (gravimetric) * All authorities	25 µg m^{-3} (target) 15% cut in urban background exposure	Annual mean Annual mean	2020 2010 - 2020
Scotland only	12 µg m^{-3} (limit)	Annual mean	2010
Sulphur dioxide	350 $\mu g\ m^{-3}$, not to be exceeded more than 24 times a year 125 $\mu g\ m^{-3}$, not to be exceeded more than 3 times a year 266 $\mu g\ m^{-3}$, not to be exceeded more than 35 times a year	1-hour mean 24-hour mean 15-minute mean	31.12.2004 31.12.2004 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. New objectives highlighted in shading

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

** Not included in regulations at present*
$^{+}$ AOT 40 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.

2.2.2 The Air Quality Banding System used for Media Reporting

Although comprehensive and soundly science-based, the UK's Air Quality Objectives are not particularly easy for the general public to understand, particularly on a day-to-day basis.

A simpler air quality banding system is therefore used extensively for media-based reporting of air quality and potential health effects to the public. This is summarised in Box 1 below.

The use of air quality bands on the home page of the UK Air Quality Archive (www.airquality.co.uk) is illustrated in Figure 2.2.

Fig 2.2 Air Quality bands are easy to understand

Box 1. The UK Air Quality Banding System

- When air pollution is LOW (1-3) effects are unlikely to be noticed even by those who are sensitive to air pollution.
- When air pollution is MODERATE (4-6) sensitive people may notice mild effects but these are unlikely to need action.
- When air pollution is HIGH (7-9) sensitive people may notice significant effects and may need to take action.
- When air pollution is VERY HIGH (10) effects on sensitive people, described for HIGH pollution, may worsen.

2.2.3 The Air Quality Indicator for Sustainable Development

Air quality is one of the UK Government's 68 key headline indicators of sustainable development. These provide a 'quality of life barometer' measuring everyday concerns, and are intended to give a broad overview of whether we are achieving a better quality of life for everyone, now and for generations to come.

A set of statistical parameters has been defined as the UK's 'Air Quality Indicator'. These statistics are reported annually by Defra, soon after the end of the calendar year.

An air quality headline indicator was first introduced in support of the UK Sustainable Development Strategy in 1999. It was expanded when the strategy was revised in 2005, to include more components, better reflecting the effects on health of long term exposure to lower levels of pollution.

The air quality indicator now comprises two parts:

- Part a), which includes trends for annual levels of particulate and ozone pollution, the two pollutants thought to have the greatest health impacts.
- Part b), which covers the number of days on which levels of any one of a basket of five pollutants were 'moderate or higher', as defined by the banding system used by the Air Pollution Information Service (www.airquality.co.uk/archive/standards.php#band). (Part b is the same as the air quality headline indicator of the former (1999) sustainable development strategy.

We'll be looking more closely at the latest air quality indicator levels for 2006 in Section 7 of this Report.

2.3 A Local Focus: grass-roots monitoring

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 Air Quality Strategy 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 both their first and second rounds of reviews and assessments against the Strategy's objectives prescribed in the 2000 Air Quality Regulations, together with subsequent amendments, and are now commencing the third round of assessment [B13,B14,B15].

To date, 207 Local Authorities – roughly 45% of those in the UK - have established one or more AQMAs, most of these in urban areas and resulting from traffic emissions of nitrogen dioxide (NO_2) or PM_{10} particles. The location of current UK AQMAs is shown in Figure 2.3.

Road traffic emissions are the main source in 95% of the AQMAs; only a few have been designated as a result of industrial sources, domestic or shipping emissions. A full list of these authorities declaring such areas may be found at: http://www.airquality.co.uk/archive/laqm/list.php. More information on AQMAs is summarised in Table 2.1 below.

Table 2.1 Current UK-wide status of Air Quality Management Areas (AQMAs) and Action Plans (July 2006)

Region	Total No. of Local Authorities	No. of LAs with AQMAs at end of Round 1 (April 2003)	Number of LAs with AQMAs (Aug 2007)	Due to NO_2	Due to PM_{10}	Due to SO_2	Due to Benzene	Draft (Final) Action plans submitted (Aug 2007)
England (excl London)	320	93	150	140	33	11	1	124 (51)
London	33	31	33	32	26	0	0	3 (0)
Scotland	32	4	9	6	3	1	0	1 (3)
Wales	22	4	5	4	1	0	0	1 (0)
N. Ireland	26	3	10	4	6	1	0	1 (0)
TOTAL	433	135	207	186	71	13	1	130 (64)

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. 130 authorities have now produced such action plans, setting out the measures they proposes 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 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 stand alone 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/laqm/guidance/index.htm.

Methodologies for local review and assessment continue to develop and improve throughout the UK. To date, since the end of the 1st round in April 2003, approximately 62 authorities in England, 4 in Scotland, and 1 in Wales have identified the need to designate new AQMAs as a result of Detailed Assessments carried out as part of the second round of reviews and assessments. Around 40% of these authorities previously declared AQMAs during the first round of the LAQM process. 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.

Authorities in Northern Ireland are now well into Round 2 of their reviews and assessments. Together with the rest of the UK, they submitted Progress Reports in April 2005. Round 1 in Northern Ireland, which was undertaken on a different timescale to the rest of the UK, resulted in 11 AQMAs being declared. The review and assessment timetable in Northern Ireland is now running in parallel to that in the rest of the UK. 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.

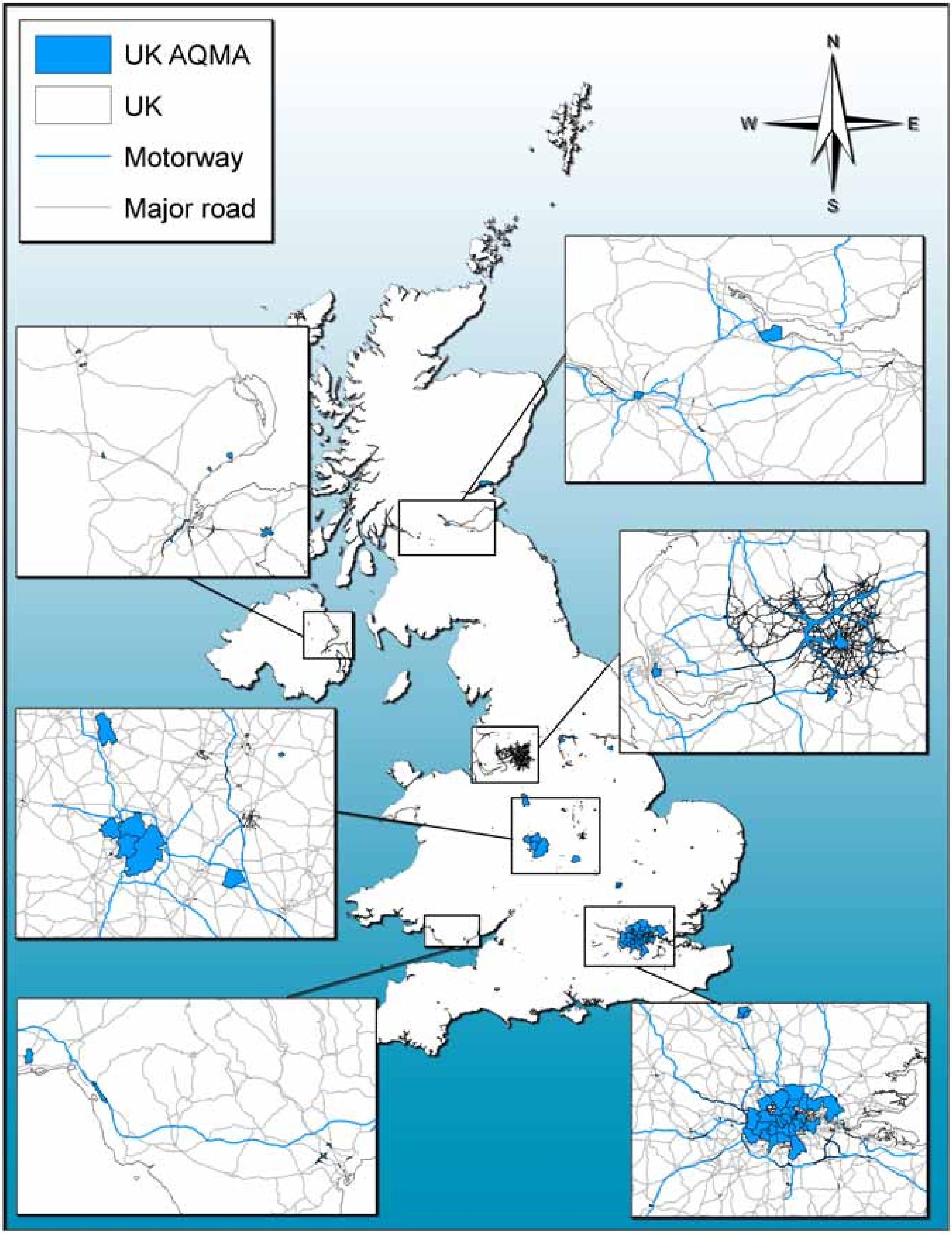


Figure 2.3 Map of UK Air Quality Management Areas (AQMAs), 2006

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

To manage something effectively, you first have to measure it…

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

In the UK, air pollution policy development relies heavily on the national air quality monitoring networks to provide basic 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.

Monitoring data have also played a central role in the development of the UK's Air Quality Strategy and in formulating national Air Quality Objectives. In addition, measurements from our networks provide the necessary data for determining compliance with the European Union's Air Quality Directives.

We are all polluters. 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 3.7.

3.2 A Brief History of Monitoring in the UK

The history of air pollution monitoring in the UK goes back a long way. Measurements of air pollutants and deposited dust have been carried out in the UK since the beginning of the 20th century, and the UK's first co-ordinated national air pollution monitoring network was set up in 1961. This monitored black smoke and sulphur dioxide, primarily in response to the serious urban smogs of the 1950s and 60s. Originally called the National Survey, this major network (which is reviewed in Section 6) went on to monitor the massive improvement of air quality since a succession of Clean Air Acts[C3] successfully targeted domestic and industrial coal burning.

The emissions responsible for this type of winter smog have decreased substantially over the years and, as a result, road transport has now become the most important source of air pollution in many parts of the UK. It is also – by far - the dominant source of pollution in all our cities. In response to this historic change, the emphasis in monitoring has moved progressively to pollutants such as ozone, nitrogen dioxide and fine particulate matter

Research measurements of air pollution using automatic analysers commenced in the UK during the early 1970s. Later, continuous measurements were increasingly required for regulatory purposes; as a result, a UK urban monitoring network was first established in 1987 to monitor compliance with the emerging EC Directive limit values on air quality. This network subsequently expanded, following commitments by Government to expand urban monitoring in the UK and improve public availability of air quality information.

Another landmark year in the evolution of automatic monitoring in the UK was 1992, when the Department of Environment–funded Enhanced Urban Network (EUN) was established. 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.

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).

The expansion in automatic monitoring is clearly illustrated in Figures 3.1 and 3.2, where we show the increase in site numbers and total hourly measurements made since the commencement of automatic air quality monitoring in the UK. At the time of writing (2007) the AURN consists of 130 sites and remains the most important single monitoring programme in the UK today.

Data from the AURN, together with corresponding measurements from the UK's network of six automatic stations monitoring hydrocarbon pollutants, are presented in this report. During 2006, the 130 sites comprising the AURN (of which 14 are London Network sites) comprised 27 kerbside and roadside sites, 81 urban and suburban non-roadside sites, and 22 rural and remote sites. 66 sites are directly funded by Defra and the Devolved Administrations, whilst 64 are affiliated sites owned and operated by Local Authorities and other organisations.

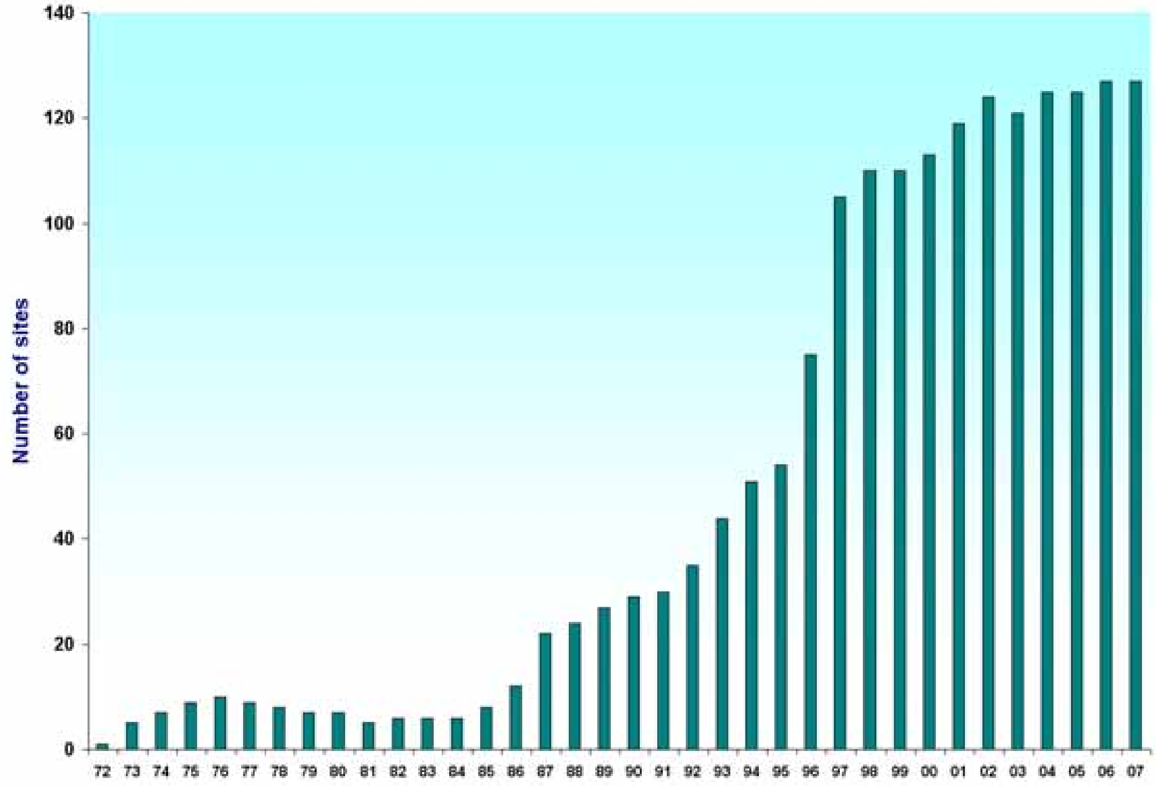


Figure 3.1 The number of government-funded automatic measurement stations in the UK has grown substantially since 1972

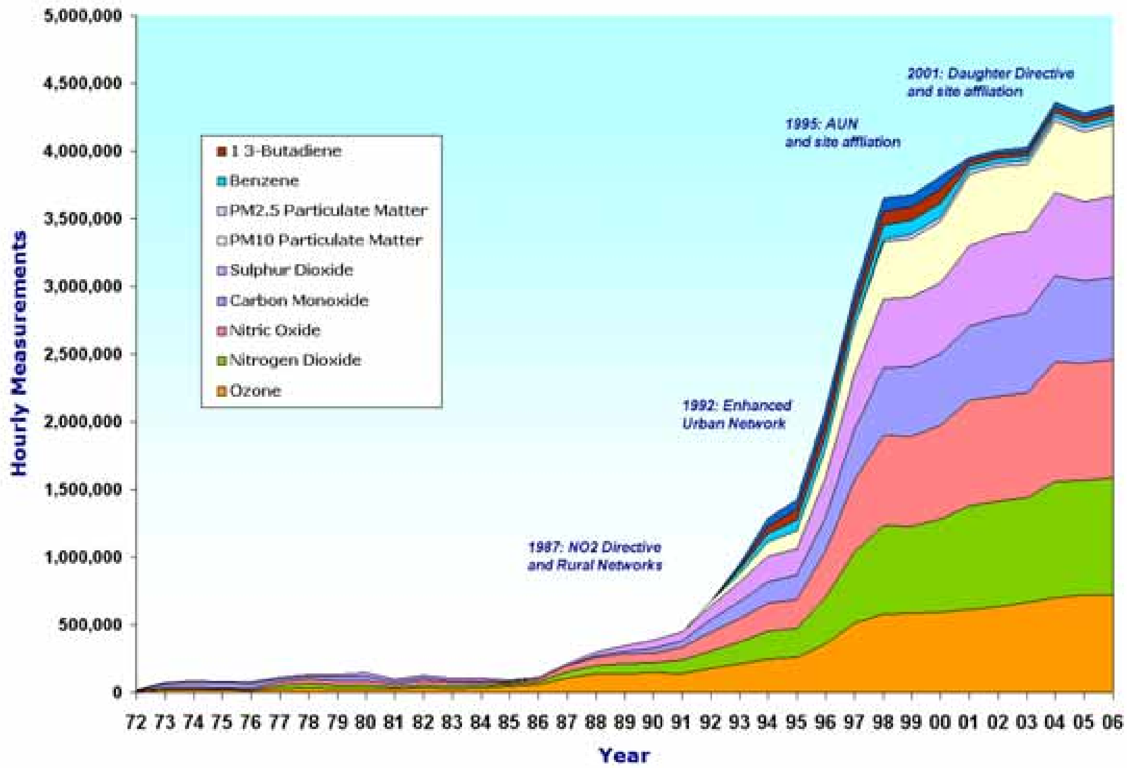


Figure 3.2 The number of hourly measurements made every year has also increased dramatically for all pollutants in the automatic monitoring networks (O_3, NO_2, CO, SO_2 and PM_{10}) and for other UK Strategy pollutants

3.3 Changes in the Monitoring Networks

The UK's automatic networks continue to evolve year-on-year. Changes in these programmes during the past year are summarised in Table 3.1.

Table 3.1 Changes to the UK automatic networks in 2006 and 2007

Sites	Date started up/closed	Pollutants
Newly established sites		
Auchencorth Moss	9th Jun 2006	VOCs, O_3, PM_{10}, $PM_{2.5}$
Fort William	22nd Jun 2006	NO_x, O_3
Inverness PM_{10}*	1st May 2007	PM_{10}
Swansea Roadside	20th Sep 2006	NO_x O_3 CO SO_2 PM_{10} $PM_{2.5}$
Wrexham PM_{10}	21st Mar 2007	PM_{10}
Site Relocations		
Bristol Centre relocated to Bristol St. Pauls	Bristol Centre closed 15th Sep 2005. Bristol St. Pauls started 15th Jun '06	NO_x O_3 CO SO_2 and PM_{10}
Port Talbot relocated to Port Talbot Margam	Port Talbot Closed down 23rd Jul '07 Port Talbot Margam started 24th Jul '07	NO_x O_3 SO_2 and PM_{10}
Sites Closed		
Swansea	Closed down 7th Aug 2006, Urban centre site replaced by Swansea Roadside.	NO_x O_3 CO SO_2 and PM_{10}

** Automatic hourly monitors installed to run in parallel with existing daily gravimetric samplers*

However, it's not just the UK's automatic monitoring networks that have expanded massively. In fact, all of the UK's monitoring programmes have evolved considerably over the past 10 years. These changes have been 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.

As well as the sites in the AURN, 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 now contribute data to nationally organised measurement programmes that are funded and supported by Central Government and the Devolved Administrations.

It should be emphasised that this report deals only with measured data from national monitoring programmes, including Local Authority sites that are affiliated to these programmes. All sites in these networks are subject to stringent quality control programmes that ensure high levels of measurement consistency and accuracy - see Section 3.6.

The value of air quality monitoring undertaken by Local Authorities - but outside the auspices of national networks - should not be underestimated, however. Information from these monitoring sites provides a sound basis for Local Air Quality Management, planning and decision-making. The quality of data from these programmes can also be high. Many sites not affiliated to national networks are now subject to the same level of quality assurance and control procedures as used in these programmes; this ensures that measurement quality and integrity is fully harmonised with national networks.

As highlighted in the previous report, the end of 2005 marked the closure by Defra of two major non-automatic monitoring networks - the UK Smoke and Sulphur Dioxide (SO_2) Network, and the NO_2 Diffusion Tube Network; these closures were in response to a number of factors including:

- Changes in the UK’s pollution climate,
- Changes in monitoring requirements
- The increasingly widespread availability and use of automatic techniques.

Section 6 tells the story of the Smoke and Sulphur Dioxide Network, and what it achieved over its 44 years of operation.

The new black smoke network, designed to continue measurements of this useful measure of particles, is discussed in Section 5 and described in detail in Appendix A3.

However, non-automatic techniques remain an important part of the UK’s air pollution monitoring. Subsequent parts of Section 3 summarise some of the non-automatic air quality monitoring activities currently undertaken in the UK to monitor pollutants including heavy metals, toxic organic micropollutants, PAHs and acid deposition.

3.4 Particle Measurements

Particulate matter poses a public health risk in the UK. It is important, therefore, that this pollutant is measured accurately and reliably in the AURN, the UK’s major automatic monitoring programme, as well as by Local Government for the purpose of Local Air Quality Management.

Unlike the standard ‘reference' method of the EU first Daughter Directive used by some countries - which produces data several days after particles are collected - the majority of monitors in the UK's network allow near real-time dissemination of information to the public; these provide sensitive individuals with the opportunity to take appropriate action should particulate levels increase.

The Equivalence Programme for monitoring particulate matter is a European Union requirement of all Member States not using the standard ‘reference' method. It ensures that the data they produce are consistent, enabling a harmonised framework for comparison of air quality across Europe.

Under this programme, the UK has completed a comprehensive evaluation of particle measurement systems currently deployed in our national networks. The results of this study, one of the most extensive yet undertaken, show that:

- The EU’s equivalence criteria are met by three monitor types (Partisol 2025 Sequential Sampler; Tapered Element Oscillating Micro-balance (TEOM) retrofitted with Filter Dynamic Measurement System (FDMS) for PM_{10} and $PM_{2.5}$; and the OPSIS SM200 by Beta) without correction for slope and/or intercept.
- Two further monitor types (OPSIS SM200 by Mass, and Met One Beta Attenuation Monitor (BAM)) meet the criteria after correction for slope and/or intercept; and
- The conventional TEOM method does not meet the equivalence criteria, with or without a correction factor. This result is consistent with preliminary investigations carried out for Defra and the Devolved Administrations.

The findings have major implications for the future development of particle monitoring in the UK. Upgrade or replacement of the TEOMs in the UK monitoring network is being implemented during 2007/8. For AURN sites and Local Authorities continuing to use standard TEOM analysers, the default correction factor of 1.3 for conventional TEOMs should continue to be used until existing equipment is changed. Further information is provided by Defra and the DAs via its local authority air quality support helpdesk (0870 190 6050; www.laqmsupport.org.uk- see also Box 3.3).

A further PM_{10} / $PM_{2.5}$ intercomparison study has been commissioned in 2007, to investigate the performance of a number of additional PM analysers, including the updated TEOM FDMS.

The report on the earlier UK's Equivalence Programme evaluations is available in full on the UK Air Quality Information Archive at:
www.airquality.co.uk/archive/reports/cat05/0606130952_UKPMEquivalence.pdf
Data are also available from here.

3.5 Current UK Monitoring Programmes

There are currently over 400 national air quality monitoring sites across the UK, organised into several automatic and non-automatic networks with different scope and coverage. Clearly defined objectives have been set for each of these, in order to optimise network design, select priority pollutants and appropriate measurement methods, and to determine the required level of quality assurance/control and data management. As noted in the introduction, the primary objectives of current UK networks are:

- To understand air quality problems in order that cost-effective policies and solutions can be developed
- To assess how far UK and European standards and targets are being achieved
- To provide public information on current and forecast air quality
- To assist the assessment of personal exposure to air pollutants.

However, in practice, each network offers a different balance of objectives, and is structured, organised and quality controlled accordingly.

As discussed previously, 131 of these sites operate automatically in the AURN, with one site in the Republic of Ireland also affiliated to the network; these are split nationally as follows:

Country	Site numbers
England	104
N. Ireland	5
Wales	8
Scotland	13
Ireland	1

These automatic sites provide high-resolution hourly information on a range of pollutants that is communicated rapidly to the public. The non-automatic sites measure average concentrations over a specified sampling period (typically from a day to a month) instead of instantaneous concentrations, but still provide invaluable data for assessing levels and impacts of pollution across the country as a whole.

A map of current UK automatic monitoring sites is provided in Figure 3.3. In the accompanying Figures 3.4 and 3.5, we map corresponding sampler-based measurement sites and show how the different networks provide comprehensive measurement coverage over the UK. Maps showing measurement coverage in different parts of the UK are presented in Appendix 2, whilst additional site maps for individual pollutants feature in Sections 9-17 of this report.

The UK's combined use of both automatic and sampler-based programmes for air monitoring has evolved over the last 40 years as the best way of quantifying pollutant behaviour in both space and time, whilst also maximising cost-effectiveness. This approach uses sampler measurements to provide good spatial coverage, area-resolution and 'hot-spot' identification. Samplers can also be used to provide compliance data for pollutants such as benzene, where European Limit Values apply for annual average concentrations. By contrast, automatic analysers, deployed at carefully selected locations, provide more detailed time-resolved data for assessing peak concentrations and for comparison with short-term UK Air Quality Objectives or EC Limit Values.

Sampler-based air measurements continue to be of considerable use in the UK. Black Smoke measurements were the earliest systematic measurements of air pollution by particulate matter in the United Kingdom, with records dating back to the 1920s. They are still believed to provider a useful measure of potential health impacts.

In 2005, monitoring of Black Smoke ceased to be a regulatory requirement in the United Kingdom, with particulate matter being regulated as PM_{10} and $PM_{2.5}$. In that year, Defra commissioned an independent review of the UK urban network for measurement of Black Smoke, SO_2 and NO_2. Its recommendations for Black Smoke monitoring included continuing a network of about 20 sites, some of which should be at AURN locations.

This newly established Black Smoke Network, discussed further in Appendix A5, commenced on 1st September 2006. It covers 10 existing AURN sites, together with 11 existing Black Smoke sites.

The pollutants measured, site numbers and areas covered in the UK's nationally co-ordinated monitoring networks are summarised in Table 3.2, whilst the main features of individual programmes are summarised in Table 3.3. Further information on the different UK air monitoring networks is provided in Appendix 3.

Many of the networks, and particularly those involving automatic measurements, are large-scale and involve a wide range of participating organisations. A good example is the AURN; this has a devolved structure with separate specialised organisations performing different duties (Figure 3.6). There is also an important role for local organisations, which are typically responsible for ongoing site operations. However, overall management and quality assurance functions for the network are centrally co-ordinated in order to ensure fully harmonised and consistent outputs.

The data from this and similar networks, presented in this report, therefore represent the end-product of the efforts of many persons and organisations in the private sector, local and central government.

Two defining characteristics of the UK national air monitoring effort may be seen as:

1) Its focus on quality assurance and control (QA/QC) to maximise measurement integrity and reliability
2) An emphasis on achieving the widest possible dissemination and use of both monitoring data and the information derived from this.

In subsequent sections, we will examine both the UK's QA/QC programmes (in Section 3.6) and air quality information services (Section 3.7) in more detail.

Table 3.2 Summary of UK measurements made for the most important air pollutants

Pollutant	Major sources	Site numbers	Areas covered
Nitrogen Dioxide (NO_2)	Road transport and industry	111 (Automatic)	Mostly urban
Ozone (O_3)	Sunlight and heat, acting on road transport and industrial emissions	91 (A)	All of UK- urban and rural areas
Particles (PM_{10} and $PM_{2.5}$)	Road transport, industry, construction, soil and natural sources	70 (A) 9 (NA) – Gravimetric 20 (NA- Black smoke)	Mostly urban
Sulphur Dioxide	Industry and fuel combustion	76 (A)	Mostly urban Rural
Carbon Monoxide (C0)	Road transport	78 (A)	Urban
Volatile Organic Compound (VOCs)	Industry, transport, solvent use and some natural sources	6 (A) 35 (NA) benzene 9 (NA) 1,3-butadiene	Mostly urban
Dioxins and PCBs	Combustion (dioxins) and past uses (PCBs)	6 (NA)	3 urban 2 rural 1semi-rural
Polycyclic Aromatic Hydrocarbons (PAHs)	Industry, domestic combustion and traffic (PAHs)	24 (NA)	Industrial, urban, rural and semi-rural
Metals- Pb, Cd, As, Ni and Hg	Industrial and other processes	17 (NA- lead and multi-element) 15 (NA- rural, multi-element)	Industrial, urban Rural
Acid Deposition	Atmospheric reactions involving fuel burning, agricultural and other emissions	38 (NA)	Rural
Ammonia	Agricultural activities	57 (NA)	Rural
Nitric Acid	Combustion and photochemistry	30 (NA)	Rural

Table 3.3 The major UK Air Quality Monitoring Networks

Network	Auto or Sampler?	No of Sites
The Automatic Urban and Rural Network (AURN)	A	130 (94 urban, 22 rural, 14 London)
Rural acid deposition, gases and particles	S	38 (acid deposition)
Automatic Hydrocarbon	A	6
Toxic Organic Micropollutants (TOMPS)	S	6
Polycyclic Aromatic Hydrocarbons (PAHs)	S	24
UK Heavy Metals Monitoring Network (previously the Lead, Multi-element and Industrial Metals Networks)	S	17
Rural metal deposition network	S	10 particle and rain, Hg in rain & air 5 rainwater 2 cloud water
Non automatic hydrocarbon- Benzene and 1,3-butadiene	S	35 (benzene) 9 (1, 3-butadiene)
Ammonia and Nitric Acid Network	S	94
Black Smoke	S	21

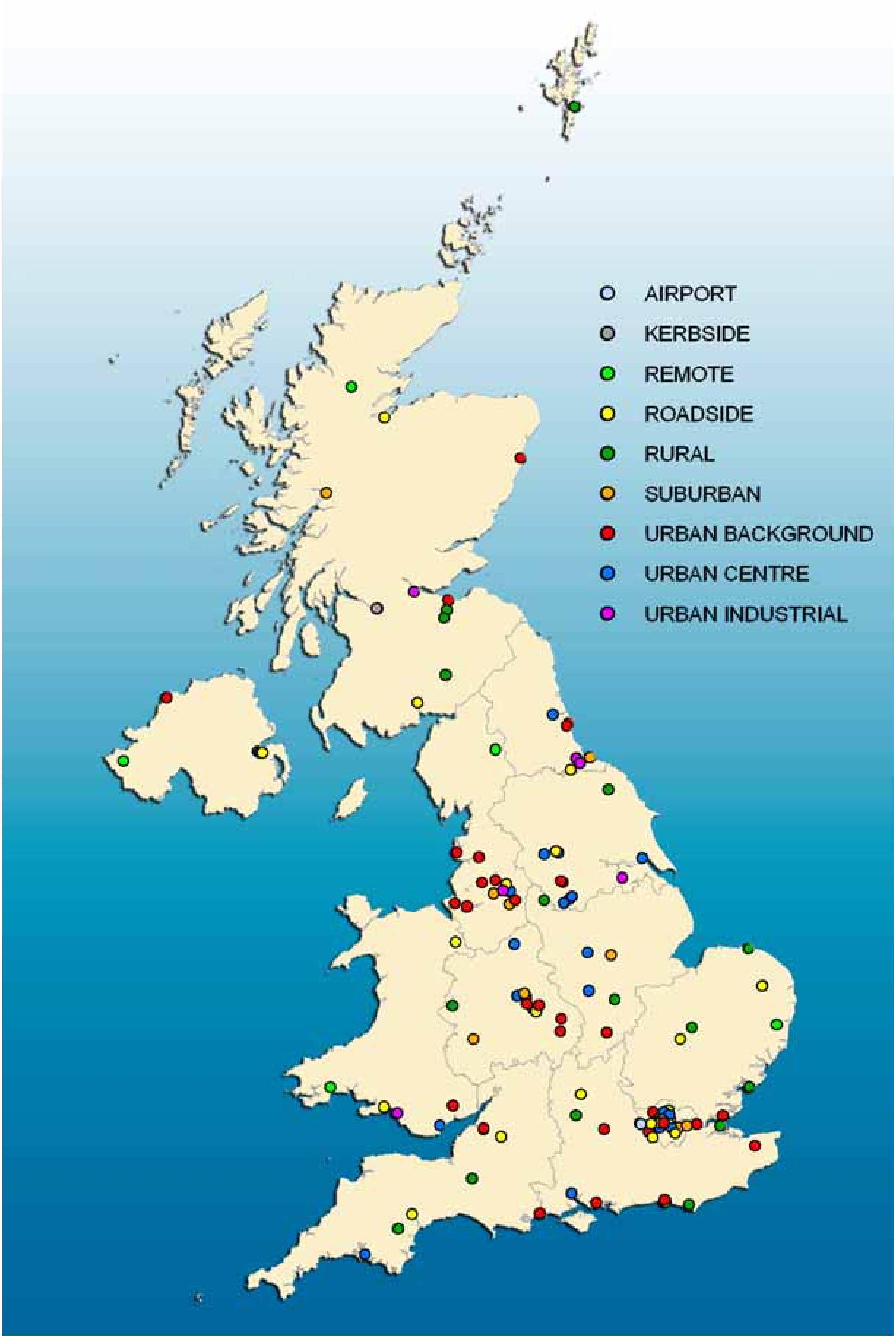


Figure 3.3 Current automatic monitoring stations in the National Automatic Urban and Rural Network (AURN)

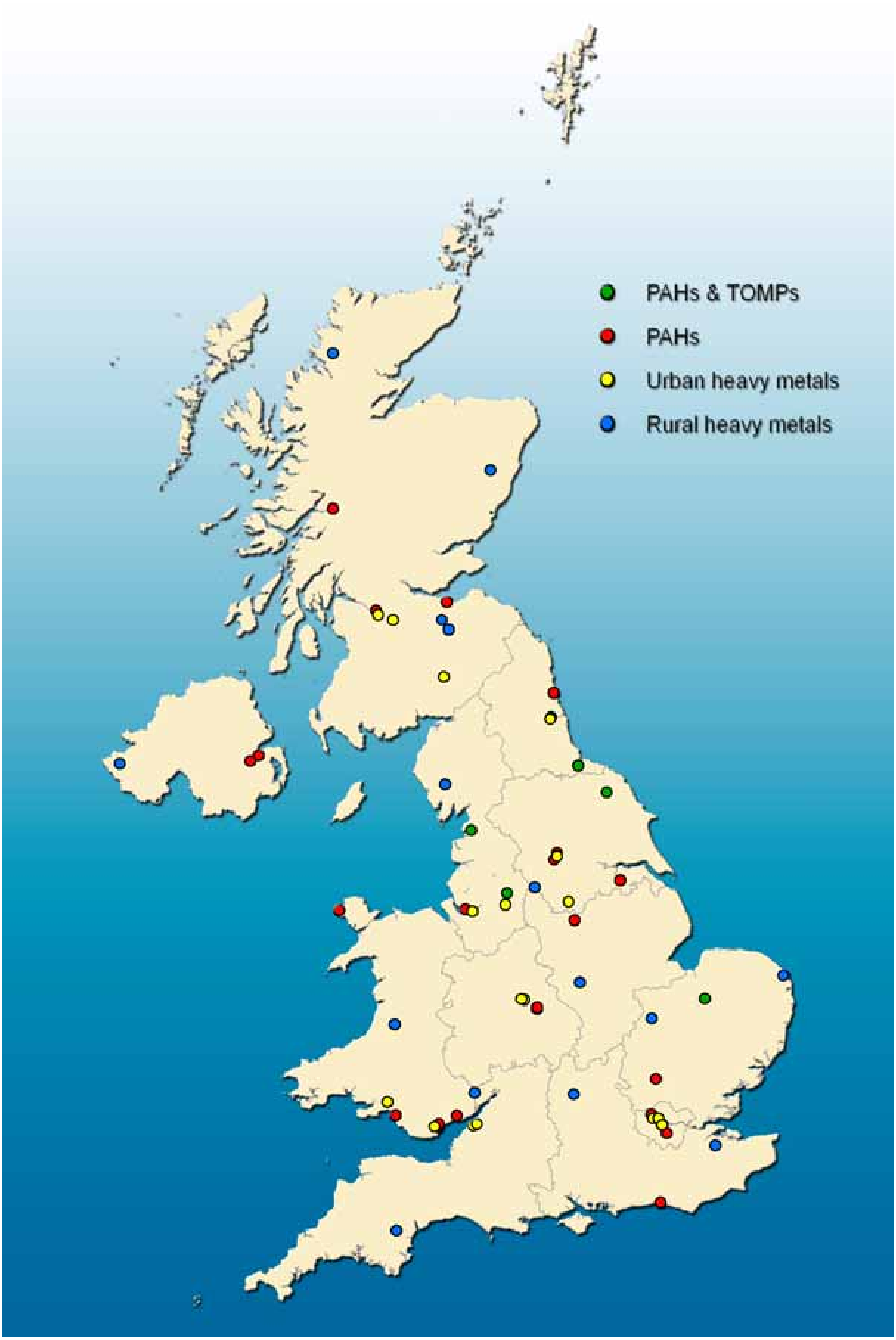


Figure 3.4 Current non-automatic monitoring stations for metals, PAHs (Polyaromatic hydrocarbons) and TOMPs (Toxic Organic MicroPollutants)

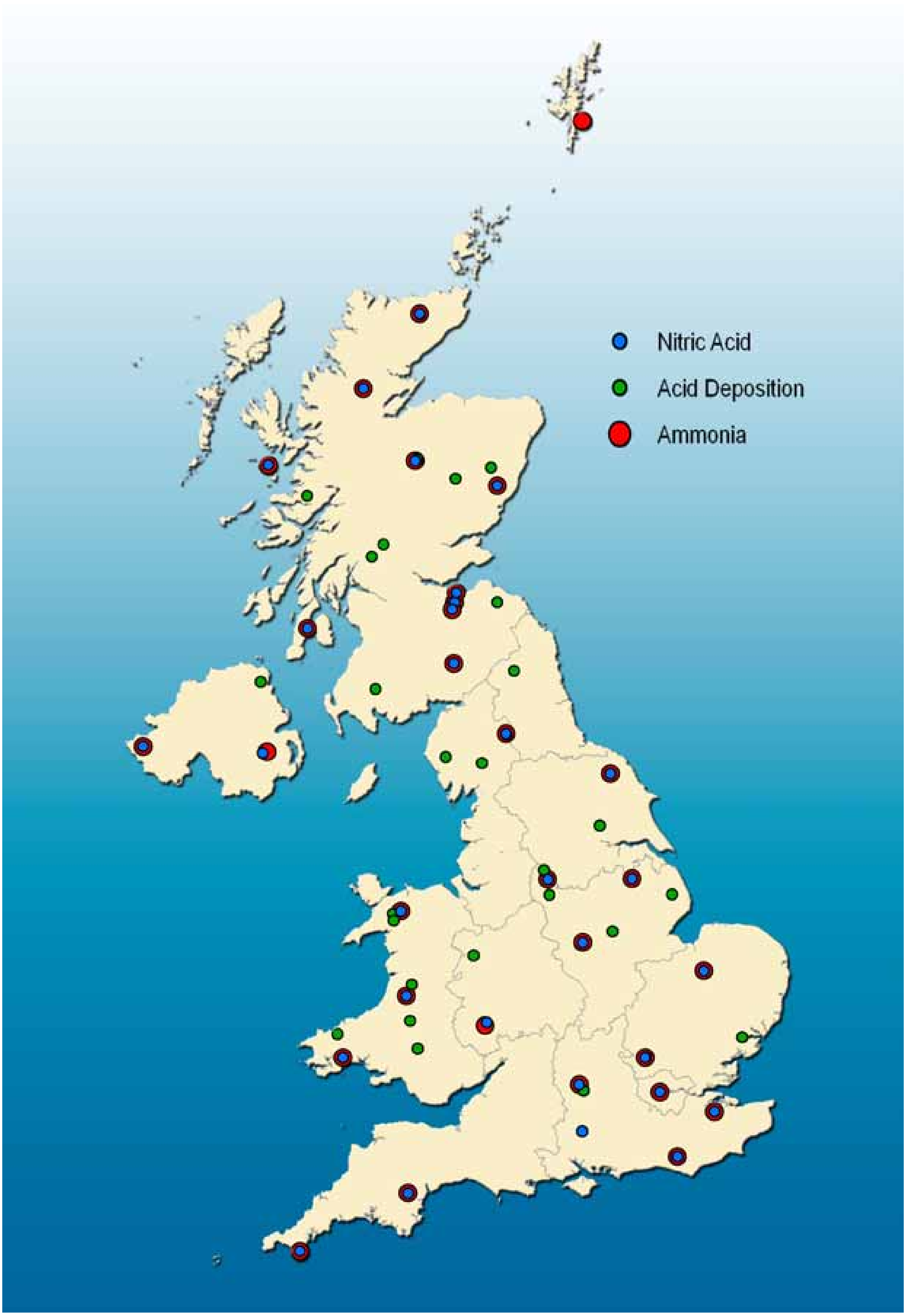


Figure 3.5 Current non-automatic monitoring stations for acid deposition, nitric acid and ammonia

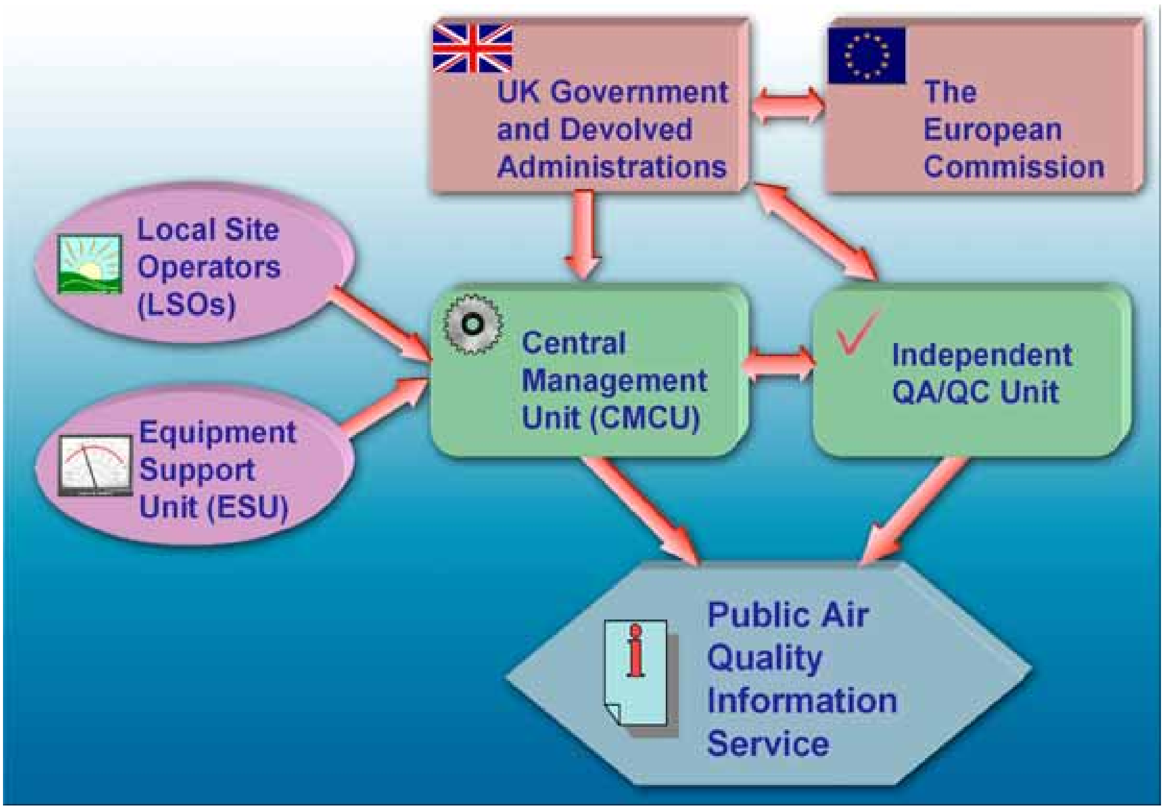


Figure 3.6 Devolved monitoring network structure, as currently utilised within the AURN

3.6 Emphasis on Data Quality

Automatic networks

The UK automatic air monitoring networks currently collect over 24 million raw individual measurements every year; after full analysis and collation, over 9 million hourly measurements are archived. In order for these data to be useful and provide a sound scientific basis for comparison against standards, public information or policy development, we need to be sure that they are accurate and reliable. This is why considerable attention is devoted in the UK monitoring networks to quality assurance and control.

> ### *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:

(i) Genuinely representative of ambient concentrations existing in the various areas under investigation
(ii) Sufficiently accurate and precise to meet specified monitoring objectives
(iii) Comparable and reproducible. Results must be internally consistent and comparable with international or other accepted standards, if these exist
(iv) Consistent with time. This is particularly important if long-term trend analysis of the data is to be undertaken
(v) 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
(vi) 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 highlight here some of the procedures employed for selected programmes.

Automatic Urban and Rural Network (AURN)

For this network, all quality assurance activities are tasked to an independent QA/QC Unit, which carries out the comprehensive range of functions identified in Table 3.4. See also Figure 3.6.

There is an increasingly important European dimension to network quality assurance and control. The EU Framework Directive 96/62/EC on ambient air quality assessment and management, together with subsequent Daughter Directives, stipulate that once relevant performance standards are published by CEN (The European Centre for Standardisation), then these methodologies can be adopted as the 'reference method'. Member States can use the reference method or one shown to be equivalent to it (for example, EN12341 for PM_{10}).

CEN Working Group 12 of Technical Committee 264 has published the relevant performance standards, transposed as British Standards: BS EN 14211:2005 for NO_x, BS EN 14212:2005 for SO_2, BS EN 14625:2005 for Ozone and BS EN 14626:2005 for CO.

These describe in detail how analysers are to be tested, approved for use, calibrated and their ongoing performance determined. These procedures will 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.

The CEN procedures will require all analysers in a network to be submitted to a designated testing facility for type approval before they may be used for statutory monitoring for the purposes of assessment against the EU Daughter Directives.

Table 3.4. QA/QC activities in the AURN

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
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, on a daily basis, that the data from analysers are scaled provisionally and are free from any obvious errors
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 (see Figure 3.7)	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.

The procedures will be adopted into the proposed EC Air Quality Directive during future reviews. The requirements of the CEN performance tests are exhaustive, but in general will include the following:

- All analysers must pass a rigorous series of tests using prescribed laboratory and field approval tests. The analysers must be field tested in the environments in which they are intended to be used
- In addition to passing the individual performance tests, the analysers must also pass an overall uncertainty evaluation. The results of the individual tests above are used as components to calculate the overall uncertainty of measurement. For NO_x, CO, O_3 and SO_2, the requirement is a measurement uncertainty of ±15% at the relevant EC Limit value.
- Once deployed in a monitoring network, the analysers have to pass a number of ongoing performance tests. The results from these tests are used to determine ongoing measurement uncertainties, reported annually to the EC.

The UK Automatic Urban and Rural Monitoring Network already has a comprehensive suite of ongoing operational and performance tests that are used to evaluate the performance of site analysers. 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.

Figure 3.7. All UK 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

A comprehensive operations manual for the AURN has been produced and disseminated to all site operators. This is available both in hardcopy form and on CD; the latter contains detailed instructions for operating all measurement and instrumentation types currently deployed in the programme. The manual is also available for the UK Air quality Information Archive at
http://www.aeat.co.uk/netcen/airqual/reports/lsoman/lsoman.html.

Local Authority NO_2 Diffusion Tube Monitoring

Many UK Local Authorities use diffusion tubes for 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, shown in Figure 3.8: 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.

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 diffuses up the tube during exposure, and is 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 calculated from the amount of pollutant absorbed. Diffusion tubes are available for a range of pollutants, but the most commonly used in the UK are for NO_2.

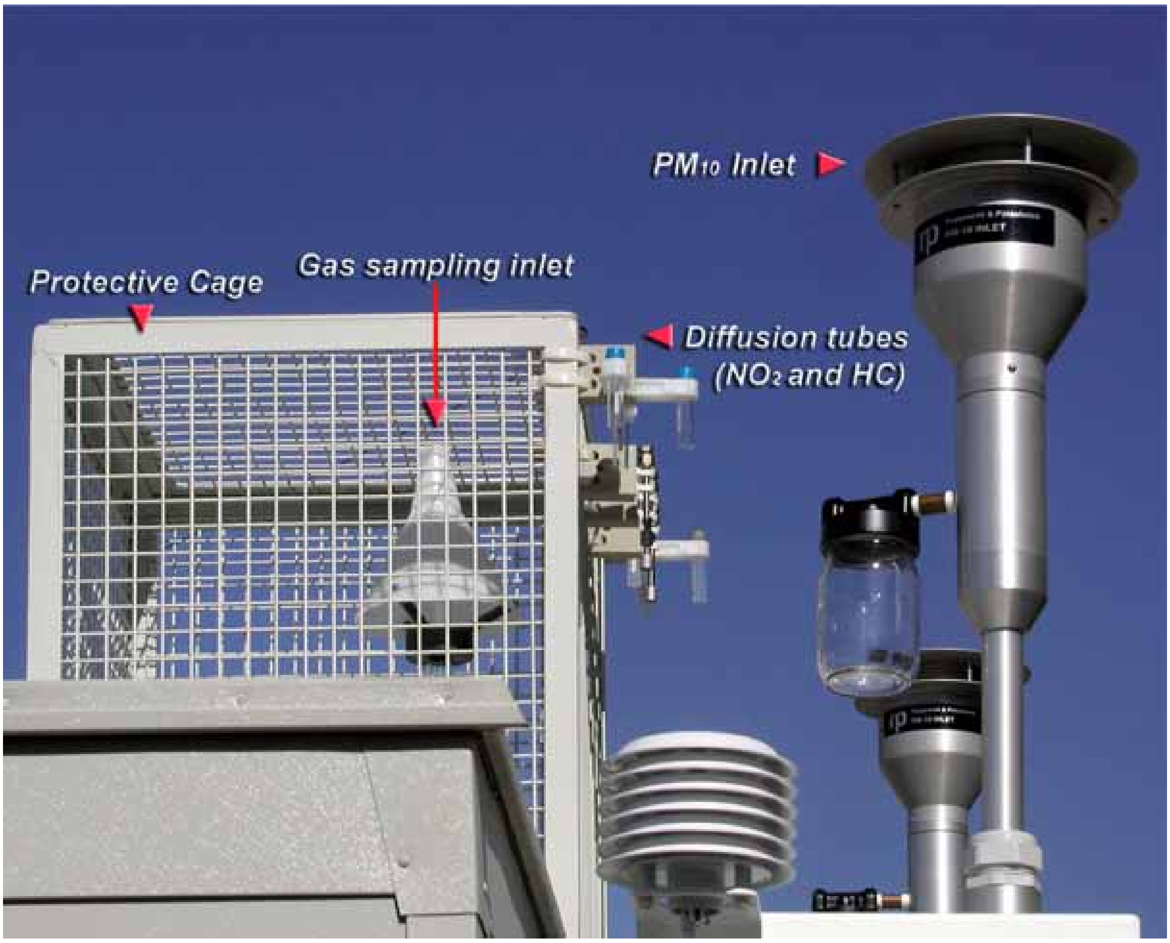


Figure 3.8 Typical deployment of diffusion tubes (NO_2 and BTX) on the rooftop of an automatic air monitoring station- *(Jaume Targa)*

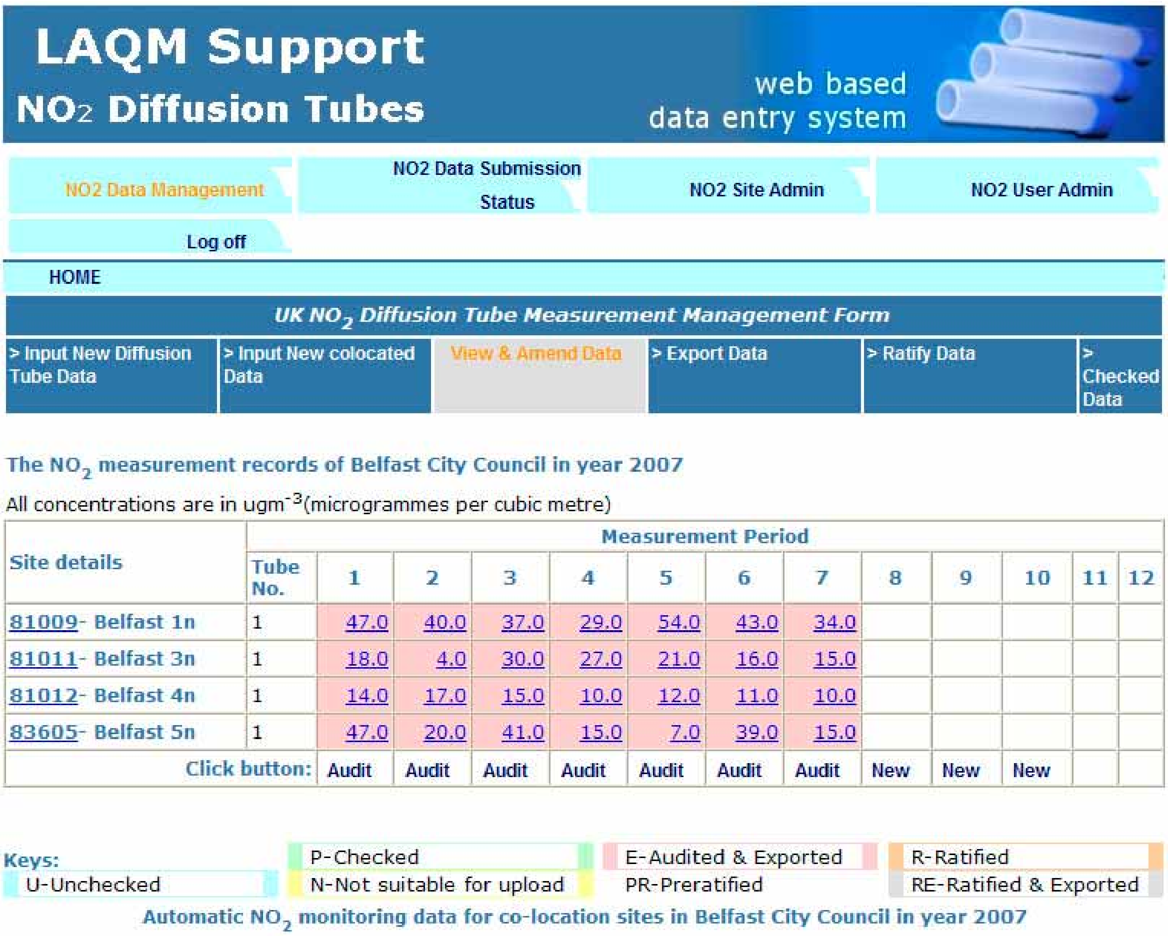
Diffusion tubes are an indicative method: they do not provide the same level of precision and accuracy as automatic monitoring methods; for example, the accuracy of diffusion tube measurements is typically around ±25%. Nor can they be used for short-term (hourly or daily) measurements. However, they 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 of the former NO_2 Network, Defra and the Devolved Administrations have continued to provide a range of support services to Local Authorities using diffusion tubes, as part of their contract 'Support to Local Authorities for Air Quality Management'; this also includes the Air Quality Monitoring and Modelling Helpdesks, discussed further in Section 3.7.

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 (Fig 3.9) - 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 is now approaching the completion of its work; it is intended to produce a practical guidance document detailing harmonised methods for diffusion tube preparation, use, and analysis, by the end of 2007.

These services are intended to improve and maintain the quality of all NO_2 diffusion tube measurements carried out by Local Authorities. Further details of this project can be found at http://www.laqmsupport.org.uk.


LAQM Support

NO2 Diffusion Tubes

web based data entry system

NO2 Data Management | NO2 Data Submission Status | NO2 Site Admin | NO2 User Admin

Log off

HOME

UK NO_2 Diffusion Tube Measurement Management Form

> Input New Diffusion Tube Data | > Input New colocated Data | View & Amend Data | > Export Data | > Ratify Data | > Checked Data

The NO_2 measurement records of Belfast City Council in year 2007

All concentrations are in ugm^{-3}(microgrammes per cubic metre)

Site details	Measurement Period												
	Tube No.	1	2	3	4	5	6	7	8	9	10	11	12
81009- Belfast 1n	1	47.0	40.0	37.0	29.0	54.0	43.0	34.0					
81011- Belfast 3n	1	18.0	4.0	30.0	27.0	21.0	16.0	15.0					
81012- Belfast 4n	1	14.0	17.0	15.0	10.0	12.0	11.0	10.0					
83605- Belfast 5n	1	47.0	20.0	41.0	15.0	7.0	39.0	15.0					
Click button:		Audit	Audit	Audit	Audit	Audit	Audit	Audit	New	New	New		

Keys:
U-Unchecked | P-Checked | N-Not suitable for upload | E-Audited & Exported | PR-Preratified | R-Ratified | RE-Ratified & Exported

Automatic NO_2 monitoring data for co-location sites in Belfast City Council in year 2007

Figure 3.9 – Web-Based Data Entry System for Diffusion Tubes

Working Group on the harmonisation of NO_2 diffusion tube measurements

Since their development in 1976, Palmes-type diffusion tubes have been widely used in the UK for measuring ambient concentrations of nitrogen dioxide (NO_2) [C4]. Since then, several modifications in the preparation, analysis and exposure of the tubes have occurred. Currently, there is considerable variation of procedures amongst both supplying laboratories and end-users of this device for measuring air pollution[C5]. It is believed that this variation in methods and procedures is contributing to the observed variation in NO_2 diffusion tube performance, and that by reducing - as far as practicable - the inter-laboratory variation in methods, it will be possible to reduce inter-laboratory variation in results.

With this aim in mind, a Working Group on Harmonisation of NO_2 Diffusion Tube Measurements was set up on behalf of Defra and the Devolved Administrations in 2006. The Working Group includes representation from laboratories, Local Authorities, the Environment Agency and other stakeholders. The task of the Working Group is to develop and agree a set of harmonised procedures for diffusion tube preparation and analysis, which will reduce the uncertainty of the data.

The Working Group commenced in April 2006, and has investigated aspects of diffusion tube preparation, use, handling and analysis. The group recently completed the draft of its Practical Guidance document, detailing the harmonised method. It is envisaged that this will be finalised and implemented over the following year.

3.7 Disseminating and using Air Quality Data

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 3.6. Once this key task 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 3.10, is vital to the success of the UK monitoring networks.

Figure 3.10 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 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 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 Government'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 (Figure 3.11, Box 3.1). 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 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 (0800 556677). 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 3.2 for further details of information available from the website. Box 3.3 provides details of a matching information resource that has recently introduced specifically to meet the needs of Local Government at www.laqmsupport.org.uk.

The UK's national air quality web site 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 (see Section 4). The Archive has become a key resource for education and research. It has received wide praise, both within the UK and internationally. A major re-design in 2006 made further improvements to the navigation, user-friendliness and overall usability of the site, as well as enhancing its accessibility to all communities.

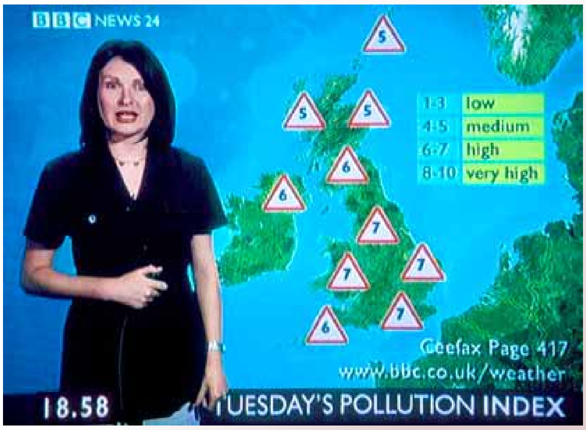
The success of the UK Archive has led to the development of similar national archives for Scotland, Wales and Northern Ireland. In 2004, a new air quality archive was established for Wales. Publicly available through its website at www.welshairquality.org.uk, this mirrors many of the services and functions of the UK National Archive. It provides a comprehensive one-stop resource for data and analyses covering all aspects of air quality in the country. The site also includes measurements from a range of monitoring sites subject to QA/QC review comparable to that employed in the national networks. Major developments to the website, introducing new functionalities and further improving its user interface, have been completed in 2007.

With 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 (Figure 3.12).

Fig 3.11 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 Air Quality Website

Twice daily web forecasts

A series of brochures & reports

Freephone 0800 556677

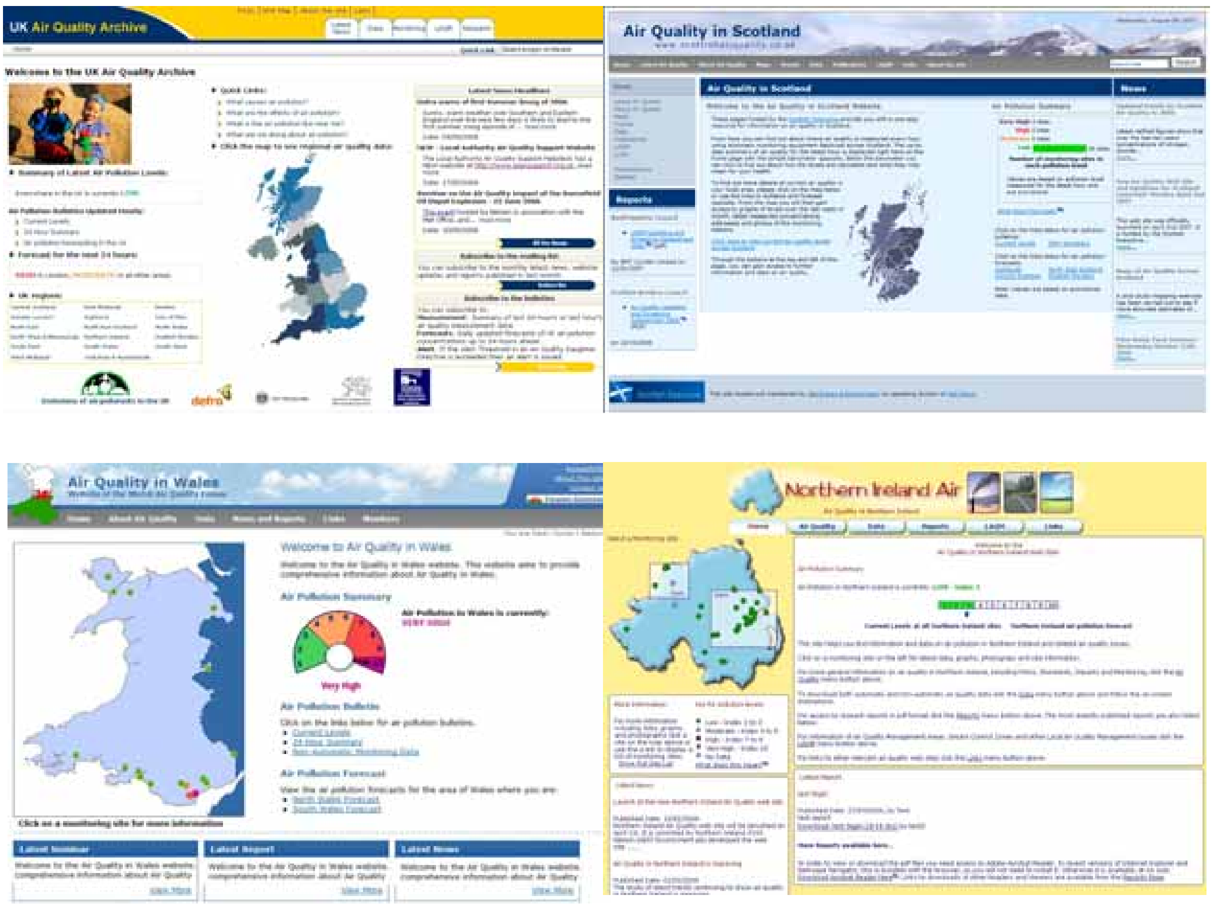


Figure 3.12 The family of UK, Scottish, Welsh and Northern Ireland websites was completed early in 2007

The evolution and development of UK Air Quality websites continue apace.

Under UK Government's Transformational Government Website Rationalisation, it is proposed to improve the quality of service by producing a more centralised and streamlined system of government websites.

At present, the plans are still in the proposal stage. For the time being, there will be no change to the service offered by www.airquality.co.uk. Whatever the outcome of this process, Government and its contractors remain totally committed to maintaining the very highest level of service to its many users in the UK and worldwide.

At present, there are no plans for this rationalisation process to apply to the corresponding Scottish, Welsh and Northern Ireland websites.

Box 3.1 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 3.2 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 3.3 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.

4 High pollution episodes

By examining periods during 2006 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***. In the next section of the report, we focus more on variations in pollution levels from area to area within the UK.

Pollution levels vary over time for two main reasons:

1) Variations in pollutant emissions
2) Changes in atmospheric conditions that allow pollution levels to build up, resulting in the transport of pollutants from other areas or encouraging their formation through chemical reactions.

All episodes occur because of a combination of these factors.

There are two major types of pollution episode in the UK- winter and summer smogs. ***Winter smogs*** 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 have been infrequent over recent mild UK winters.

By contrast, ***summer smogs*** occur in hot and sunny weather. Sunlight and high temperatures accelerate chemical 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.

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 long-running series of annual reports.

In this section, we review the most significant air pollution events during 2006. The first occurred in May, involving the long-range transport of particulate matter from fires in Western Russia. We also examine an extended photochemical episode in June and July.

4.2 A particle episode involving long-range transport: 7- 12 May 2006

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.

Over the period Sunday 7th May to Friday 12th May 2006, measurements from approximately one third of the fully automated particulate PM_{10} monitors in the Defra AURN unexpectedly entered the 'Moderate' health band, a level at which mild effects are seen on individuals who are sensitive to air pollutants. Of the nineteen sites which measured 'moderate' particle levels, four went on to reach the 'high' pollution band, which is considered to be a level at which significant effects are likely to be noticed in sensitive individuals.

Most of the monitoring sites that reached the 'Moderate' health band were situated in urban areas. However, the highest measurements during the initial phase of the episode were generally observed in Scotland and the north of England, as shown in Figure 4.1. It was these locations that showed the greatest impact of long-range transport of particles from a source outside the UK. As we shall see, considerable evidence has pointed to this being due to emissions from forest fires in western Russia.

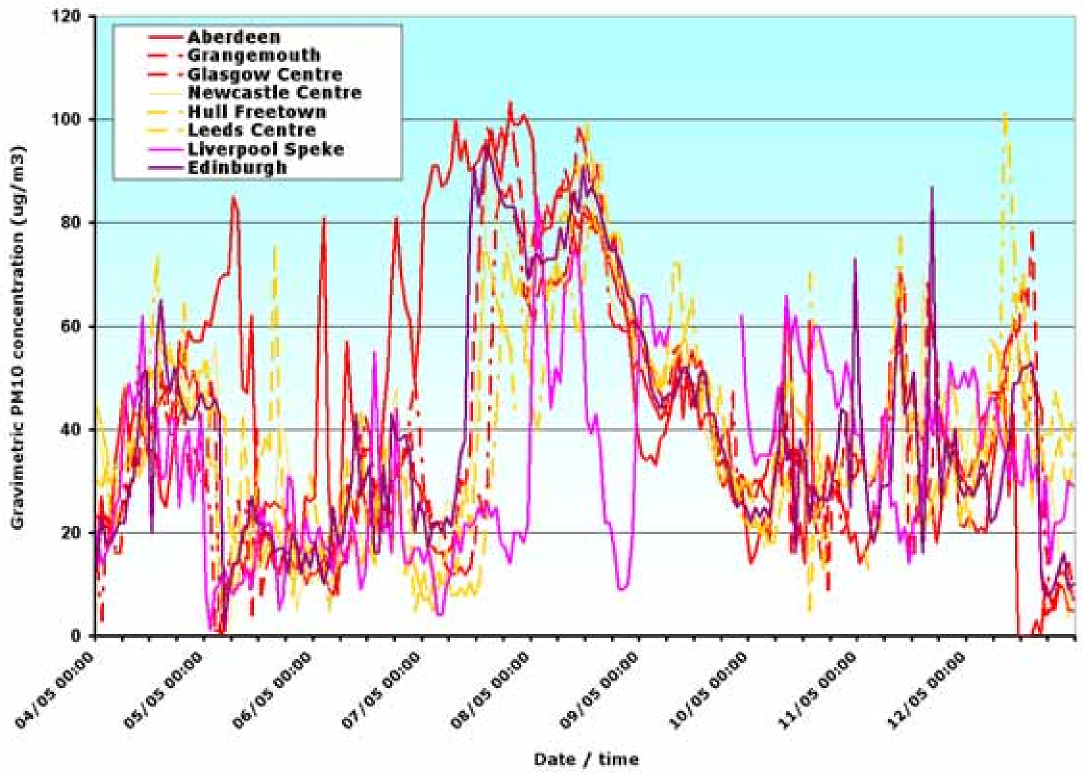


Figure 4.1 Hourly mean PM_{10} measurements at selected northern sites in the UK, May 4th to 12th

A detailed estimate was made of the additional contribution of PM_{10} from non-UK sources at sites in the north of the UK. For example, Figure 4.2 shows daily contribution estimates at the Edinburgh St Leonards monitoring site.

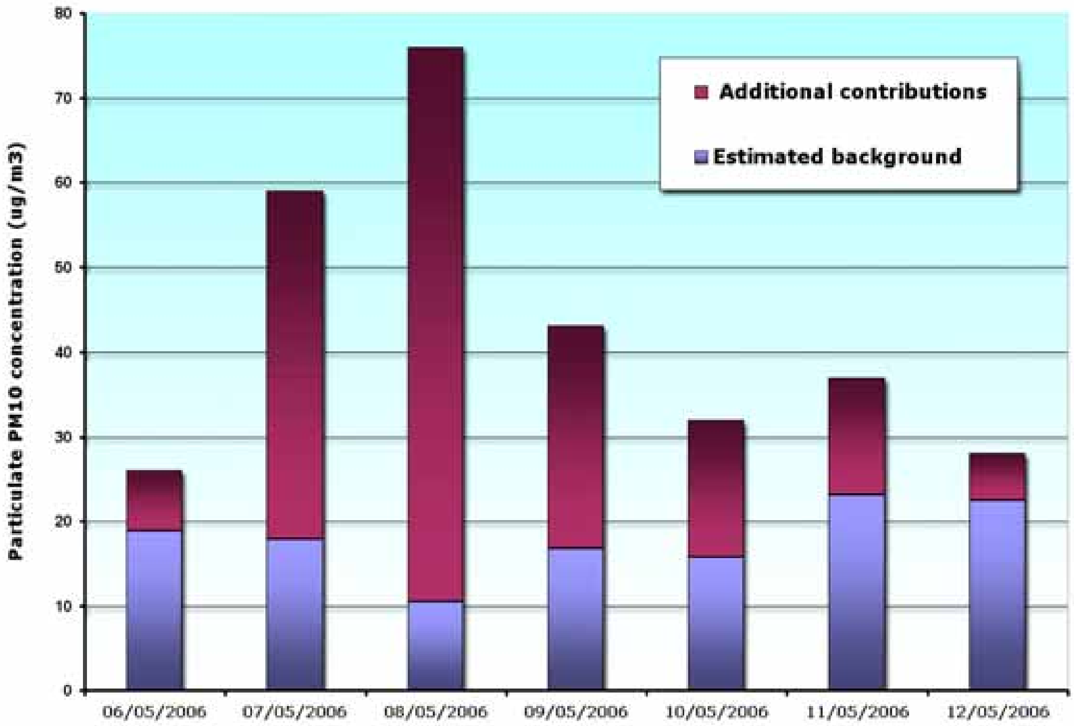


Figure 4.2 Estimated additional contributions of particulate PM_{10} at Edinburgh St Leonards.

Forecasted 4-day air mass back-trajectory data indicated that - in the days leading up to the UK episode - air arriving in the UK on the 8th May had passed over the north of Europe (Figure 4.3).

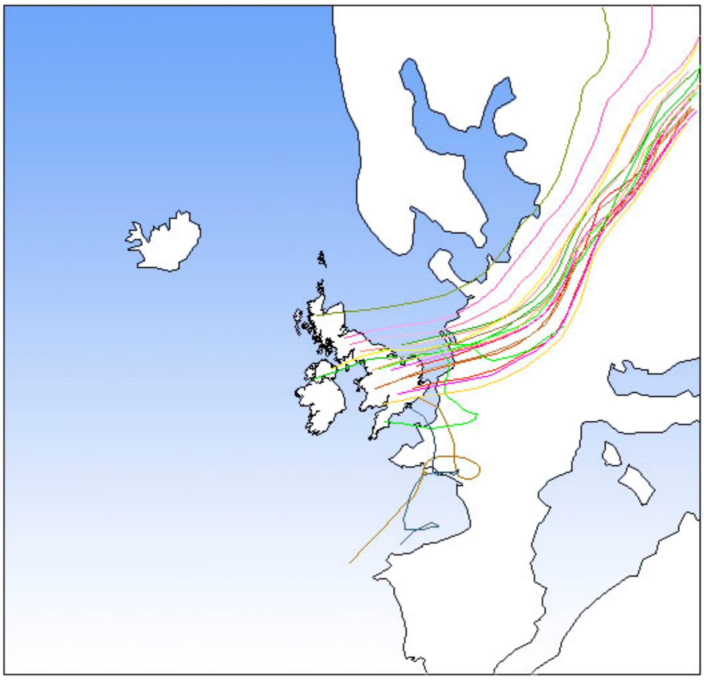


Figure 4.3: Air mass back-trajectories for 8th May

This shows where air arriving in the UK has travelled over the last 96 hours up to 12:00 on that day.

On this occasion, the air has clearly been transported from Russia and passed through Northern Europe on its way to the UK.

This sort of trajectory can often be associated with summer photochemical episodes, as well as those caused by long-range transport.

At the end of April and beginning of May, widespread agricultural fires in western Russia were observed by a moderate resolution imaging satellite (Figure 4.4). During this period, smoke from the fires was transported north-westwards over the Gulf of Finland. A plume of particles was clearly seen to the north of Scandinavia on 30th April (Figure 4.5).

Figure 4.4 Fires in western Russia (indicated by red dots) on 3rd May. Courtesy of Dundee University and NERC

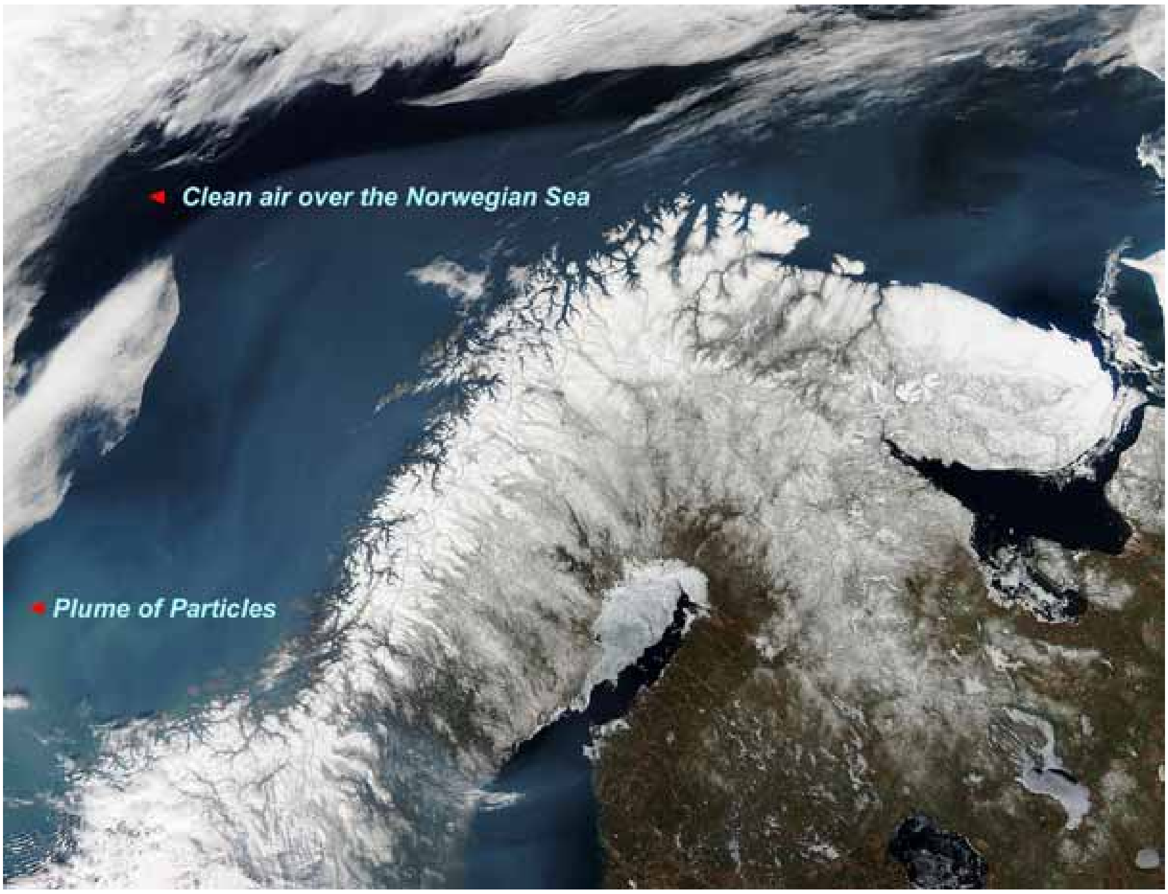


Figure 4.5 30th April – A plume of particulates detected to the north of Scandinavia- courtesy of Dundee University and NERC

In order to definitively determine the origin of the air affecting Scandinavia and then the UK, the UK Met Office ran sophisticated atmospheric dispersion models for a selection of sites in the north of the UK for the period when PM_{10} levels were elevated. The resultant air origin map (Figure 4.6) showed that on the 8th May – the day with the highest PM_{10} exceedences – the air mass arriving in Scotland had travelled over the large region of Russian forest fires seen in earlier satellite imagery.

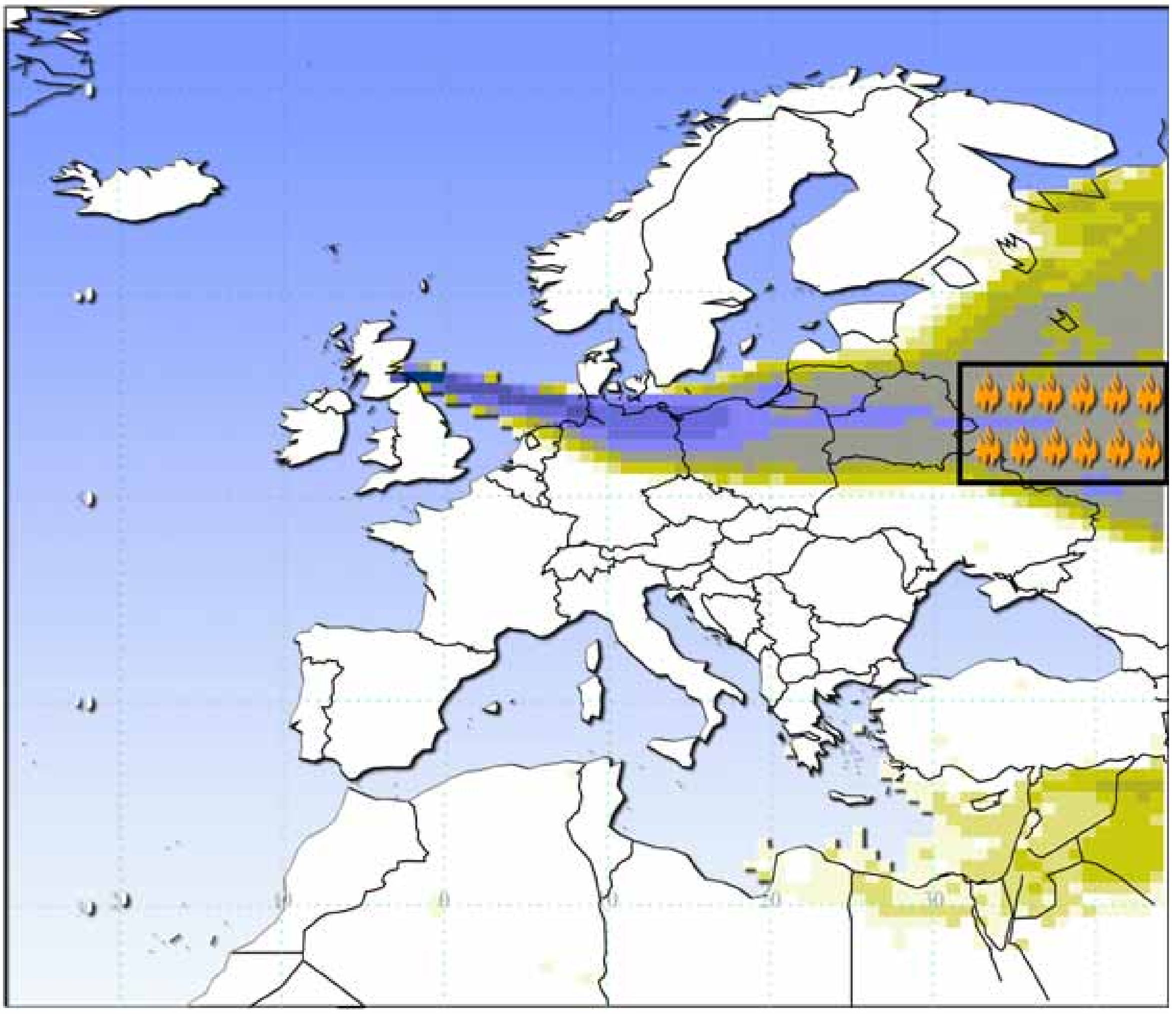


Figure 4.6 Air origin map for the north of the UK on the afternoon of the 8th May

A high-resolution satellite image of Europe taken on 6th May, shown in Figure 4.7, also shows that the particle-laden air had passed in transit over much of continental Europe and southern Sweden and was likely to have originated from the affected area of Russia.

A second high resolution satellite image, taken on the 8th May during the height of the episode, explained the reason for the highest measurements being observed to the north of the UK. A weather front bisecting the UK from north to south on that day had effectively protected southern areas from the particulate-laden air during the early phase of the episode, as shown in Figure 4.8.

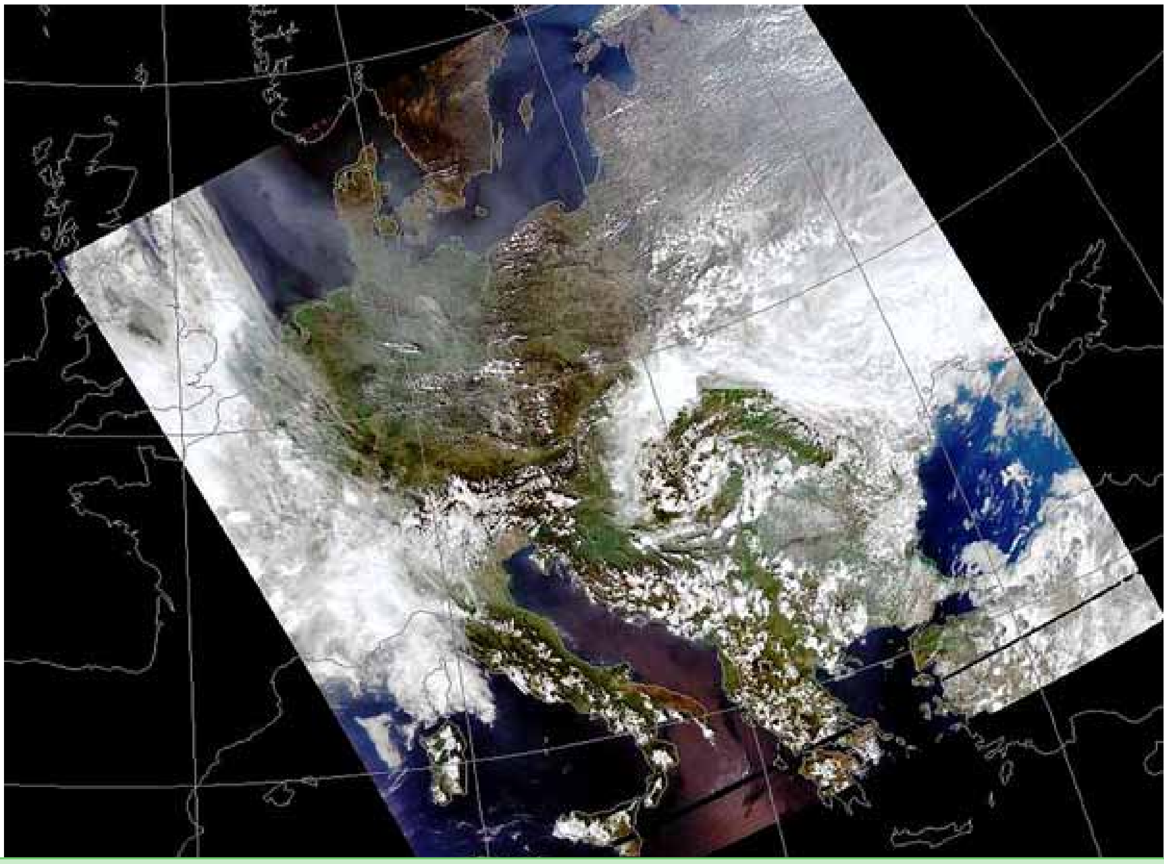


Figure 4.7: Saturday 6th May (high resolution image centred on Europe) - courtesy of Dundee University and NERC

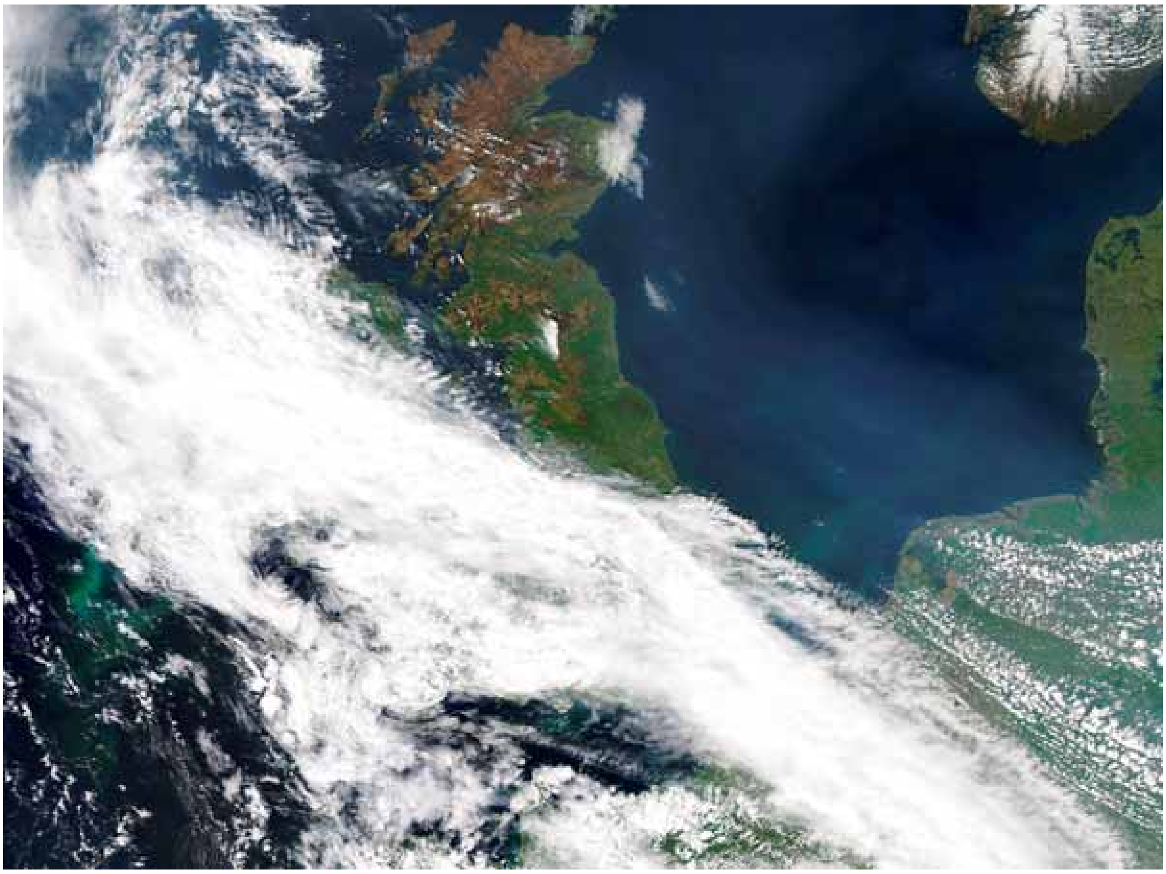


Figure 4.8: Monday 8th May – a high resolution image showing the position of the weather front across central UK- courtesy of Dundee University and the National Environment Research Council (NERC)

Optical and scanning electron microscopic analysis of a sample collected during the early phase of the episode in Scotland was undertaken to help clarify the source and nature of the particles. At a magnification of x500, the sample revealed that many of the particles collected were carbonaceous or 'soot-like' in appearance with other red 'rust-like' grains present. A smaller number of pollen-like particles also contributed to the overall mass (Figure 4.9).

Figure 4.9

High magnification scanning electron micrograph of various inorganic and organic material on filter dated 8/5/06.

Magnification x 3000

Courtesy Dr Alison Crossley of Oxford Materials

A number of conclusions can be drawn from the various analyses and imagery:

- Between approximately 6th May and 10th May, air affecting the UK originating from western Russia and had passed over northern Europe.
- This air mass contained high concentrations of particles, primarily originated from agricultural and forest fires.
- A cold front over the UK initially kept the plume of particles to the east of the UK but, as the front moved south-westwards, increased levels of ground-level PM_{10} were measured in Scotland and the north east of England.
- Four monitoring sites recorded concentrations of PM_{10} in the 'High' pollution band, although this was not solely attributable to the particles transported from Russia.
- After the break-up of the cold front, the particulate-laden air was able to spread to England and Northern Ireland; however, by this time it had been diluted and - in consequence- measured particle concentration at ground level were lower.

A considerably more extensive and detailed analysis of this episode may be found in the reports section of the Air Quality Archive[D1].

4.3 A summer photochemical smog episode: June/July 2006

As discussed in Section 4.1, elevated ozone levels are usually observed in the UK during periods with sustained high temperatures and sunshine levels. This is because the photochemical reactions in the atmosphere that produce ozone are favoured by such conditions. Because these reactions can take some time to proceed, transport of ozone and its precursors from outside the UK can also exert a strong influence on ozone levels in this country. High temperatures, coupled with the re-circulation of air masses over Europe and the UK, are often conducive to ozone pollution episodes.

During June and July 2006, precisely these conditions resulted in widespread elevated ozone levels. 'High' band ozone levels were measured at no less than sixty Automatic Urban and Rural Network (AURN) stations, primarily in England and Wales. Figure 4.10 shows the geographical extend of stations measuring high levels during this period. Ozone levels exceeded the index 8 HIGH band (240-299 μgm^{-3}) at four locations: Wicken Fen, Stoke-on-Trent Centre, Haringey and Blackpool Marton. The highest hourly concentration of 278 μgm^{-3} was measured on the 19th July at Wicken Fen at 18.00.

The 3rd Daughter Directive (Directive 2002/3/EC) on ozone in ambient air has established an alert threshold of 240 μgm^{-3}; this was exceeded at Wicken Fen on 19th July when 8 consecutive hours were measured above 240 μgm^{-3}.

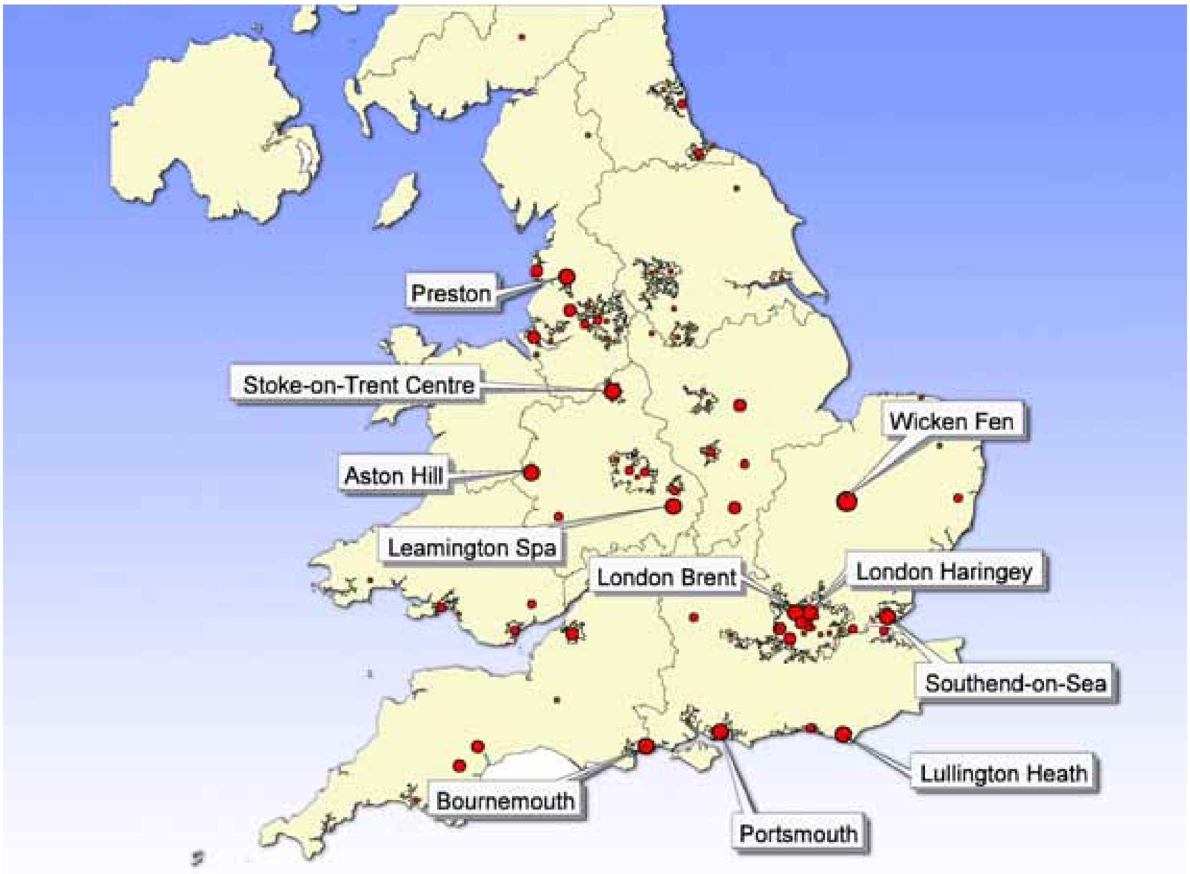


Figure 4.10 – Number of high ozone days across AURN stations in England and Wales during the photochemical episode

High ozone levels were measured across a range of UK local air quality networks, as well as across continental Europe. Elevated levels of PM_{10} particles were also measured during this period, together with elevated SO_2 levels in July; these were mostly in London and South East England.

Weather conditions

The weather conditions during this period across England and Wales were very warm and dry. July was exceptionally hot, with temperatures of 36°C on 19th July setting a new UK monthly temperature record. By contrast, temperatures across Scotland and Northern Ireland were much cooler. Table 4.1 below shows the monthly weather summaries produced by the Met Office for June and July.

Table 4.1 – Monthly weather summaries for June and July 2006 (Met Office)

June	July
A very warm, dry and sunny month across most areas. Mean temperatures generally 1-2°C above average. Rainfall ranging from close to average across western Scotland, to exceptionally below average across the Midlands. Sunshine levels well above average across southern England. *Central London recorded a maximum temperature of 32.4 C on 12th. Altnaharra recorded a minimum temperature of -1.4 °C and Kinbrace -1.7 C on 26th (both Highlands).*	An exceptionally warm month. Many areas had their warmest July since 1914. Sunshine was also exceptionally above average, with the sunniest areas over north-east England. Rainfall was generally below average, although there were some notable exceptions. *Wisley recorded a temperature of 36.5 °C on 19th July setting a new UK July temperature record. Penhow recorded a temperature of 34.2 °C on 19th July, setting a new Welsh July temperature record.*

Source: http://www.meto.gov.uk/climate/uk/2006/index.html

Air quality monitoring

Eleven AURN stations measured HIGH ozone levels for more than five days. Maximum hourly concentrations ranged between 278 μgm^{-3} (Wicken Fen), 246 μgm^{-3} at London Haringey and 244 μgm^{-3} at Stoke-on-Trent. Table 4.2 shows the number of days measuring high or moderate ozone levels across the AURN. The maximum hourly mean concentrations and the date of its measurement are also shown. The majority of maximum hourly mean concentrations were measured between the 18th and 19th of July, whilst others were measured earlier in the month.

Table 4.2. Number of days of Moderate and High levels at each station across the AURN between June and July 2006

Site	Number of Days		Max hourly (μgm^{-3}) *Provisional*	Date of hourly max concentration
	High	Moderate		
Wicken Fen	13	41	278	19/07/06
Stoke-on-Trent Centre	8	24	244	19/07/06
Southend-on-Sea	8	38	232	04/07/06
Preston	7	18	218	18/07/06
London Haringey	6	25	246	19/07/06
Lullington Heath	6	29	238	18/07/06
Bournemouth	6	21	232	18/07/06
Portsmouth	6	27	230	18/07/06
Leamington Spa	6	25	228	19/07/06
London Brent	6	28	222	01/07/06
Aston Hill	6	26	220	19/07/06

Air Quality Forecasting

Daily air quality forecasting continued as usual during June and July 2006. The two weekly air pollution forecast emails were delivered on schedule, with additional updates provided during high zone periods. Tables 4.3 illustrates a typical air pollution forecast update issued during this period.

Table 4.3 Air quality forecasting email on 30th June

From: Paul Willis, Netcen To: Air Quality Forecast Recipients Subject: High Air Pollution Forecast for Friday June 30th to Monday July 3rd	30/06/2006 09:26:52
Dear Colleagues, Exceptionally hot weather continues to be forecast for the UK over the coming few days. A high pressure remains centered to the north-east of the UK and will draw easterly continental air to much of the UK as the weekend progresses. High ozone pollution is forecast for London and south-east England later today or tomorrow, and this is expected to extend further north and west on Sunday, Monday and Tuesday. By Tuesday temperatures of 26 or 27 degrees Celsius are currently forecast in Northern Ireland and for much of Scotland so it's possible that even these areas could be affected (although uncertainties in the weather this far ahead are obviously greater). There may possibly be some thunderstorms on Sunday but otherwise dry and mainly sunny throughout. Paul Willis Netcen	

Reasons for the ozone episode

As noted previously, analyses of previous summer ozone episodes over the UK have demonstrated that these are usually characterised by high temperatures and air masses re-circulating over northern Europe and the UK [D2, D3, D4]. These conditions typically result in summer smog episodes as the ozone precursor chemicals react in the presence of sunlight and are transported over domestic or continental distances to their point of impact.

The June and July 2006 ozone episode is typical of such an episode. It appears that both high temperatures and re-circulation of air masses need to be coupled together to result in a UK summer smog episode.

Temperatures

Temperatures across June and, especially, July were exceptionally high. A temperature of 36.5°C was measured on 19th July, setting a new UK July temperature record. As can be seen in Figure 4.11, the days in June and July 2006 when high ozone levels have been measured mostly coincide with periods of elevated temperatures.

Re-circulation of air masses

Despite the apparent correlation between high temperature and high ozone shown in Figure 4.11, the re-circulation of air masses over Europe and the UK is also a key element contributing to elevated ozone concentrations.

To assist daily air quality forecasting in the UK, *1000mB 96-hour Forecast Air Back-Trajectories* are produced and used on a daily basis. Airmass Trajectories are simple linear representations of large-scale air movements in the atmosphere. Although they are relatively easy to understand and to visualise, they do not take into account the effects of turbulent mixing and therefore do not show the full range of air movements possible.

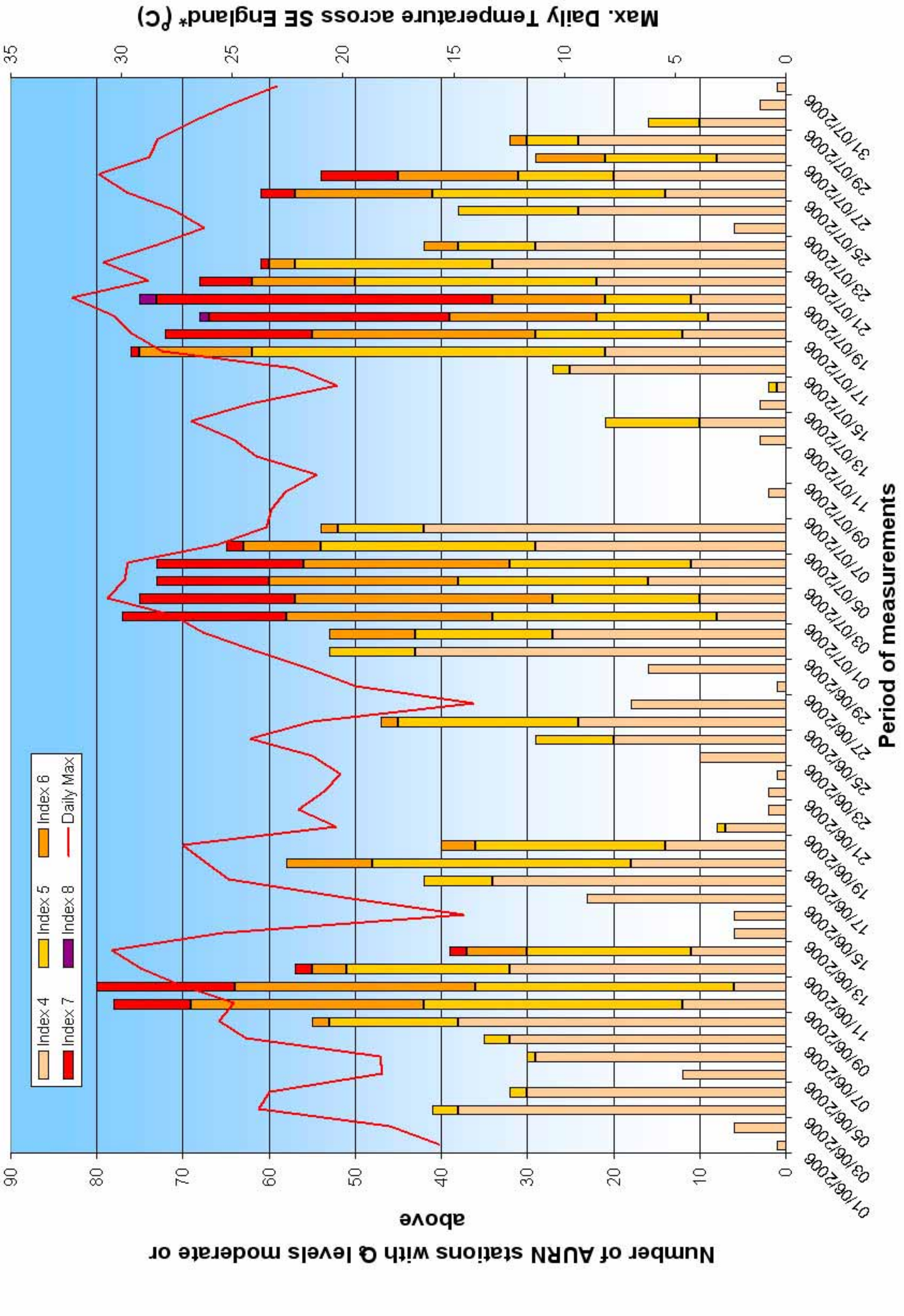


Fig 4.11 Number of high and moderate days, plus temperature, during Ozone episode

Back-trajectories show how air masses may have been transported prior to reaching their destination, whereas forward-trajectories show the movement of air after leaving its origin.

Figure 4.12 shows the 96-hour airmass back-trajectories for the 17th until 20th July, demonstrating clear re-circulation of air masses over Europe during those days when high ozone levels were measured.

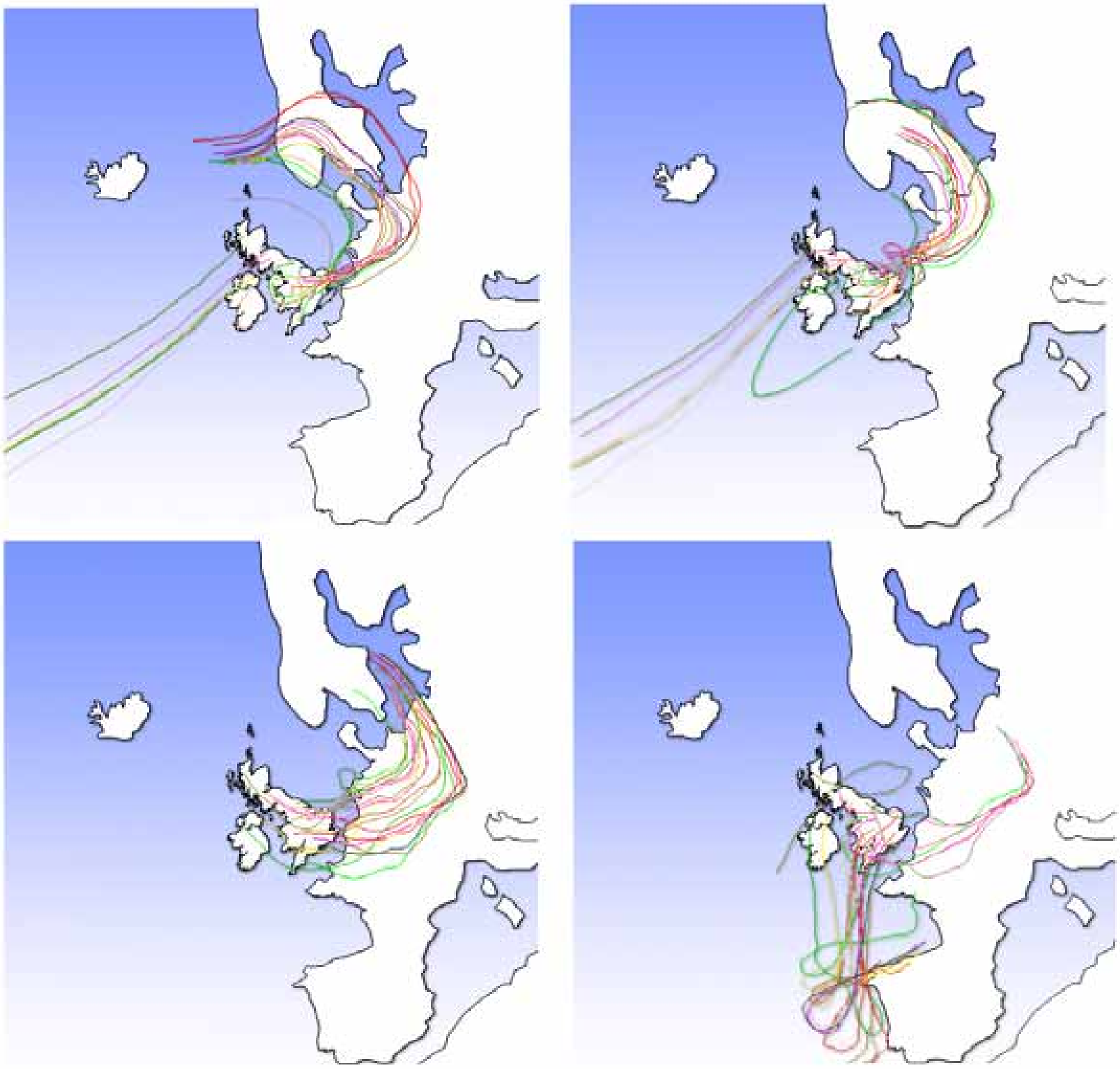


Figure 4.12 96-hour airmass trajectories for July 17-20th

The Ozone Episode across Europe

The high temperatures affecting England and Wales were also experienced across Europe. Heat wave conditions arrived at the end of June in a number of European countries including the UK, Ireland, France, Belgium, the Netherlands, Luxemburg, Poland, the Czech Republic and Germany. In some countries, July 2006 was the warmest month since official measurements began. The highest temperatures were generally recorded on 19th July.

Figure 4.13 is a false-colour satellite image showing surface temperatures on 19th July over Northern Europe. It can be seen that temperatures elsewhere in Europe were as hot or hotter than in the UK. Figure 4.14 clearly the geographical extent of the ozone episode on that day. Apart from the UK, high ozone levels were also measured in Ireland, France, Belgium, the Netherlands, Luxembourg, Germany and Czech Republic.

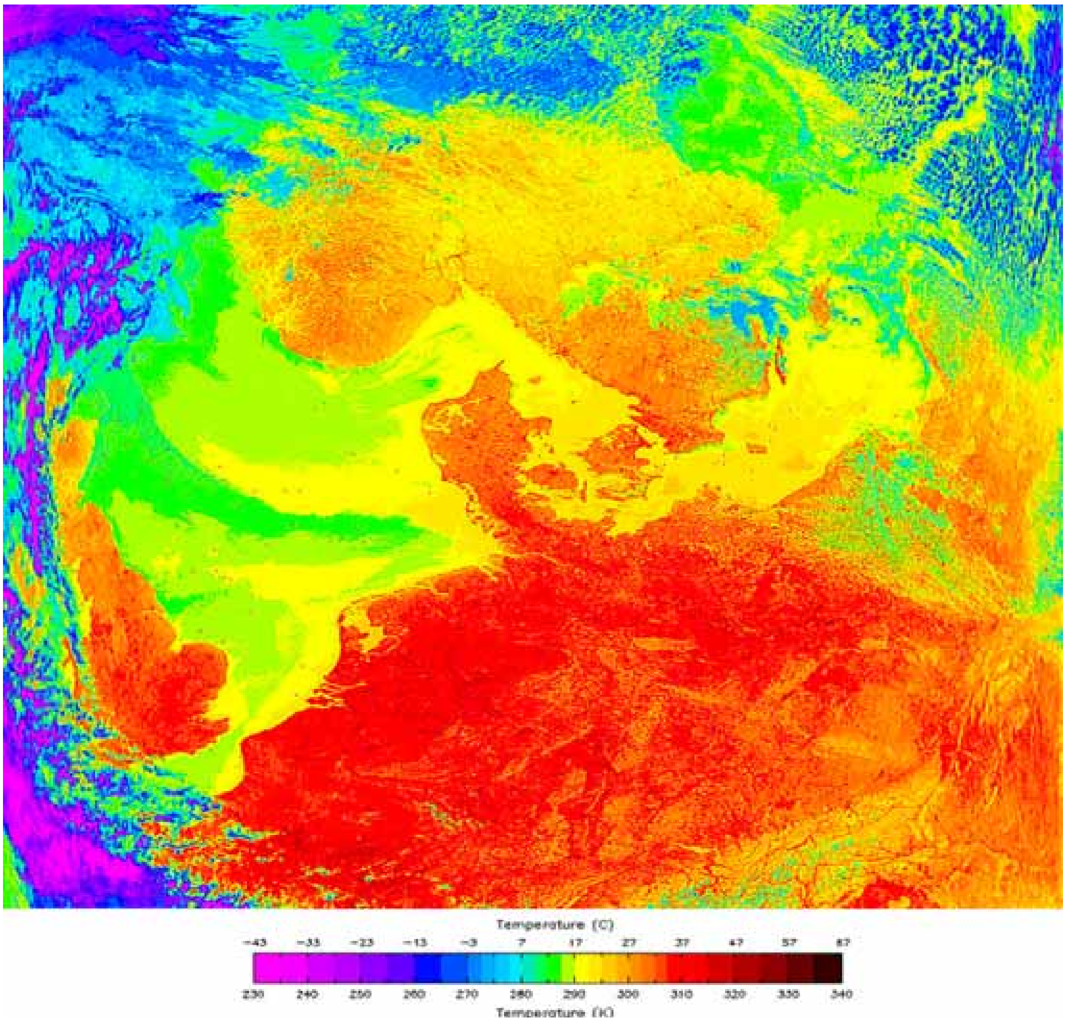


Figure 4.13 – MODIS Satellite Image showing Europe-wide temperatures on 19th July 2006 at 10:35 UTC

Figure 4.14- Ozone Episode across Northern Europe on 19th July at 16:00 from the European Environment Agency's Ozone Web (*provisional*) – see http://www.eea.europa.eu/maps/ozone/welcome

Conclusions

The main features of the June/July 2006 ozone episode may be summarised as follows:

- High summer temperatures, combined with recirculating air over Europe and the UK resulted in the most prolonged ozone episode of 2006.
- The area of the UK primarily affected was England and Wales
- This episode was also measured across Europe, and particularly in the Low Countries, Germany, France and the Czech Republic
- Over 60 AURN monitoring stations recorded ozone concentrations in the 'high' band.
- Ozone levels exceeded the index 8 HIGH band (240-299 μgm^{-3}) at four locations: Wicken Fen, Stoke-on-Trent Centre, Haringey and Blackpool Marton.
- The highest hourly average ozone concentration recording during the episode was 278 µgm-3 (index 8) on the 19th July at Wicken Fen at 18.00.
- The 3rd Daughter Directive ozone alert threshold of 240 µgm-3 was exceeded for 8 consecutive hours at Wicken Fen on 19th July.
- This threshold was also exceeded at a non-AURN site, Lodsworth (Sussex Air) on 18th July.
- Changes in temperature and airmass back trajectories brought the episode to an end as clean air arrived from the Atlantic

A more extensive and detailed analysis of this episode may be found in the reports section of the Air Quality Archive[D5,D6,D7]

5 How air pollution varies across the UK

Levels of air pollution vary across the UK. We see how these patterns relate both to emissions and the behaviour and transport of pollutants once emitted into the atmosphere

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 sources 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 hydrocarbons (VOCs) such as benzene and 1,3-butadiene; it also emits a significant proportion of particles (PM_{10} and $PM_{2.5}$). Concentrations of all these pollutants are therefore usually highest in built-up urban areas with high traffic densities.

In general, patterns of ***secondary pollutants*** such as ground-level ozone and some fine aerosols, which are formed by chemical reaction in the atmosphere, are markedly different from those of primary pollutants; these 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} particles.

5.2 Mapping methods

We have used two different approaches for modelling and mapping levels of air pollution across the UK in 2006. For NO_2 and PM_{10}, maps have been estimated using a combination of atmospheric dispersion models, the UK's National Atmospheric Emissions Inventory (NAEI) and data from the UK monitoring networks. Together, these provide the basis for robust pollutant models; these enable us to produce detailed maps (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[E1]. The mapping methods for PM_{10} have also been described in detail[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 enables us to predict future concentrations by taking into account the projected changes in emissions over the coming years.

The maps produced by the 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 air quality problems in the most direct and cost-efficient manner.

An empirical approach has been adopted to map a range of measurements describing ozone concentrations in 2006. 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 nitrogen monoxide (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 described elsewhere [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 some sources are less well characterised.

The mapped concentrations have been verified by comparison with automatic monitoring data, including data from non-national network sites that are of known high quality.

5.3 NO_x and NO_2

UK-wide patterns of nitrogen oxides (NO_x= nitrogen dioxide NO_2 plus nitrogen monoxide NO) concentrations in 2006 are shown in Figure 5.1. NO_x patterns follow precisely emissions, with large gradients between urban and other heavy traffic areas – on the one hand – and more background or rural parts of the country.

Corresponding variations in the UK-wide patterns of nitrogen dioxide concentrations in 2006 are shown in Figure 5.2. 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. Comparison with Figure 5.1 for NO_x shows NO_2 levels to be lower overall – naturally. We can also see concentration gradients (differences from one place to another) to be characteristically lower as well. These issues are discussed and analysed in depth in the forthcoming AQEG NO_2 report[E4].

Although the data mapped in these figures are for background rather than roadside pollution levels, they clearly follow closely the country's major motorways and road network infrastructure.

5.4 Ozone

UK-wide concentrations of ozone (expressed here as the accumulated hours above 80μg m^{-3} –AOT40) in 2006 are shown in Figure 5.3. This way of expressing ozone has been chosen to represent the impact of this pollutant on vegetation. Values of this parameter will be highest at locations with either higher average concentrations or where concentrations are elevated due to summer ozone episodes. Figure 5.4 shows the ozone concentration expressed as the number of days with running 8-hour mean concentrations greater than 120 μg m^{-3}. 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. Values of this metric will be highest at locations where concentrations are elevated due to summer ozone episodes. The situation is also influenced by changes in background ozone concentrations, which are starting to approach the 80μg m^{-3} threshold at some locations.

Ground-level ozone is formed by a series of chemical reactions involving precursor pollutants - oxides of nitrogen 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.

UK-wide patterns of ground-level ozone are also influenced by other factors. Concentrations in busy urban areas are often lower than in the surrounding countryside. This is because road transport emissions of NO react very quickly with O_3 to generate NO_2 , resulting in lower ozone concentrations in urban areas.

The net result of these effects, acting together, is shown in Figures 5.3 and 5.4. 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. It can also be seen, particularly clearly in the area of lower ozone concentrations around London, that levels of this pollutant are characteristically depressed in urban areas. This results from its 'scavenging' from the atmosphere by road transport emissions.

5.5 PM_{10}

Unlike the other pollutants measured in the automatic networks, particulate matter (PM) is not a distinct chemical species; rather, it consists of material from many sources and is usually classified on the basis of size and not chemical composition. In the UK automatic monitoring networks, PM of average aerodynamic diameter less than 10 microns (where one micron is a thousandth of a millimetre) is measured. This fine PM fraction can be inhaled into the lungs and therefore provide a better indication of potential health impacts than larger particle size ranges.

The map of total PM_{10} concentration in 2006 is shown in Figure 5.5. PM_{10} 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 individual particles in the atmosphere generally include a range of components from a variety of sources. Figure 5.6 shows the contribution from primary PM, which is generally greatest in urban areas close to emission sources. The sources of primary PM_{10} are diverse. Elemental and organic carbon is produced by combustion processes such as from motor vehicles, fuel burning and industrial emissions. Mechanically generated particles are produced by building work and quarrying. Resuspended Soil and road dust can also be considered as primary particles.

A significant proportion of PM_{10} is secondary, formed by the reaction of gases in the air. Sulphates and nitrates are formed by chemical reactions in the atmosphere from emissions of SO_2 and NO_x. Like ozone, secondary PM can therefore be produced considerable distances from the emission sources. Figure 5.7 shows the spatial distribution of secondary PM. The concentrations of sulphate, nitrate and ammonium (known as secondary inorganic aerosol) have been derived from measurements made at rural monitoring sites. Secondary organic aerosol has been estimated using a chemical transport model. It can be seen that secondary PM concentrations are generally greatest in the south and east of the UK, which are more often downwind of and closest to polluted areas of Northern Europe.

Figure 5.8 shows the contribution from the remaining PM sources. This has been calculated as the sum of sea salt PM (derived from chloride measurements) and a constant residual non-modelled contribution of 4 μg m^{-3}. Sea salt PM concentrations are generally highest in the most exposed coastal areas of the UK. The map of total PM_{10} presented in Figure 5.5 is therefore the sum of the three components shown separately in figures 5.6, 7 and 8: primary, secondary and other PM.

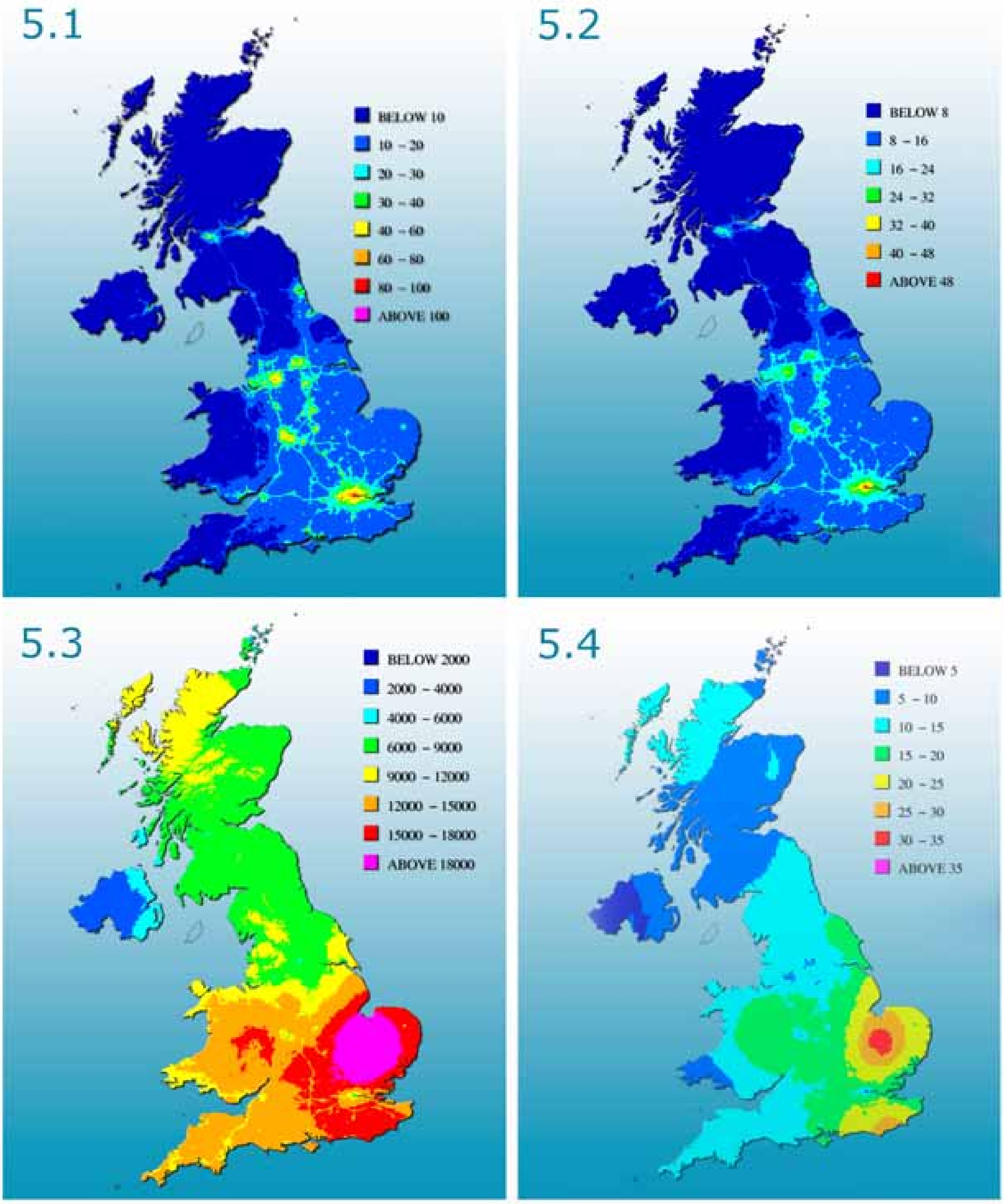


Figure 5.1 Annual mean background NO_x ($\mu g/m^3$)
Figure 5.2 Annual mean background NO_2 ($\mu g/m^3$)
Figure 5.3 AOT40 (Above Ozone Threshold40) metric ($\mu g/m_3$.hours)
Figure 5.4 Estimated no. of ozone days above 120 $\mu g/m^3$ (max daily running 8hr mean)
All data are for 2006

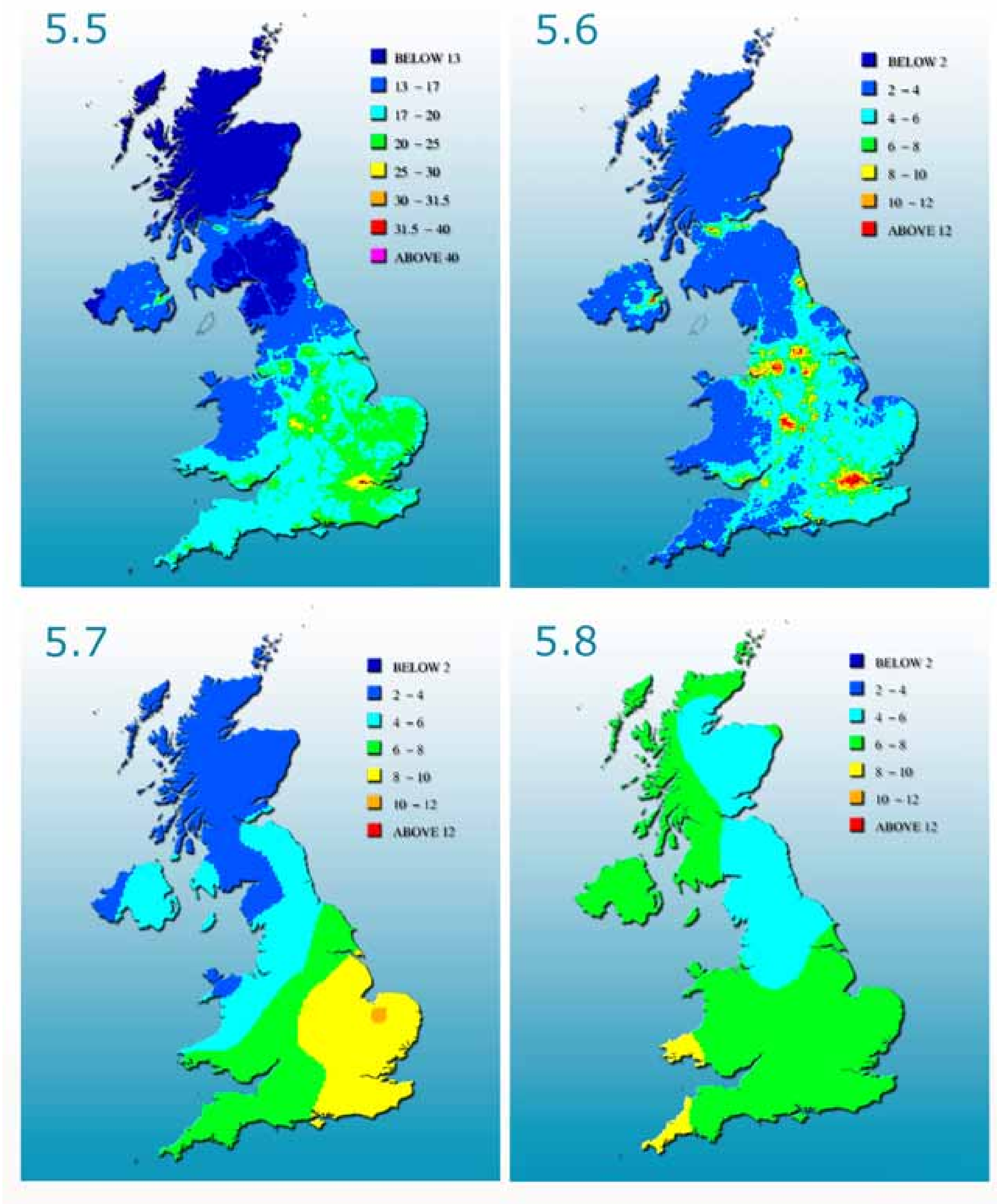


Figure 5.5 Annual mean background PM_{10} (μg/m^3 gravimetric) total
Figure 5.6 Annual mean background PM_{10} (μg/m^3 gravimetric) - primary
Figure 5.7 Annual mean background PM_{10} (μg/m^3 gravimetric) - secondary
Figure 5.8 Annual mean background PM_{10} (μg/m^3 gravimetric) – other sources
All data are for 2006

6 What historic sampler 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 substantially over the decades.

The end of 2005 saw the closure of one of the UK's- and the world's - oldest, longest running and most influential air pollution monitoring networks: the Smoke and Sulphur Dioxide Network. In this section, we take a look at the story of this programme, and what it achieved during its 44 years of operation.

6.1 Origins of the Smoke and SO_2 Network

Air pollution had been a matter of growing public concern since the Industrial Revolution and earlier, when the UK's cities became polluted through the widespread burning of coal and other solid fuels. During the 18th Century, smoke from England was blamed for reducing yield from French vineyards- resulting in severe strain to diplomatic relations between the two countries! Victorian London was notorious for its smoke and fog; though some smoke control legislation was in place at this time, its effectiveness was limited.

By the early years of the 20th century, scientific interest in air pollution led to the first systematic measurements of air pollution in the UK. These were undertaken by enthusiastic Local Authorities and coordinated by a Committee for Investigation of Atmospheric Pollution. To better organise and develop these activities, an organization called the 'Standing Conference of Co-operating Bodies' was established. This later evolved into the 'Investigation of Air Pollution Standing Conference', which still exists today, though in a very different role – that of organising twice-yearly conferences on air quality for Local Authorities and others.

In the winter of 1952, a deadly winter smog occurred in London; this single event is now estimated to have caused the deaths of up to 8,000 people (Fig 6.1). This prompted the passing of the first of a series of Clean Air Acts in 1956. At this time, smoke and sulphur dioxide were monitored daily at about 150 sites. After the Clean Air Act was passed, a Working Group of the Standing Conference was set up in 1959 to design a National Survey of Air Pollution for the UK. This National Survey commenced operation in 1961, with the following aims and objectives:

- To provide guidance to central and local government in the application of existing clean air legislation;
- To assess improvements that were occurring as a result of such legislation;
- To provide a technical basis for further legislation if necessary;
- To provide a systematic body of data for use by the medical authorities for epidemiological studies, and by universities, government laboratories and other interested parties for further investigations.

This was the UK's and probably the world's first co-ordinated national air pollution monitoring network. From its inception, this network was co-ordinated by the DTI's Warren Spring Laboratory (WSL) until its merger with AEA Technology in 1994. The network was then run by AEA until its closure.

At grass-roots level, individual Local Authorities, operated each site in the survey- at their own expense. WSL provided the overall co-ordination, data handling and reporting functions.

Figure 6.1 An iconic image of the Great London Smog of 1952 © unknown

Fig 6.2 Major sources responsible for coal smogs- domestic heating (above) and industry (below)- © unknown

6.2 Monitoring methods

Early measurements were made using the now obsolete lead dioxide candle method for sulphur dioxide (SO_2), and Grit and Dust samplers for deposited particulate material. In the late 1950's, new methods for sampling SO_2 and suspended particulate matter as 'Black Smoke' were developed by the Fuel Research Station in Greenwich- which was later moved to Hertfordshire and became Warren Spring Laboratory.

Smoke was measured by a simple but robust method, subsequently adopted as a British and International Standard. Sampled air is drawn through a filter paper, and the suspended particulate forms a dark stain on the paper. The darkness of the smoke stain is measured by a reflectometer. Ambient smoke concentration is then determined from a standard calibration.

Sulphur dioxide was also measured by a British Standard method. Sampled air is bubbled through dilute, acidified hydrogen peroxide solution, for absorption of sulphur dioxide and other strong acids. The ambient concentration is determined by titration of the solution back to its original pH.

Early and late examples of apparatus used in the National Survey are shown in Fig. 6.3.

Figure 6.3 Early and late examples of the smoke and SO_2 samplers used in the National Survey- the colour image shows an '8-port' sampler.

6.3 Measurements

Annual reports have been produced throughout the survey's lifetime, and all daily data since October 1961 are available electronically on the UK Air Quality Archive website at www.airquality.co.uk .

6.3.1 The 1950s and 60s

Figure 6.4 shows the dramatic fall in ambient smoke and SO_2 concentrations measured by the survey – in line with declining emissions of these pollutants throughout the UK. The reasons for this include:

- The move away from coal for domestic heating
- Tighter regulation of industrial emissions
- Adoption of cleaner fuels and improvements in combustion technology.

However, one of the major factors contributing to the decline in emissions has been the strict enforcement of smoke control measures in industry, through the Clean Air Acts from the 1950s onwards.

The immediate impact of this legislation on black smoke concentrations in London is shown in Figure 6.5. This figure includes black smoke monitoring data from sites in London that were operating before the establishment of the National Survey. Although this graph is based on fewer monitoring sites than Figure 6.4, by including data from before the beginning of the National Survey it shows even more clearly the precipitous fall in smoke levels in London from 1954 onwards.

6.3.2 The 1970s and 80s

The National Survey formed the backbone of the UK's air pollution monitoring throughout the subsequent decades. At its peak in the 1970s, it comprised over 1200 monitoring sites.

In 1980, the National Survey took on a new role: that of monitoring compliance with the new EC Directive 80/779/EEC on SO_2 and Suspended Particulate Matter. Two years later, the Survey underwent a major rationalisation and reduction in size. The new slimmed-down network became known as the UK Smoke and SO_2 Network, and its re-defined objectives were:

- To monitor compliance with EC Directives relating to these pollutants.
- To provide a representative assessment and analysis covering major population centres throughout the UK, based on a core sub-set of sites with a wide spatial coverage.
- To provide a long-term database, for the purposes for assessing trends and spatial distribution.

The Smoke and SO_2 Network operated in this format until 1997.

6.3.3 The 1990s and beyond

The 1990s saw the emergence and increasingly widespread adoption of automatic air quality monitoring methods. Unlike the sampler-based methods for Smoke and SO_2 which required subsequent laboratory analysis to determine measured pollutant concentrations, automatic methods provide continuous readings and offer a number of advantages. However, they have always been more complex and expensive to operate.

Automatic monitoring inevitably began to take over part of the role of the network. Levels of smoke and SO_2 in much of the UK continued to fall throughout the 1980s and 1990s. The last occasion on which any exceedences of the Limit Values of the EC Directive occurred was in 1993.

However, there remained regions of the UK in which levels of Smoke and SO_2 were relatively high, due primarily to continued domestic coal use. One area of particular interest has been Northern Ireland, particularly Belfast. The Smoke and SO_2 Network frequently highlighted these higher concentrations throughout the 1990s.

6.3.4 Focus on Northern Ireland

Trends in smoke and SO_2 concentration in Northern Ireland have not always followed those throughout the rest of the UK. This is because historically – until relatively recently – there has been limited availability of natural gas in the region. This has led to much greater domestic use of solid fuels and oil, and consequently to higher concentrations of pollutants such as SO_2, particularly in residential areas.

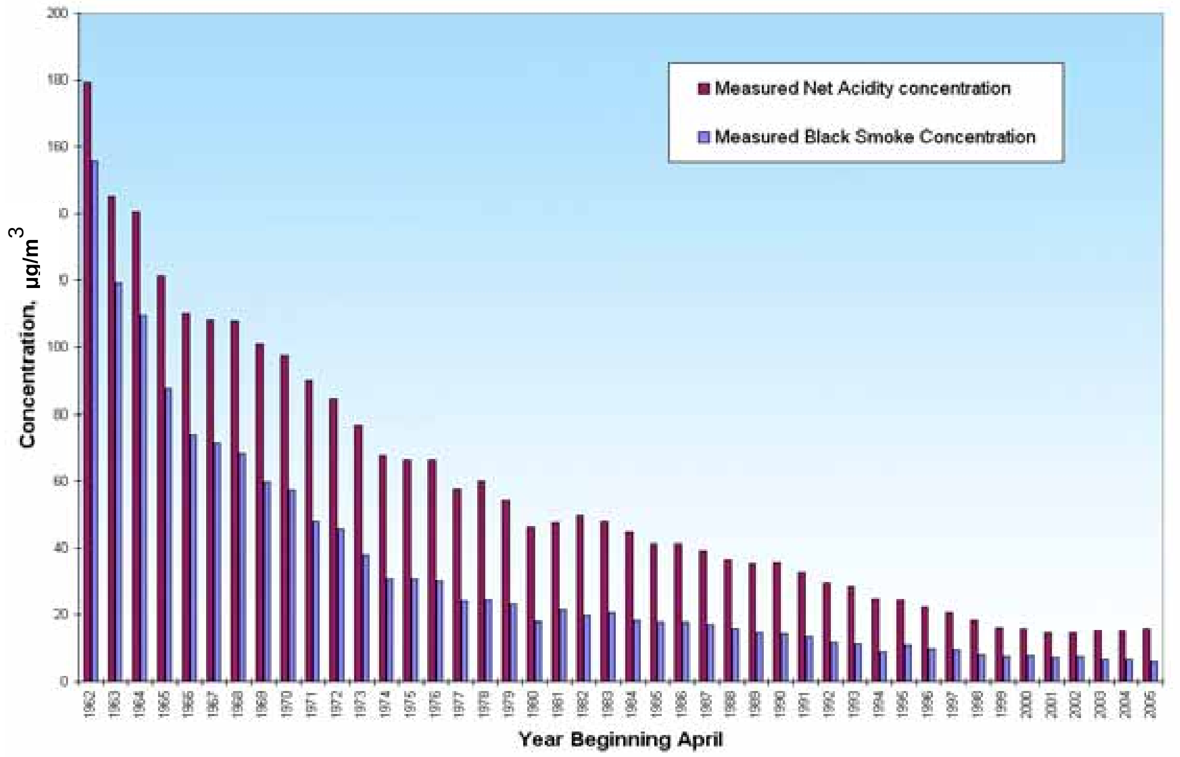


Figure 6.4 Trends in UK SO_2 and Black Smoke from the inception of the national monitoring network to 2005

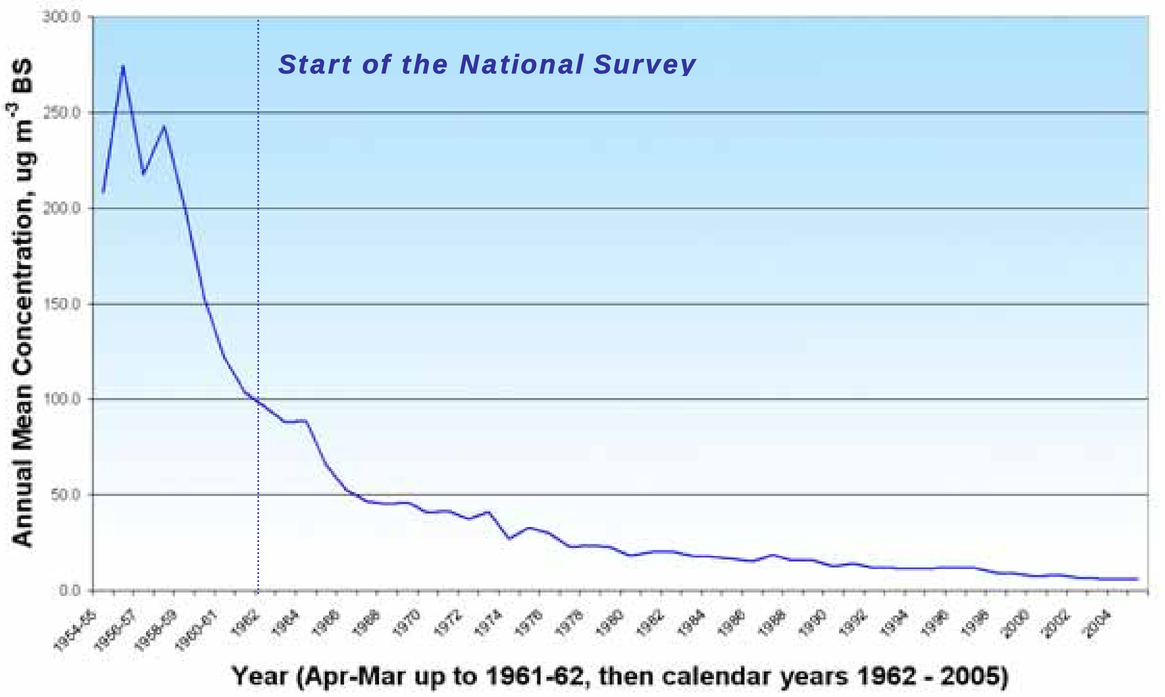


Figure 6.5 Decline in black smoke concentrations in London over 60 years, including data from 1954 to 2005

Figures 6.6a and b (showing smoke and SO_2 respectively) compare the annual mean concentration based on all sites in Northern Ireland, with that based on the UK Network as a whole. Also shown are the annual means at three long-running sites in Belfast.

Trends in SO_2 concentration in Northern Ireland (Figure 6.6a) show a particularly interesting pattern. Until 1980, Northern Ireland's urban SO_2 concentration was typically lower than the UK average, and followed approximately the same declining trend. However, from 1980 – 1987, average concentrations in Northern Ireland rose, overtaking the UK average, before the downward trend continued again from the late 1980s. A possible explanation for this rise in the early 1980s is the phasing out of 'town gas' use over this period. With natural gas not widely available in Northern Ireland as an alternative, this may have resulted from a rise in coal and oil burning.

Until very recently, Northern Ireland's ambient smoke and SO_2 levels remained considerably higher than those in most other UK regions. However, since 2000, the increasing availability of natural gas – together with other factors - has substantially closed the gap. Figure 6.7a and 6.7b (for smoke and SO_2 respectively) show part of the same trend for 1990 onwards. This clearly illustrates how the difference between the average for all Northern Ireland sites, and the Network as a whole, has decreased since 2000. By 2005, the difference in mean SO_2 concentrations was just 3 $\mu g\ m^{-3}$; for the first time since the early 1980s, Northern Ireland's SO_2 levels were once again similar to those in England, Wales and Scotland.

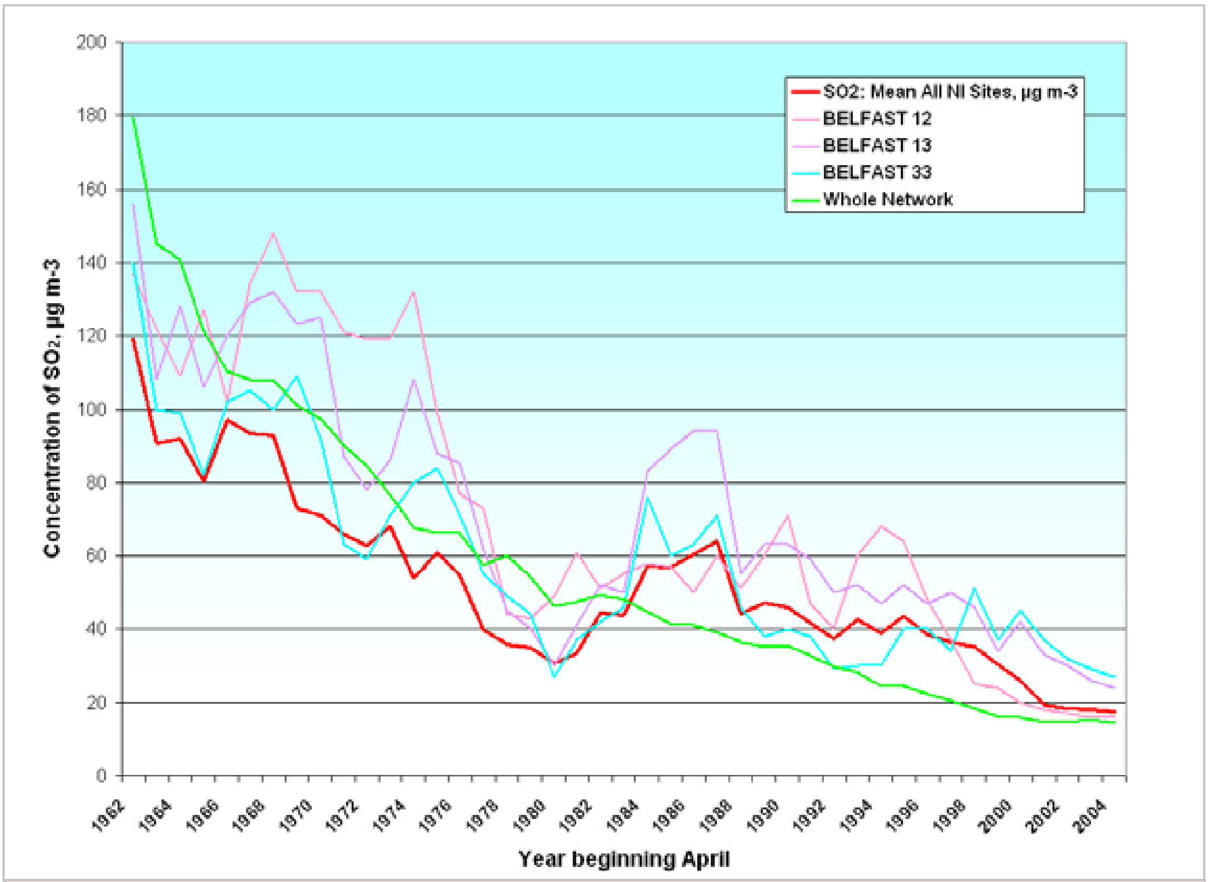


Figure 6.6a Annual Mean SO_2 Concentrations in Northern Ireland. Northern Ireland average, Network average and three long-running Belfast sites from 1962.

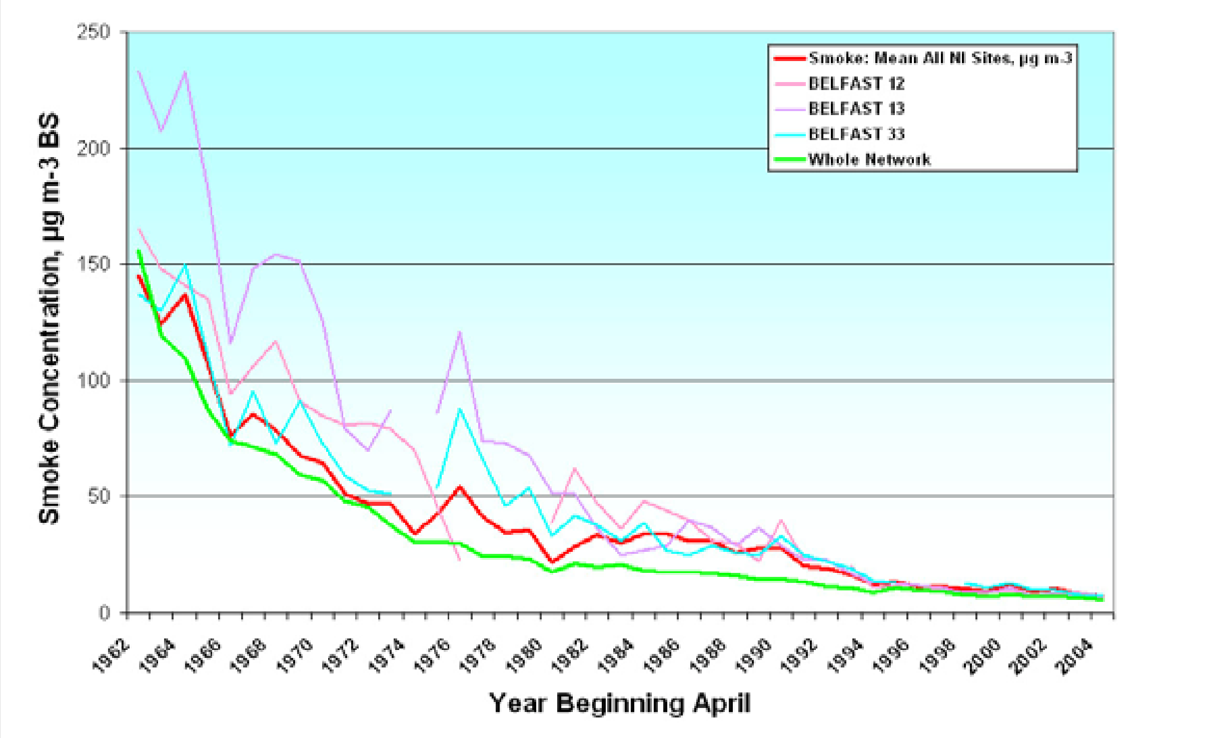


Figure 6.6b Trends in Black Smoke Concentrations, Northern Ireland. Northern Ireland average, Network average, and three long-running Belfast sites from 1962

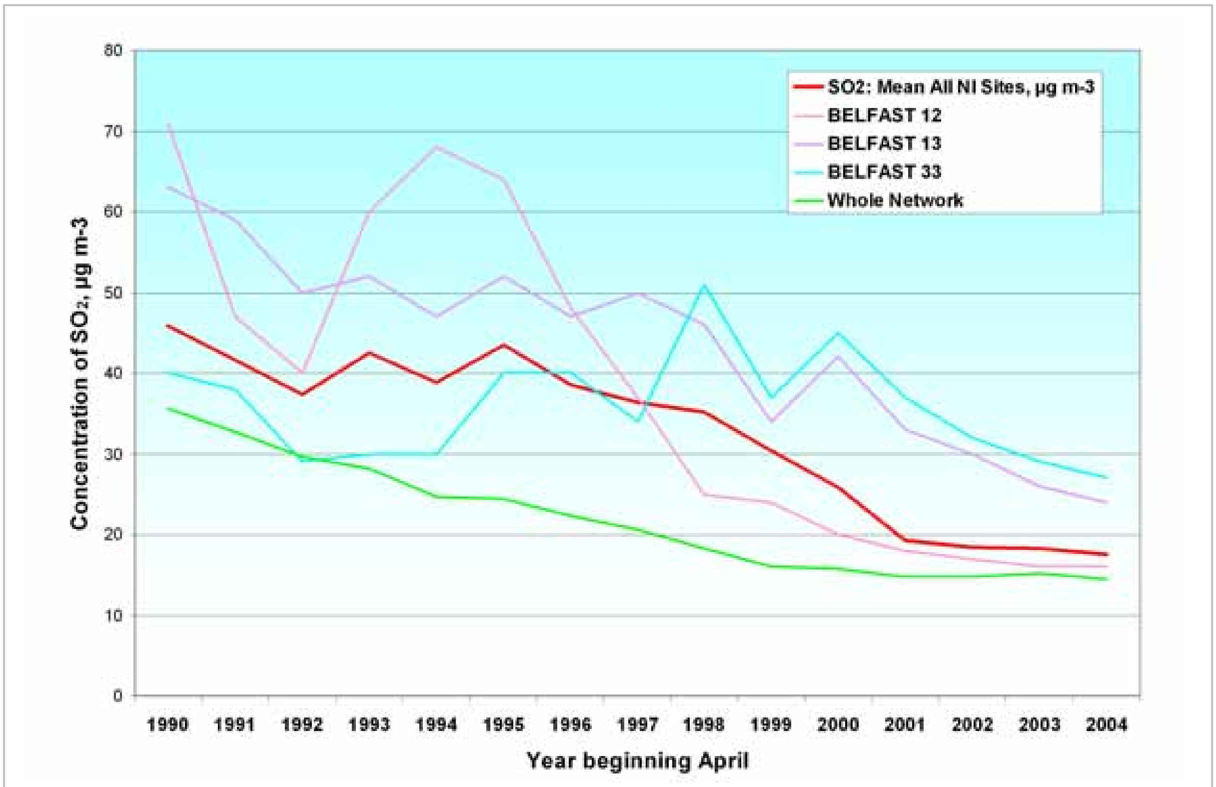


Figure 6.7a Annual Mean SO_2 Concentrations in Northern Ireland. Northern Ireland average, Network average and three long-running Belfast sites from 1990.

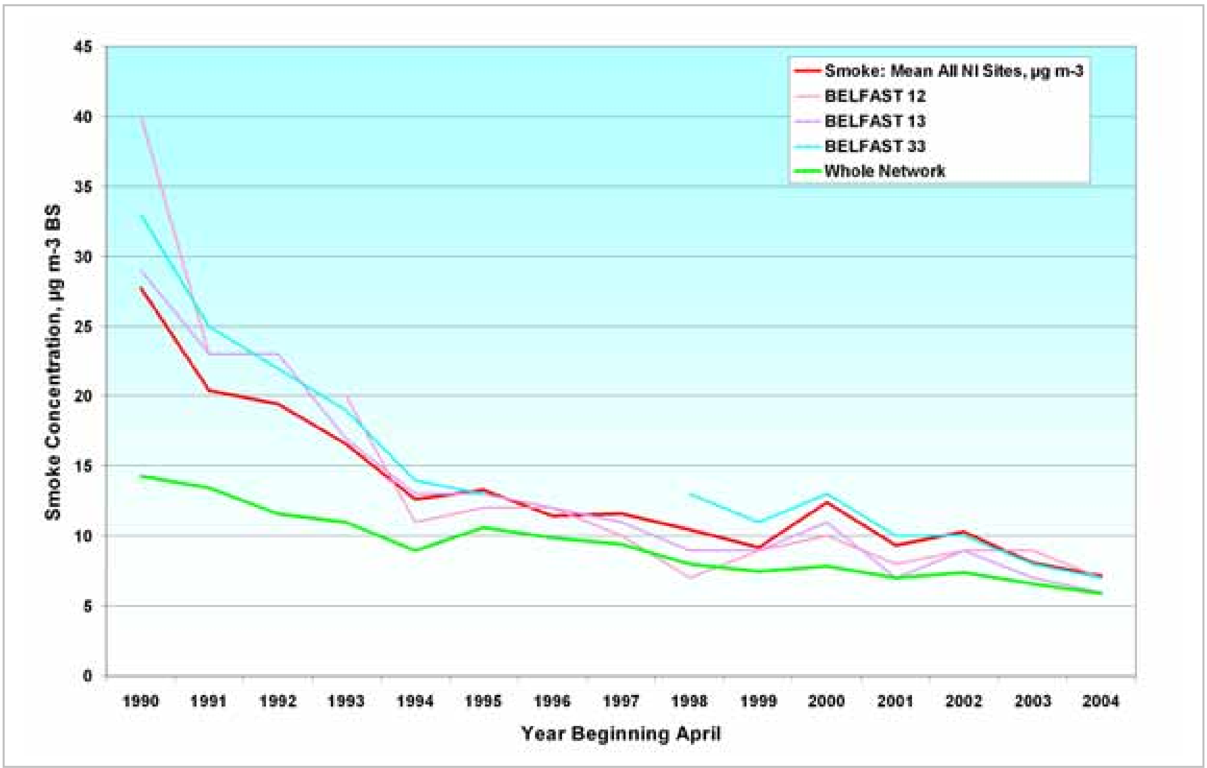


Figure 6.7b Annual Mean Smoke Concentrations in Northern Ireland. Northern Ireland average, Network average and three long-running Belfast sites from 1990.

6.4 The final phase of the Network

As the new millennium approached, the Network increasingly faced a number of challenges:

- The end of its compliance-monitoring role, with the repeal of EC Directive 80/779/EEC on 1st January 2005.
- The newer Limit Values and Objectives in the 1st EC Daughter Directive and the UK Air Quality Strategy require PM_{10} and SO_2 to be monitored using continuous analysers.
- The number of automatic monitoring sites for PM_{10} and SO_2 in the UK has increased massively in recent years, largely taking over the role of compliance monitoring.
- Ambient concentrations of both parameters, but especially sulphur dioxide, fell significantly throughout the 1990s and early 2000s

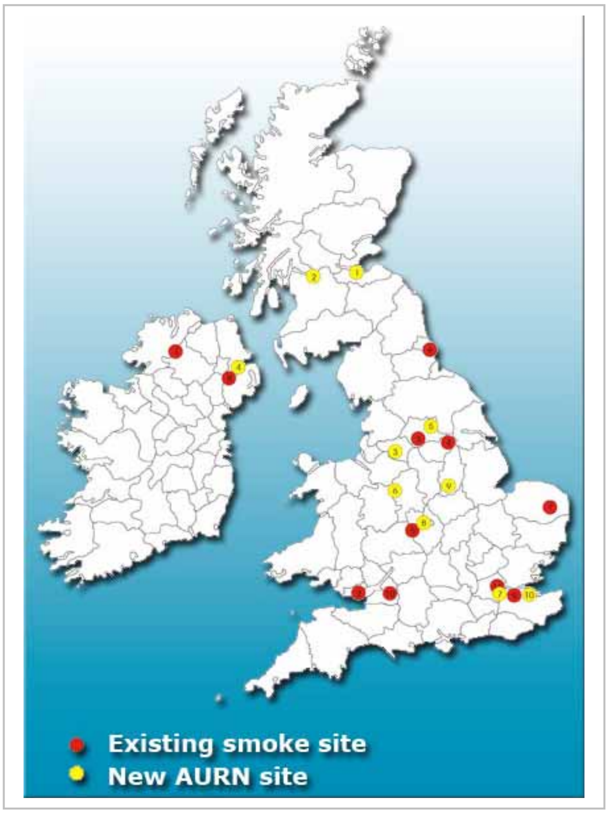


Fig 6.8. The new smoke network

- As a result:
  - Average SO_2 concentrations were well below the minimum level for which use of the net acidity method is recommended, and
  - It could no longer be assumed that SO_2 is the main contributor to net acidity.

In 2005, Defra and the Devolved Administrations commissioned a review of the network, which concluded that - in its existing form- it had finally come to the end of its useful life. However, the review also acknowledged that the scientific community remains interested in black smoke as a useful particulate metric correlated with health effects. It concluded that a small network of sites should therefore be retained, monitoring smoke only.

The long-running Smoke and SO_2 Network has evolved into the new UK Black Smoke Network (Fig 6.8) This new network began operation in 2006 and is operated by NPL. It consists of 21 monitoring sites; half of these sites are former Smoke and SO_2 Network sites, whilst the remainder are AURN sites at which a smoke sampler has been installed. The new network has specifically been designed to maximise the usefulness of the data in epidemiological studies. Black smoke is monitored on a daily basis, using the same technique as used by its forerunners.

More information on the new network is provided in Appendix 3.7 (Part 3 of this report). The first annual report from this programme is available on the Air Quality Archive at http://www.airquality.co.uk/archive/reports/cat05/0706141352_2006_Annual_Report_final.pdf

6.5 Use of data in health effect studies

The massive dataset obtained by the National Survey remains of considerable use to the scientific community. Smoke data, in particular, are still widely used in health effect studies and other scientific work. Numerous studies have identified associations between black smoke concentration and significant population health effects.

- The Expert Panel on Air Quality Standards (EPAQS) published an analysis in 2001 of daily mortality and hospital admissions, PM_{10}, $PM_{2.5}$, $PM_{2.5-10}$, particulate sulphate and black smoke in the West Midlands[F1].
- One key conclusion of this study was that, "of all the particle measures, Black Smoke appeared to be one most consistently associated with health effects, and was most stable in models which included other pollutants".
- A clear link between mortality and medium-term exposure to particulate pollution measured as black smoke, in Dublin over years 1980 – 1996 was reported and analysed in 2004[F2].

Fig 6.9 Smogs were associated with major health impacts © unknown

- A study of daily mortality in eight Spanish cities found that black smoke had a nearly linear association with daily deaths, with no evidence of a threshold[F3].
- A study of daily mortality in the Netherlands reported that "aerosol sulphate, nitrate and black smoke were more consistently associated with total mortality than was PM_{10}.[F4]
- Most recently, a study by Imperial College London[F5] reported in the journal Thorax in July 2007 used data from the Smoke and SO_2 Network in a major study of population exposure to smoke and sulphur dioxide from 1966 onwards. The study found significant associations of black smoke and SO_2 concentrations with mortality, particularly from respiratory illness.

These and other studies demonstrate that black smoke is still a valid particulate metric, and that - even at today's relatively low concentrations- it remains closely linked to human health impacts.

6.6 Achievements

In many respects, the National Survey has proved to be a key and trend-setting programme:

- It was the earliest example of a nationally coordinated pollution monitoring network in the world.
- It provided the scientific and medical community with a robust, high quality and long-term historical record of UK's air quality over an uninterrupted period of more than 40 years.
- Network measurements provided the basis for pioneering epidemiological studies, which firmly established the link between air pollution and serious health impacts.
- It successfully highlighted air pollution issues specific to certain regions - such as the changing pollution climate in Northern Ireland – enabling these to be tackled effectively
- The network provided a successful model for the new automatic Enhanced Urban Network, which later became the Automatic Urban and Rural Network (AURN).
- It also provided an overall approach to running large-scale air monitoring programmes, which was followed worldwide.
- By providing an authoritative record of the progress of the Clean Air Acts, the Network has provided a clear example of how Government policy and action can successfully improve air quality.
- It offers important lessons to countries which still have serious problems from coal burning, such as China.

The Network's dataset remains available in full on the UK Air Quality Archive at www.airquality.co.uk .

The authors of this report would like to thank all those people – in both Warren Spring Laboratory and Local Authorities throughout the country- involved in the operation of the National Survey and Smoke & SO_2 Network over its many years of operation from 1961 to 2005.

7 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

7.1 Introduction

The concentrations of different 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; these changes depend primarily on the size, timing and distribution of their emission sources. Secondary pollutants (those that are created in the atmosphere), such as ozone, may vary more slowly over time 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 respiratory conditions in sensitive individuals. In the long-term, exposure to air pollution affects our quality of life and overall life expectancy.

In this section, we focus on the UK 'pollution climate', examining long-term trends in UK air quality and illustrating how our overall exposure to harmful air pollutants is changing over time in an effort to answer the question "*to what extent is air quality in the UK improving or declining?*" 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, these issues substantially involved the assessment of Black Smoke and Sulphur Dioxide data. We have seen in the previous section how levels of these pollutants have declined markedly throughout the UK, in response to changing emission patterns, usage of new fuels and successful legislation.

As these pollutants have become less problematical over time, attention has shifted progressively to assessing and controlling the impacts of secondary pollutants, particles and traffic-related species. Increased monitoring (Section 3) has made it possible to examine trends in these pollutants in great detail. In this section, we consider these trends in the context of:

1. The UK Government's air quality indicators (Section 7.2 and 7.3)
2. Compliance with specific objectives set out in the UK Air Quality Strategy (7.4)

Please note 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 '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. Whilst both the outcomes and indicators are similar at present to those in the rest of the UK, these may diverge in future. Please see http://new.wales.gov.uk/topics/environmentcountryside/epq/Envstratforwales/About_the_strategy/?lang=en for further information.

7.2 Pollution indicator 1 – PM_{10} and ozone (O_3)

The Government's Sustainable Development indicators for Air Quality provide two significant measures of how the air quality has changed in the period from 1990 to 2006. The first of these indicators is graphed in Figure 7.1. This statistic, first established in 2005, shows trends in two specific pollutants: daily maximum 8-hour ozone and annual mean particulate matter (PM_{10}). This indicator demonstrates the special prominence of these two pollutants, which are believed to pose the most significant threats to public health through long-term exposure.

Figure 7.1 shows that ozone concentrations have been rising more rapidly at background locations than at rural sites over the last decade; this has reduced the historic gap between the urban and rural environments, which has been due primarily to ozone 'scavenging' by traffic-related NO_x emissions in urban areas (see next Section).

Measured ozone concentrations in 2006 were comparatively high - though not reaching levels recorded during the record 2003 heatwave. This was as a result of meteorological conditions that led to a prolonged heatwave and photochemical episode in June and July. This has been discussed at length in Section 4. Extensive analyses of this episode, together with an assessment of its potential health impacts, are also available for download from the UK Air Quality Archive[G1,].

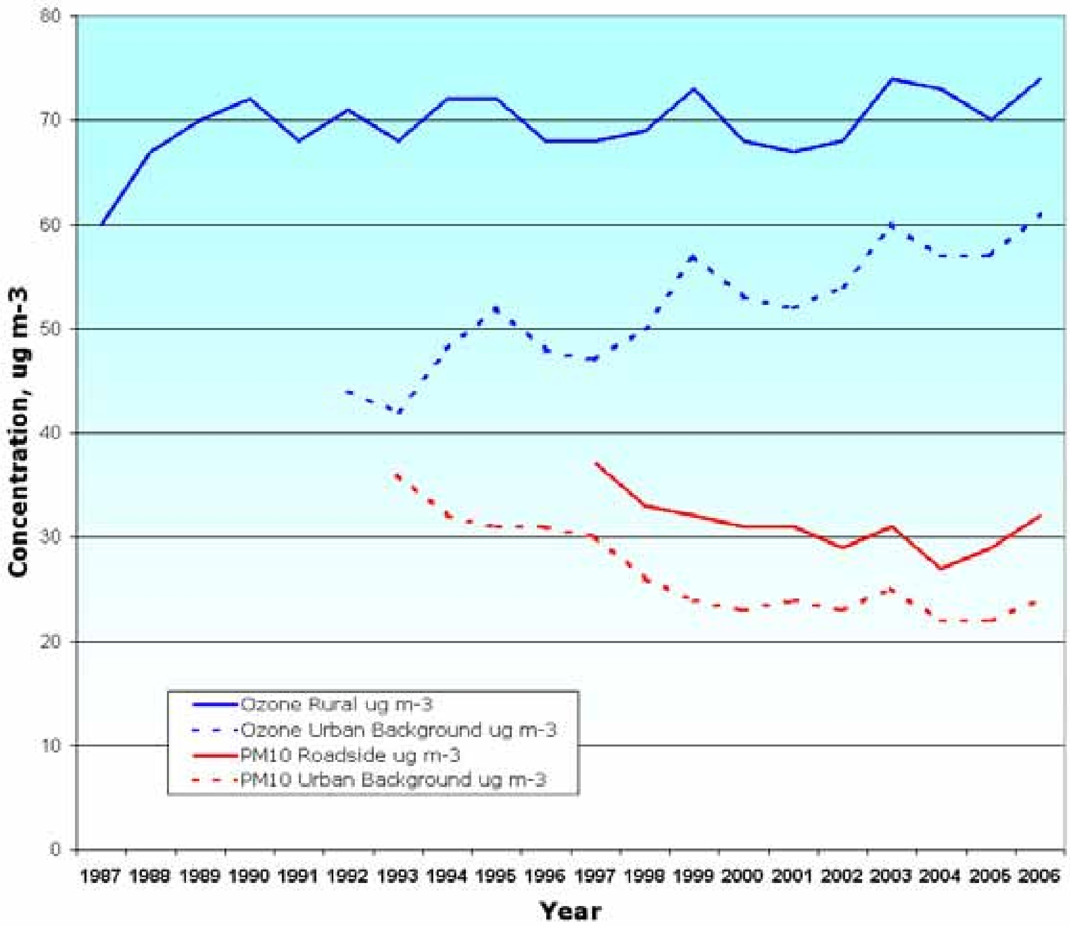


Figure 7.1 Trends in Air Pollution Indicator 1 from 1988 to 2006: gravimetric PM_{10} annual mean and ozone annual mean of the daily maximum running 8hr mean

By contrast to ozone, concentrations of PM_{10} have been steadily falling at background and roadside sites until about 2000. The rate of this decline has been similar at both environments. Concentrations measured over the last few years demonstrate that this decline in concentrations may now be levelling off; in fact, the trend appears to be flat from 2000 onwards.

It is possible that secondary particles generated in the atmosphere during the June and July heatwave contributed to the elevated levels of PM_{10} in 2006 that are shown in Figure 7.1. Additional contributions to elevated PM_{10} levels in 2006 have been attributed to Russian biomass burning from forest fires[G2,3] in May 2006 (discussed in Section 4) and from a PM_{10} episode with continental origins in September 2006[G4].

7.3 Pollution indicator 2 – number of moderate or higher 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 per site on which pollution levels were above the UK's 'moderate' air quality band (as defined in Section 3, box 1). These bands represent defined concentrations associated with different levels of health risk. When air 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.

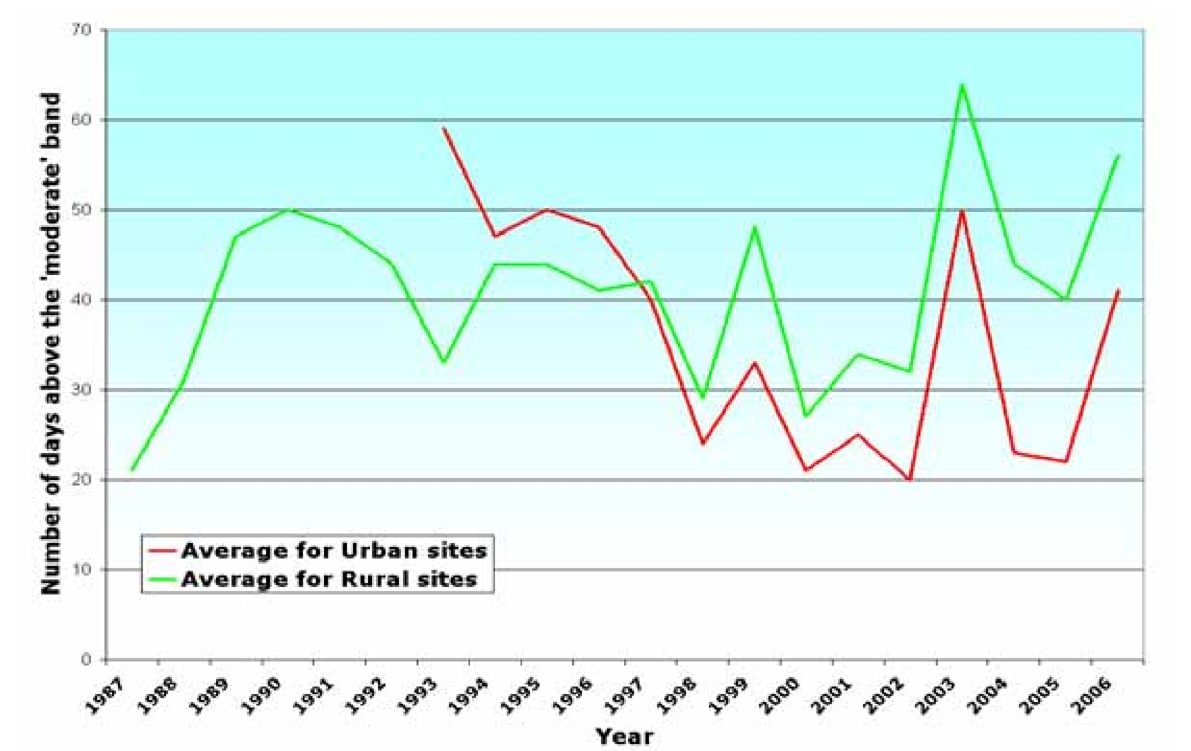


Fig 7.2 Trends in air Pollution Indicator 2 from 1987 to 2006: number of days exceeding 'moderate' air quality band

Figure 7.2 shows how the number of moderate or higher air pollution days in the UK has changed over the period from 1987 to 2006. With the exception of the notable peak in 2003 and 2006, the number of such days at urban sites has declined significantly since 1993. The weather can cause significant variation from year to year in the number of days of moderate or higher air pollution. The year 2003 therefore stands out in this analysis as a result of the unusual weather conditions that persisted and which were discussed in detail in that year's annual air quality report. During the spring of 2003, there were regular easterly winds bringing continental air pollution to the UK. This was followed during the summer months by prolonged exceptionally hot weather; this led to a series of photochemical ozone episodes and the high number of pollution days shown in this figure.

The number of days of 'moderate' or above air pollution measured at rural sites in Figure 7.2 shows no clear trend. This may be because ozone is the dominant pollutant in rural areas. As well as being a secondary pollutant, created in the atmosphere from precursor emissions, ozone is also present naturally. Concentrations of this pollutant are heavily dependent on a range of factors, including the weather and long-range transport. As a result, it is harder to control ozone concentrations. The transboundary nature of ozone means that the Government is working at in international level to reduce the emissions of the precursor pollutant emissions that can react in the atmosphere to form ozone.

7.4 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 Table 2.1 of Section 2.2) and those not in Regulation or of more localised coverage for London or other parts of the country. Results from the analysis carried out for 2006 are summarised in Figures 7.3 and 7.4.

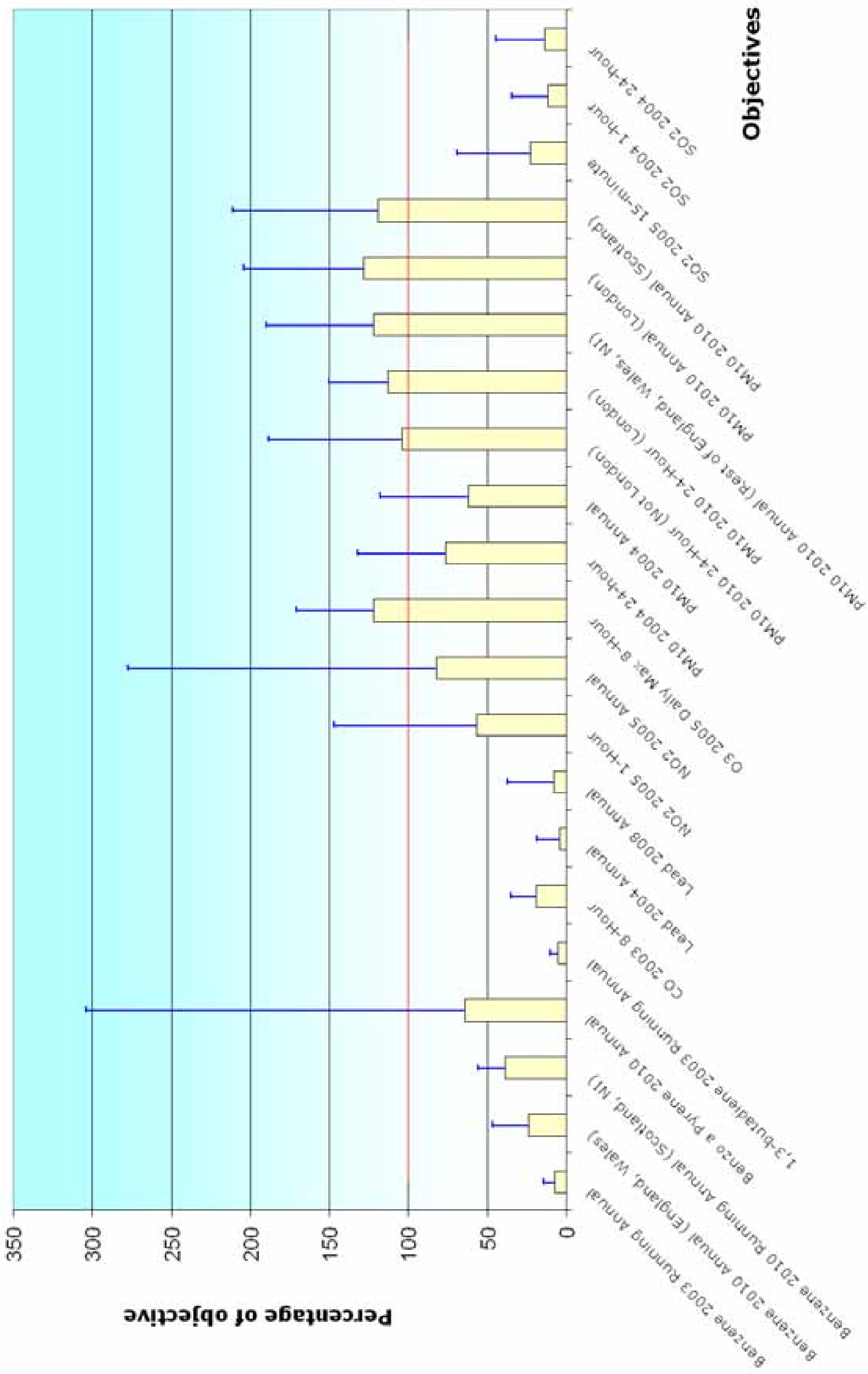
As in previous reports, Figure 7.3 is presented as a 'box and whisker' plot showing mean compliance statistics averaged across all measurement sites in the AURN, normalised and expressed as a percentage of the Air Quality Strategy Objective. To provide additional information, the maximum site statistic is also graphed. The height of each yellow bar in the figure represents the average statistic across the whole network compared with the relevant national objective, while the blue lines 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 7.3 is discussed in greater detail in Appendix 6.

Figure 7.3 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 2006 show a continuation of the trends 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 ozone and PM_{10}; network averages of these pollutants, rather than just the highest concentrations measured, exceed their respective objectives.

Figure 7.4 presents time series analyses for specific examples of pollutant objectives including BaP, NO_2, ozone and PM_{10}. The average and maximum concentrations are presented in $\mu g\ m^{-3}$, rather than as percentages of the objective value as shown in Figure 0.5. These graphs show how levels are changing over time in relation to each objective.

Figure 7.4a demonstrates that BaP concentrations are, on average, close to the objective. The network average concentrations may exhibit a slight downward trend. This downward trend is more marked in the decline of the maximum concentration, although this remains shallow and maximum measured concentrations for BaP remain significantly above the objective value. The highest BaP concentration in 2006 was recorded at Scunthorpe, where industrial emissions are known to make a substantial contribution.

Figure 7.3 Measured concentrations of pollutants in the UK in 2006 as a percentage of the relevant objectives (mean of all sites and highest site)



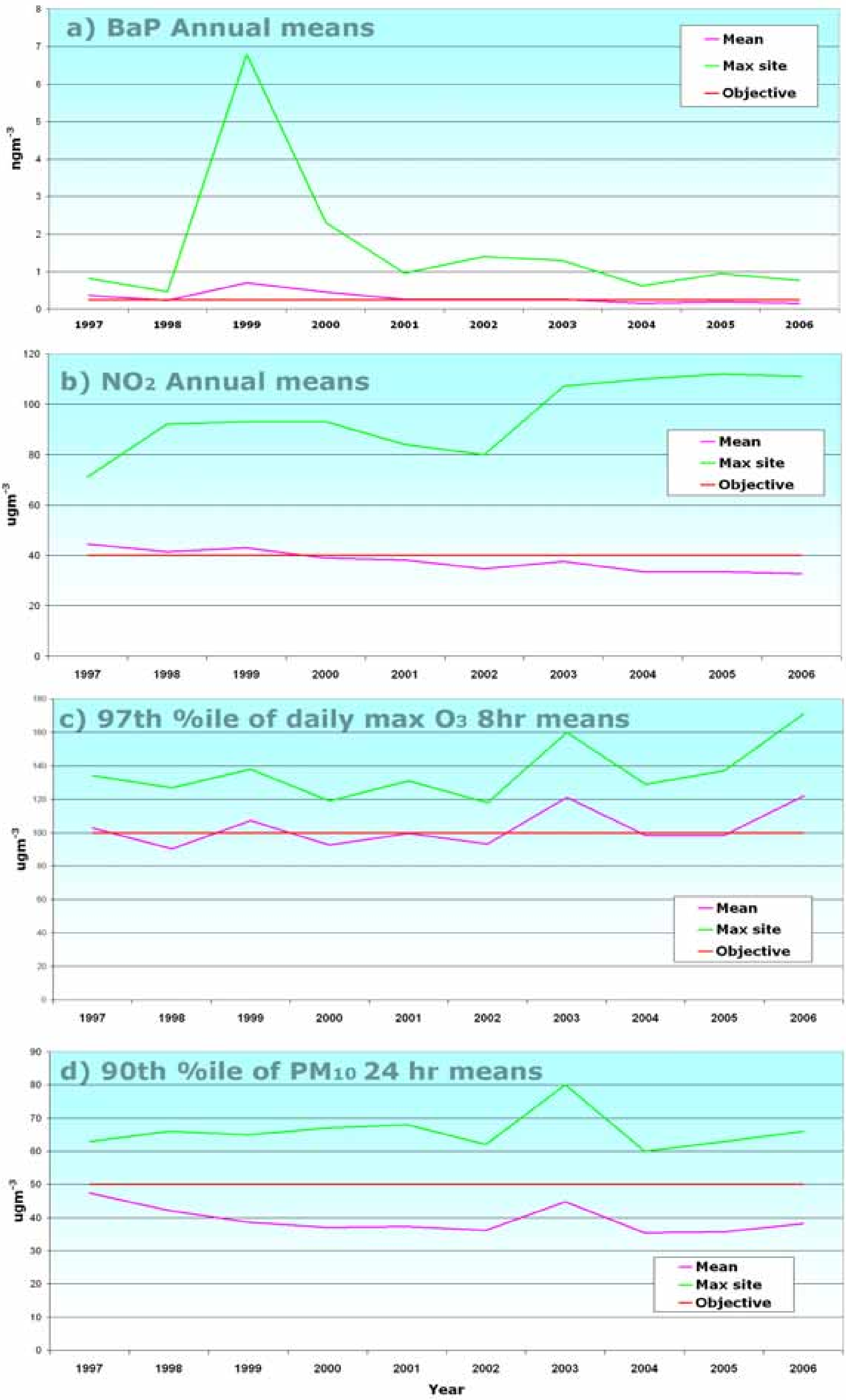


Figure 7.4 a) to d) Trends from 1997 to 2006 in mean and maximum measured concentrations for four selected pollutants against their corresponding UK Air Quality Strategy Objectives

decade and have been below the objective value since 2000; this trend looks set to continue. However, the highest concentrations of NO_2 measured by the network appear to have been actually 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 7.4c) have risen slightly over the last decade and it is likely that both these will exceed the objective value in the next few years. It has been suggested that background levels of ozone are increasing in the northern hemisphere and that climatic change will result in longer summer seasons and increased intensity of sunshine. Both these factors will tend to further accelerate the chemical reactions that create ozone in the atmosphere. It should be noted that the increase in average ozone concentration measured across the 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 7.1.

Figure 7.4d shows corresponding trends in average and maximum PM_{10} when 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.

Both the time series plots for ozone and PM_{10} (Figures 7.4c and 7.4d) clearly show the unusually high concentrations of these pollutants measured during the ‘heat wave’ year of 2003 and – for ozone- 2006.

8 A broader perspective on UK Air Pollution

How does air pollution in the UK compare with other parts of the world? This is not a topic we have previously examined in these UK annual air quality reports. Here we provide an initial assessment, focussing on our European neighbours.

8.1 Introduction

Previous sections in this report, and all the 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 EU.

We have chosen, therefore, in this section to compare current UK levels of key pollutants- PM_{10} particles and ozone - with corresponding measurements throughout Europe. We also compare UK trends in air quality since 1997 with corresponding changes throughout the European Union.

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

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

Why have we selected these pollutants in particular? This is primarily because long-term exposure to PM_{10} and O_3 are now believed to pose the most significant threats to public health in UK and throughout Europe.

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 2005. 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 Particulate Matter (PM_{10}) Levels

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

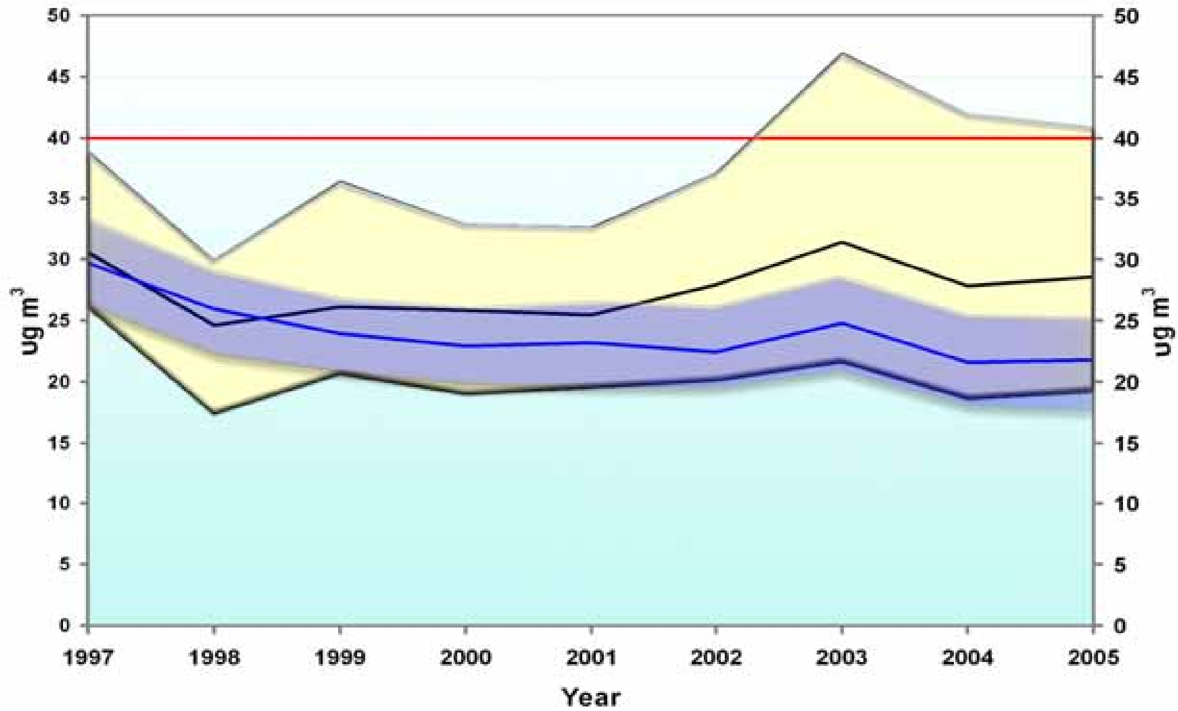


Figure 8.1 Comparison of UK urban background PM_{10} levels (blue line and shaded area) with European Averages (yellow): 1997 to 2005. Ranges shown from 10th to 90th percentile values. EU average shown by black line.

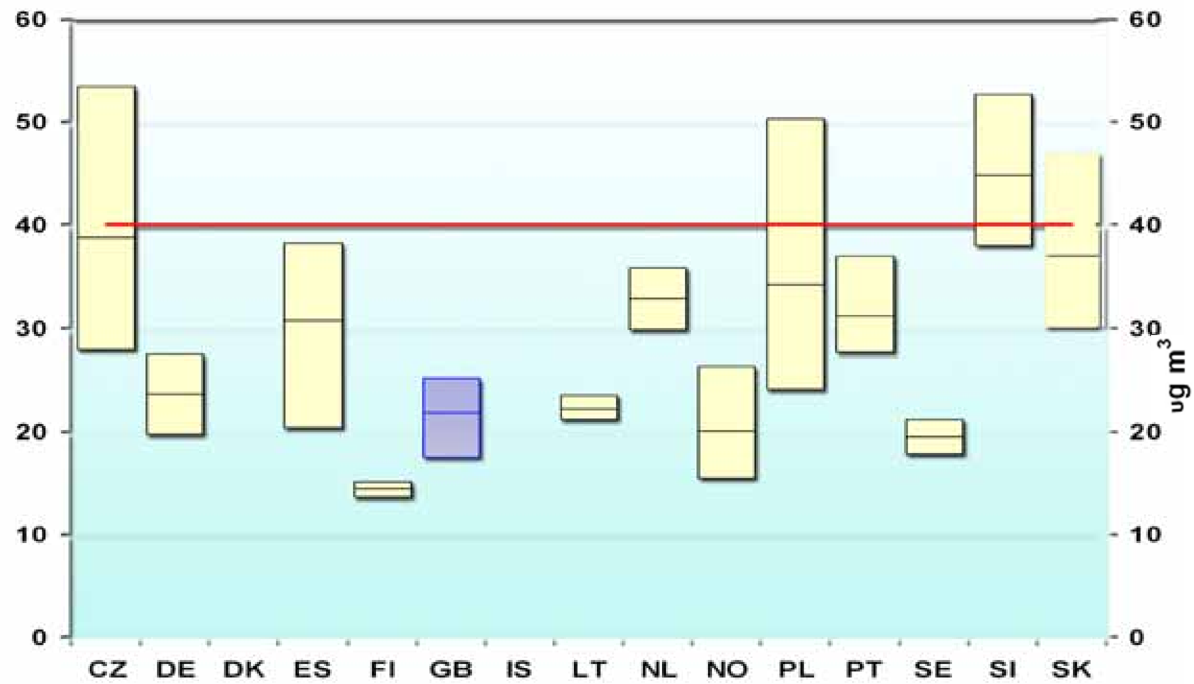


Figure 8.2 Comparison of UK urban background PM_{10} levels (blue) with other European Nations (yellow) for 2005. Ranges shown from 10th to 90th percentile values.

In Figure 8.1, we examine annual mean PM_{10} levels across urban background stations in the UK from 1997 to 2005: 90th percentile, mean and 10th percentile levels are graphed in blue. By way of comparison, the corresponding EU-wide statistics (15 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 eight years.

Figure 8.1 clearly shows that current annual means for PM_{10} across urban 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.

Note also from Fig 8.1 the peak in all data in 2003; as highlighted in previous reports, elevated levels of a range of pollutants were seen throughout UK and Europe during the unusual 'heat wave' summer experienced that year.

Figure 8.2 compares UK background PM_{10} concentrations with those of individual EU countries for the latest year of measurements available in AirBase- 2005. UK data are shown in blue, with upper and lower ranges denoting the 10th and 90th percentile measurements respectively, and the middle line showing the mean.

This figure re-enforces the observations summarised in Figure 8.1. It shows that the UK levels that year were broadly similar to those in other countries like Denmark and Norway, but markedly lower than those in most of other countries, including the Netherlands, Czech Republic, Poland, Portugal 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 – say – 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 background sites. This might be expected; after all, roadside environments are more homogenous 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 urban background locations. This lends support to the possibility than UK urban 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 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.

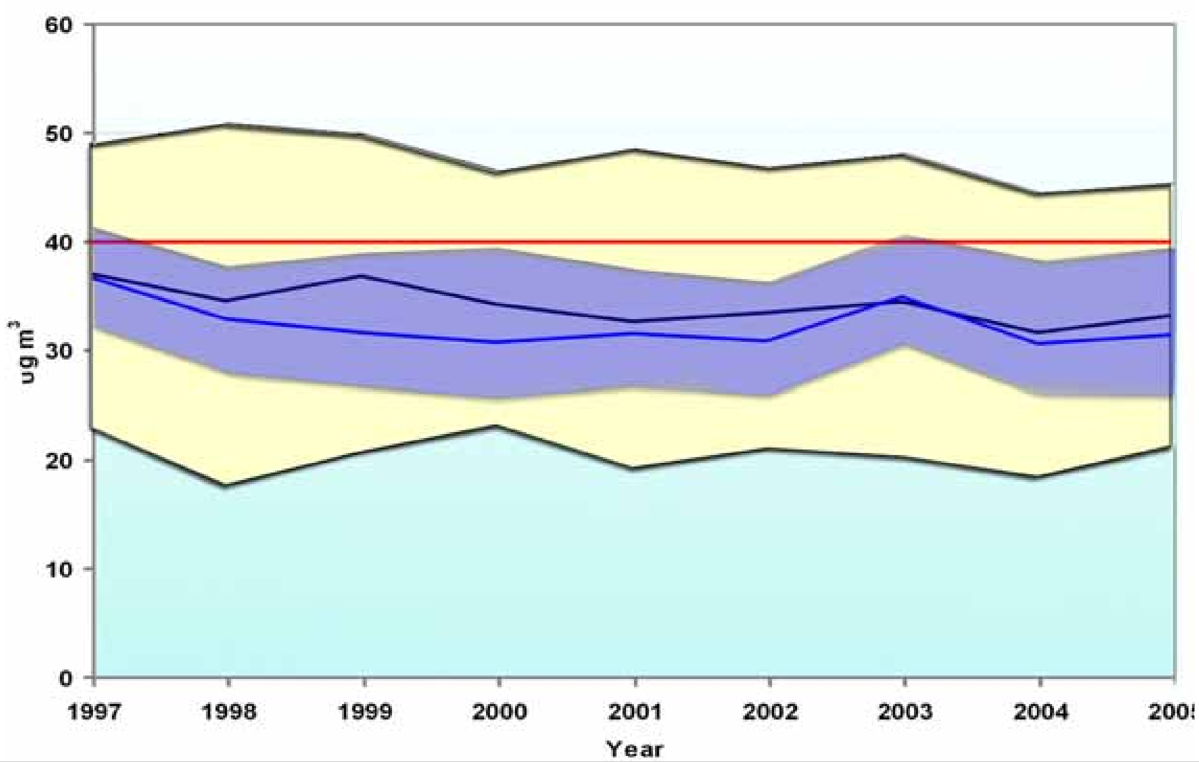


Figure 8.3 Comparison of UK roadside PM_{10} levels (blue line and shaded area) with European Averages (yellow): 1997 to 2005

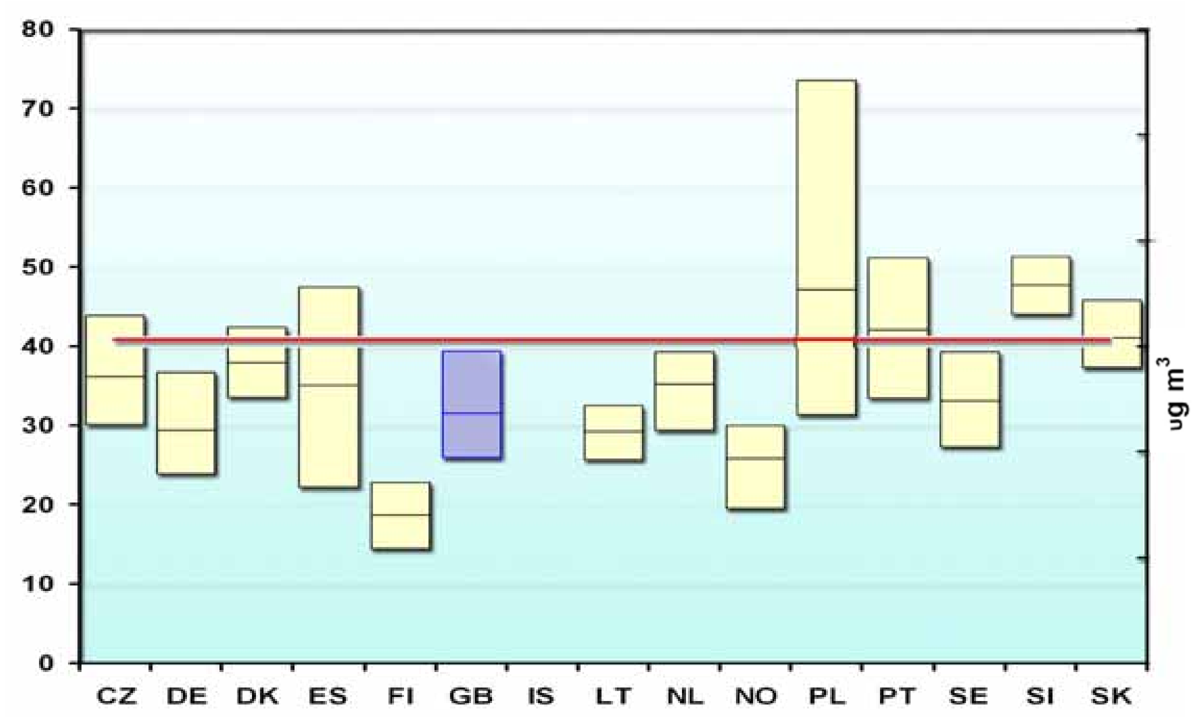


Figure 8.4 Comparison of UK roadside PM_{10} levels (blue) with other European Nations (yellow) for 2005

8.3 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 has been used here as an indicator.

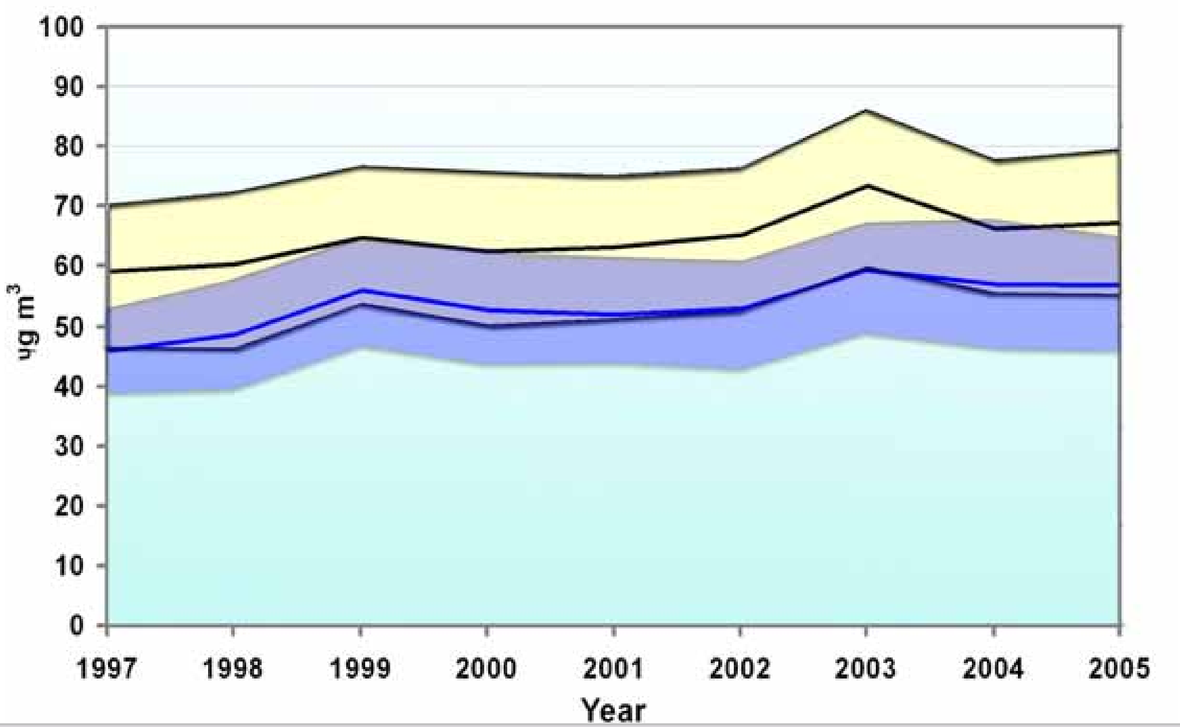


Figure 8.5 Comparison of UK urban background O_3 levels (blue line and shaded area) with European Averages (yellow): 1997 to 2005

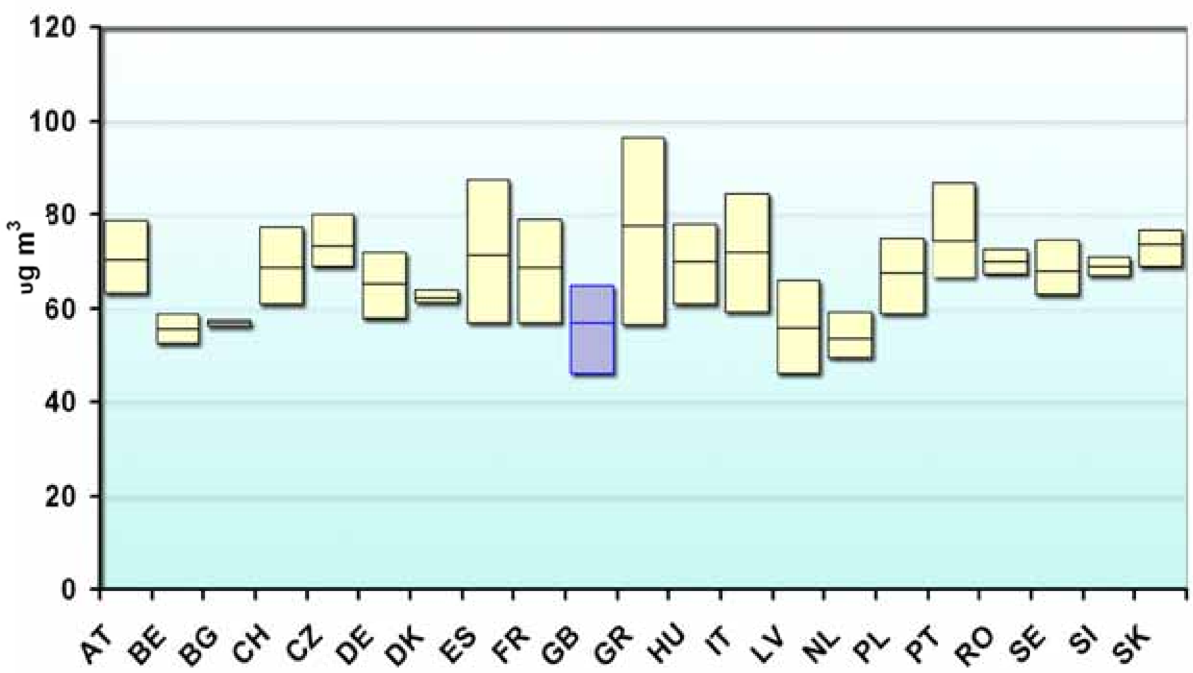


Figure 8.6 Comparison of UK urban background O_3 (blue) with other European Nations (yellow) for 2005

Figure 8.5 shows 10th percentile, mean and 90th percentile O_3 levels at UK urban 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 'heat wave' summer peak is strongly evidenced again.

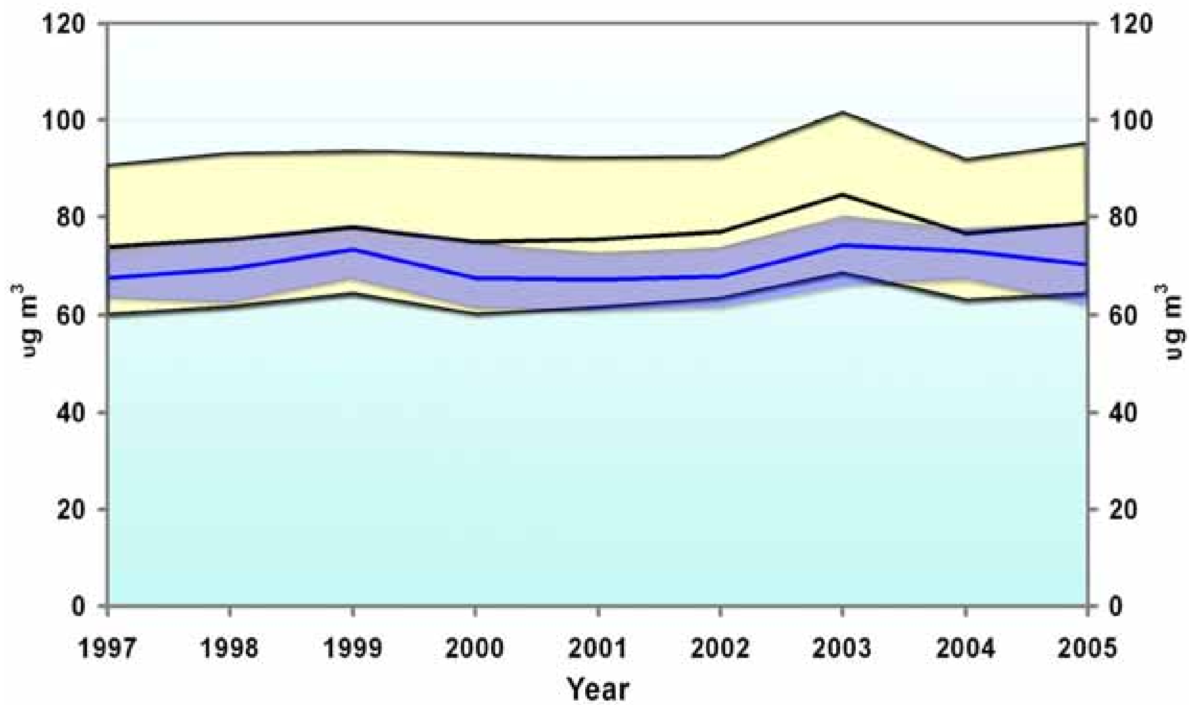


Figure 8.7 Comparison of UK rural O_3 levels (blue line and shaded area) with European Averages (yellow): 1997 to 2005

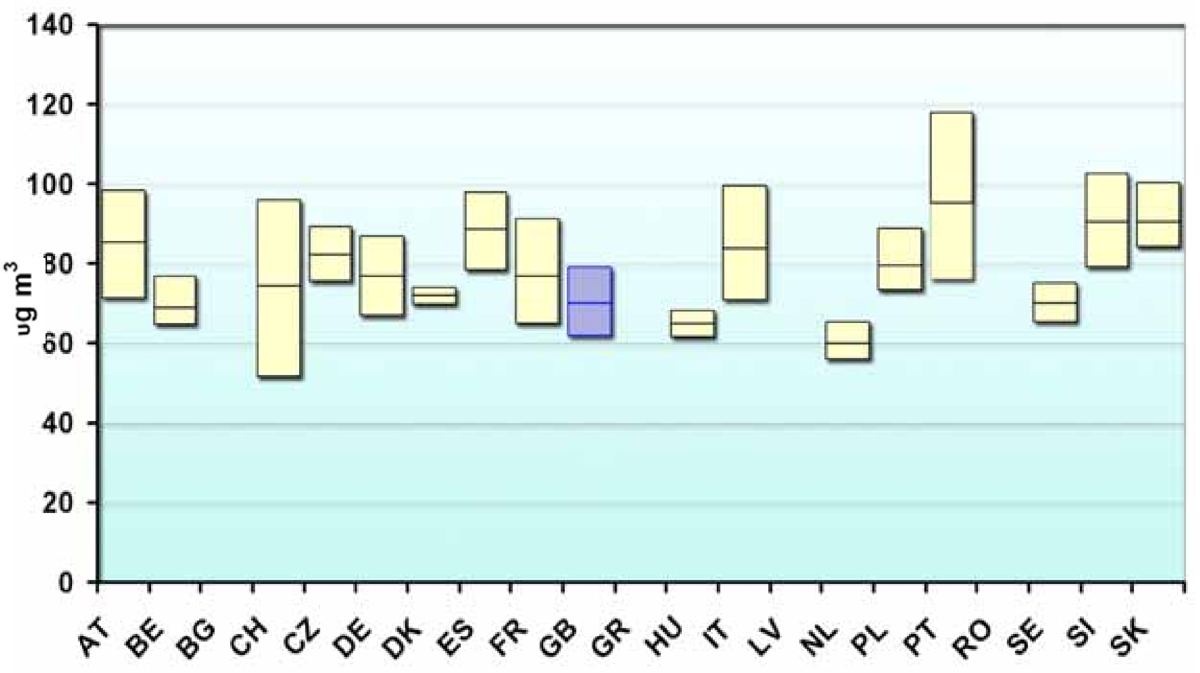


Figure 8.8 Comparison of UK rural O_3 (blue) with other European Nations (yellow) for 2005

Examining 2005 measurements in greater detail (Figure 8.6) shows UK urban ozone levels to be similar to those in NW European/Baltic states such as the Netherlands, Belgium and Latvia, but considerably lower than in most EU states including France, Spain, Italy and Portugal.

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, Spain and Portugal.

When it comes to rural ozone levels (Figures 8.7 and 8.8), we again see UK levels to be consistently lower than the EU average. Comparing Figures 8.7 and 8.5 shows an interesting difference, however; urban background ozone levels in UK and throughout Europe are rising, whilst corresponding rural levels of this pollutant are broadly stable.

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, indeed, 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.

One significant side affect of decreasing urban NO_X emissions, however, is less overall capacity for chemical 'scavenging' of ozone by nitric oxide (NO) in the atmosphere:

$$\mathbf{NO + O_3 \longleftrightarrow NO_2 + O_2}$$

We present in Figure 8.9 and 8.10 the trends in urban background and rural NO_x levels; these do, indeed, confirm (Fig 8.9) an overall downward trend in urban NO_X, both in UK and throughout Europe. The situation is more complex for rural NO_X - UK levels appear to be falling, whilst those throughout Europe as a whole are rising. Clearly, other factors apart from just vehicle emission controls are work here.

It is interesting to note (Figure 8.9) the apparent step-change in NO_X concentrations from 1988 to 1989. The reasons for this are not altogether clear. Possible influencing factors may be unusual meteorology or the implementation of the first EU Directive on NO_2.

In future years, we intend to examine NO_2 and NO_x trends and mean levels in the UK and Europe in greater detail.

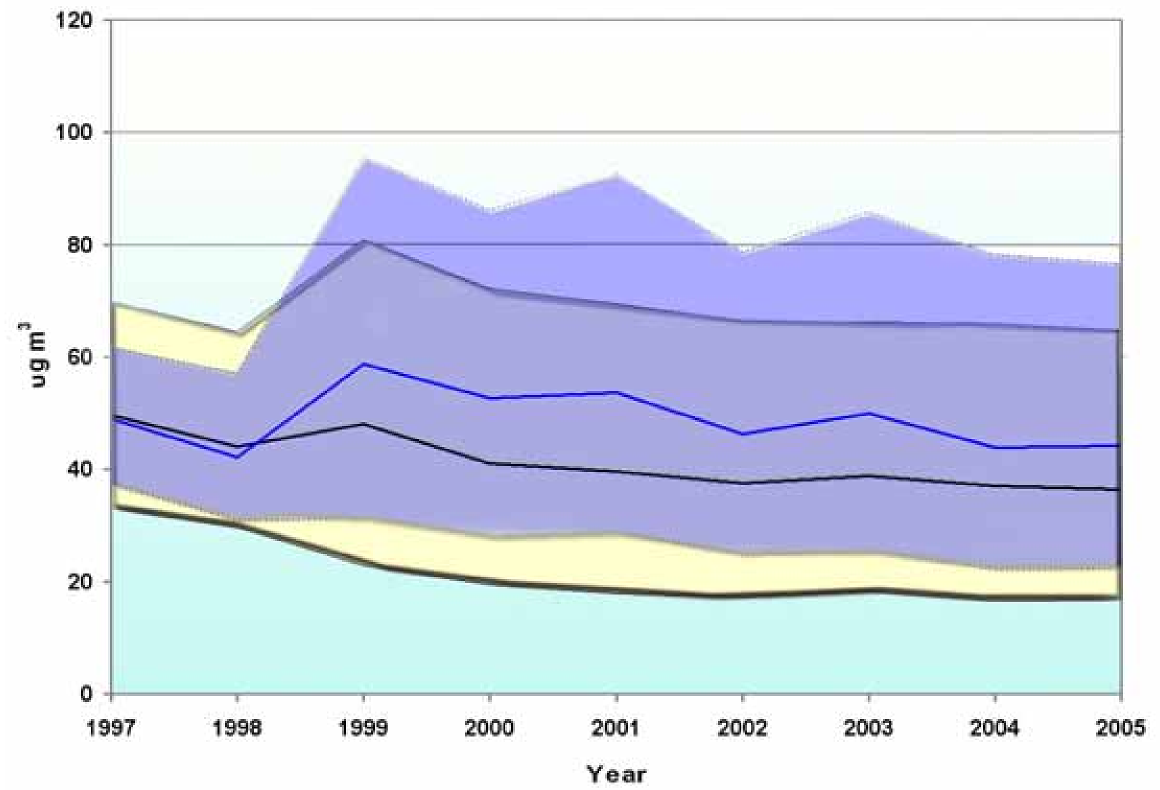


Figure 8.9 Comparison of UK urban background NO_x (blue) with other European Nations (yellow) for 2005

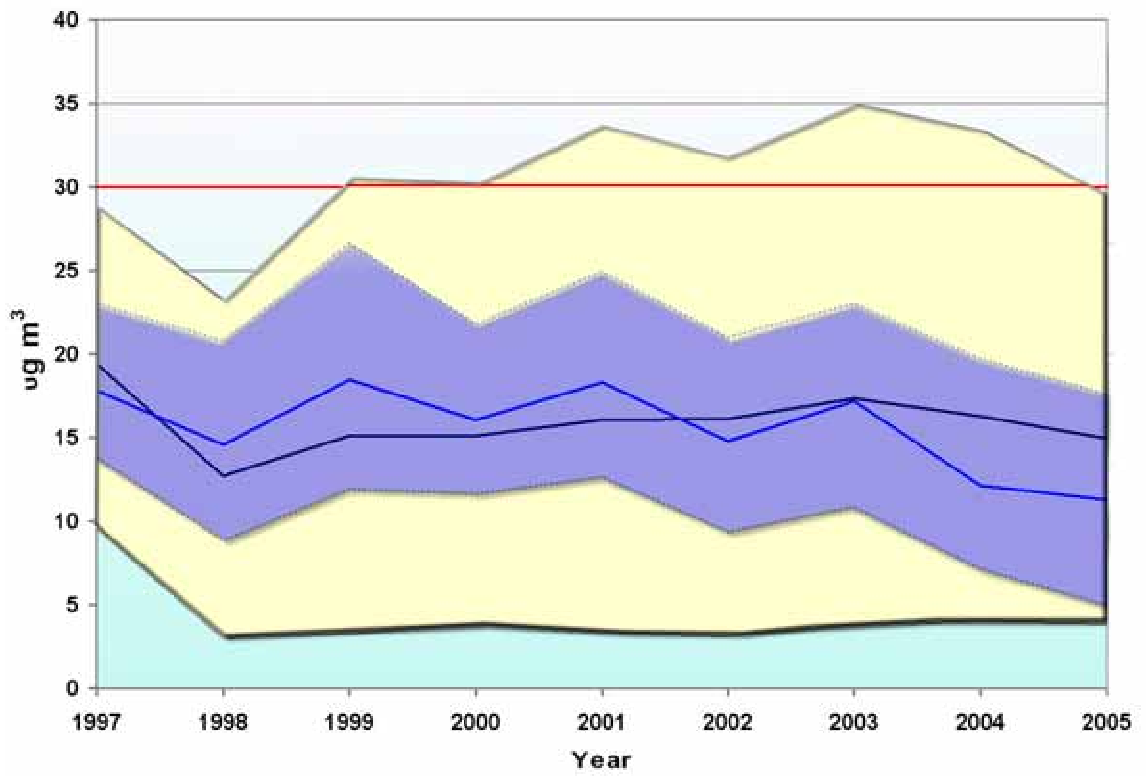


Figure 8.10 Comparison of UK rural O_3 (blue) with other European Nations (yellow) for 2005

Air Pollution in the UK: 2006

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 2006. 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.

9. Benzene-Measurement Sites, Instrumentation and Statistics

9.1 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.

9.2 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.*

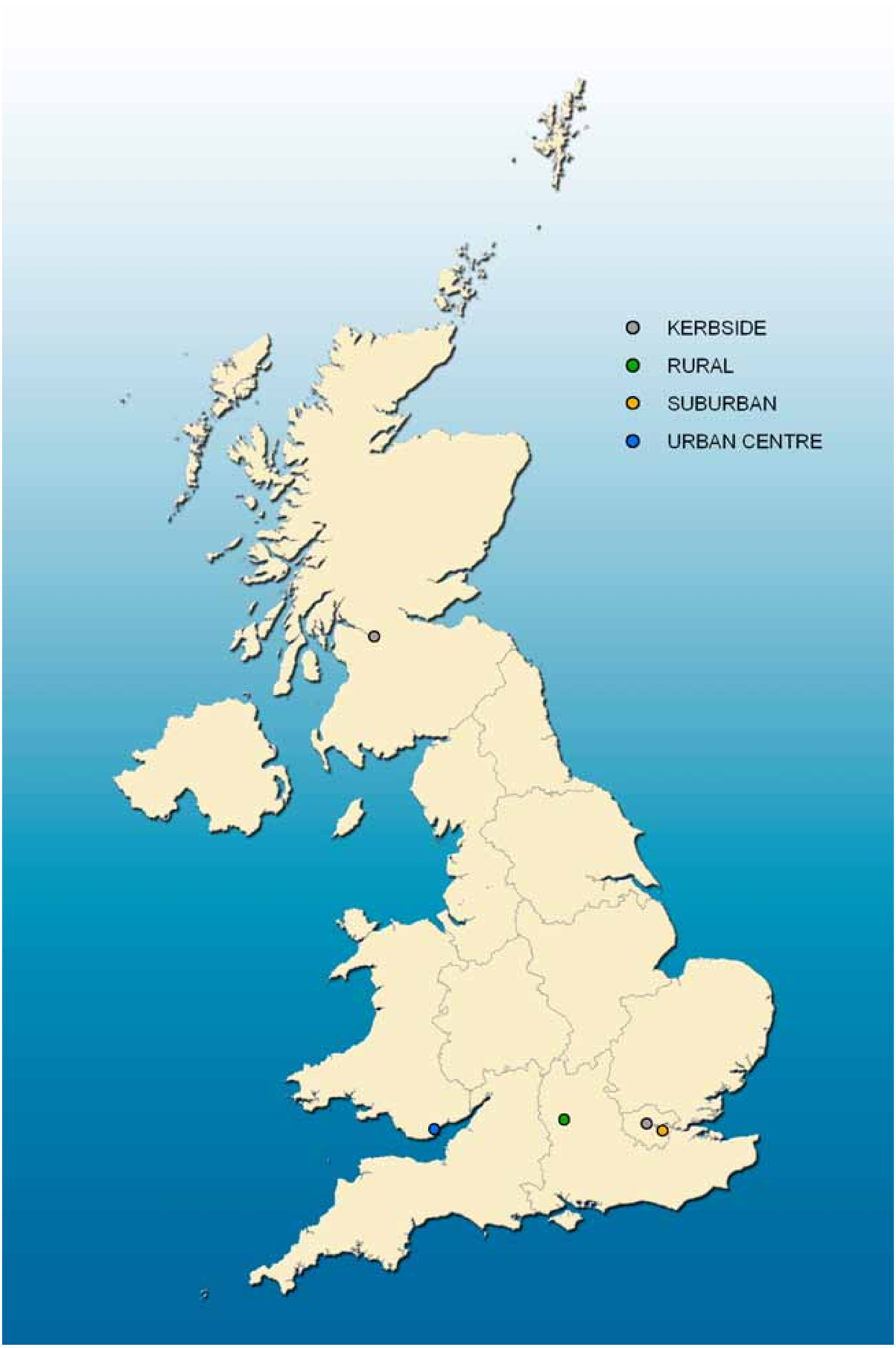
9.3 Data Quality Requirements of EC Directive 2000/69/EC

Uncertainty 15%
Minimum data capture 90%

9.4 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

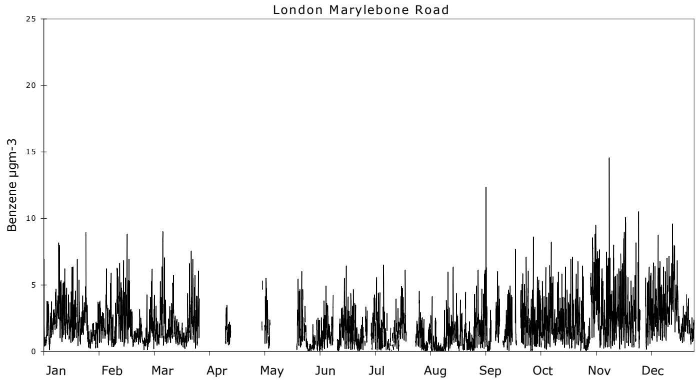
No bandings are set for benzene, as there are no known short-term health effects for this pollutant.



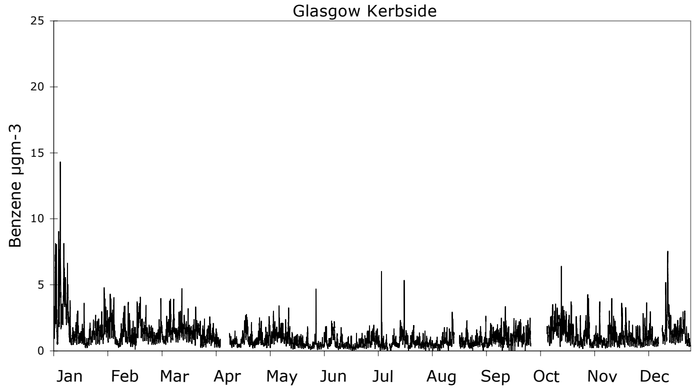
UK Automatic Benzene Monitoring Sites 2006

9.5 Hourly Average Concentrations

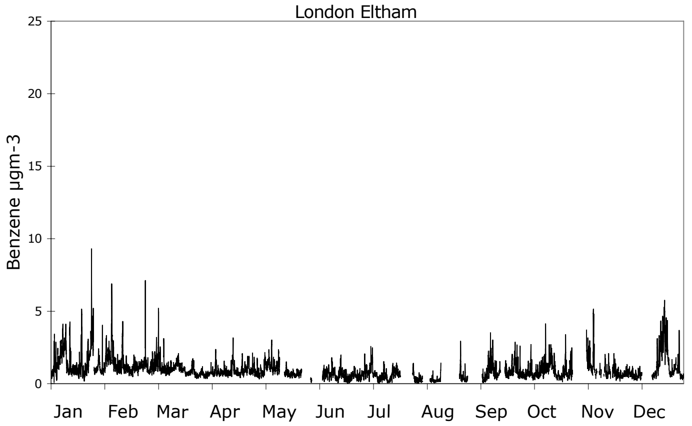
These figures show time series graphs of hourly average benzene concentrations at four *typical* site types for 2006.



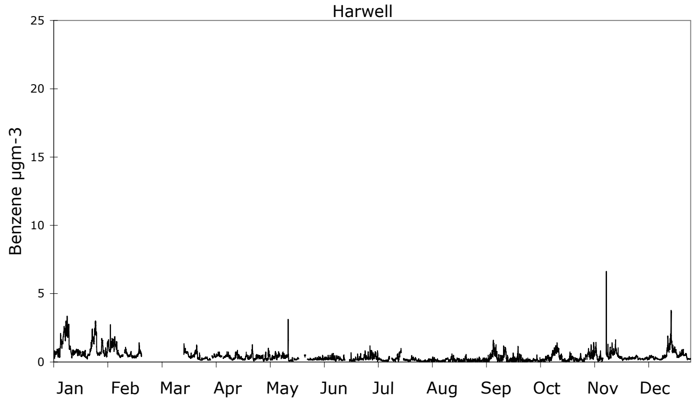
Kerbside Site
(Marylebone Road)



Kerbside Site
(Glasgow)



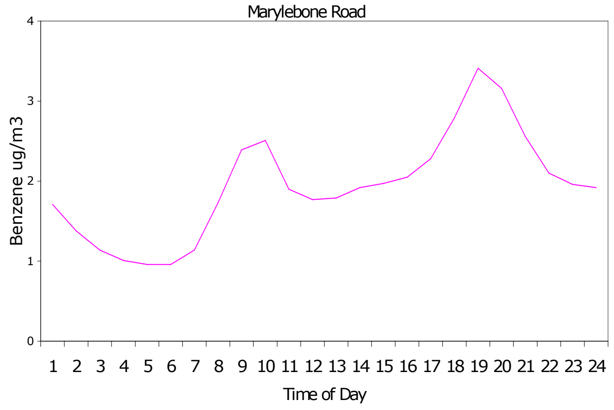
Suburban Site
(London Eltham)



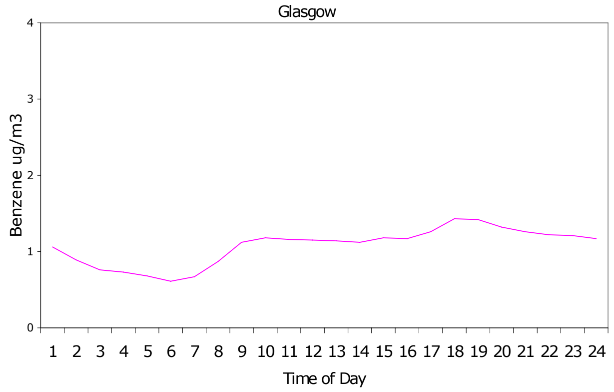
Rural Site
(Harwell)

9.6 Diurnal Variations

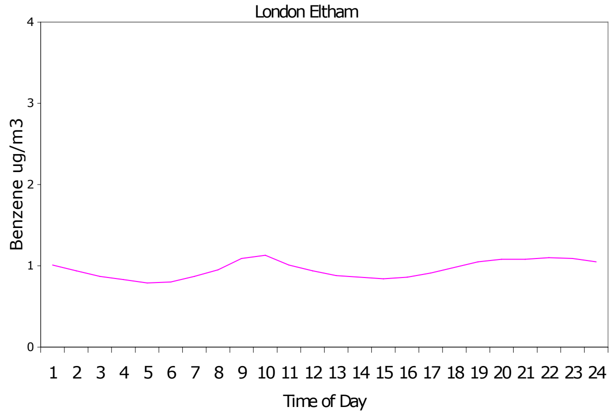
These figures show how benzene concentrations vary on average for each hour of day during 2006, at a number of selected *typical* monitoring site types. Local time is used, rather than GMT, since this will more closely reflect the daily cycle of man-made emissions.



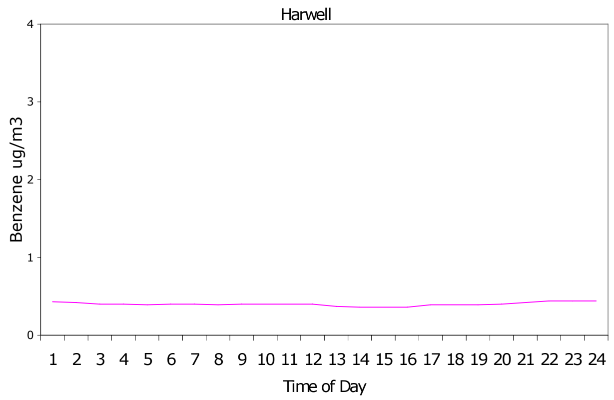
Kerbside Site
(*Marylebone Road)*



Kerbside Site
(*Glasgow)*



Suburban Site
(*London Eltham*)

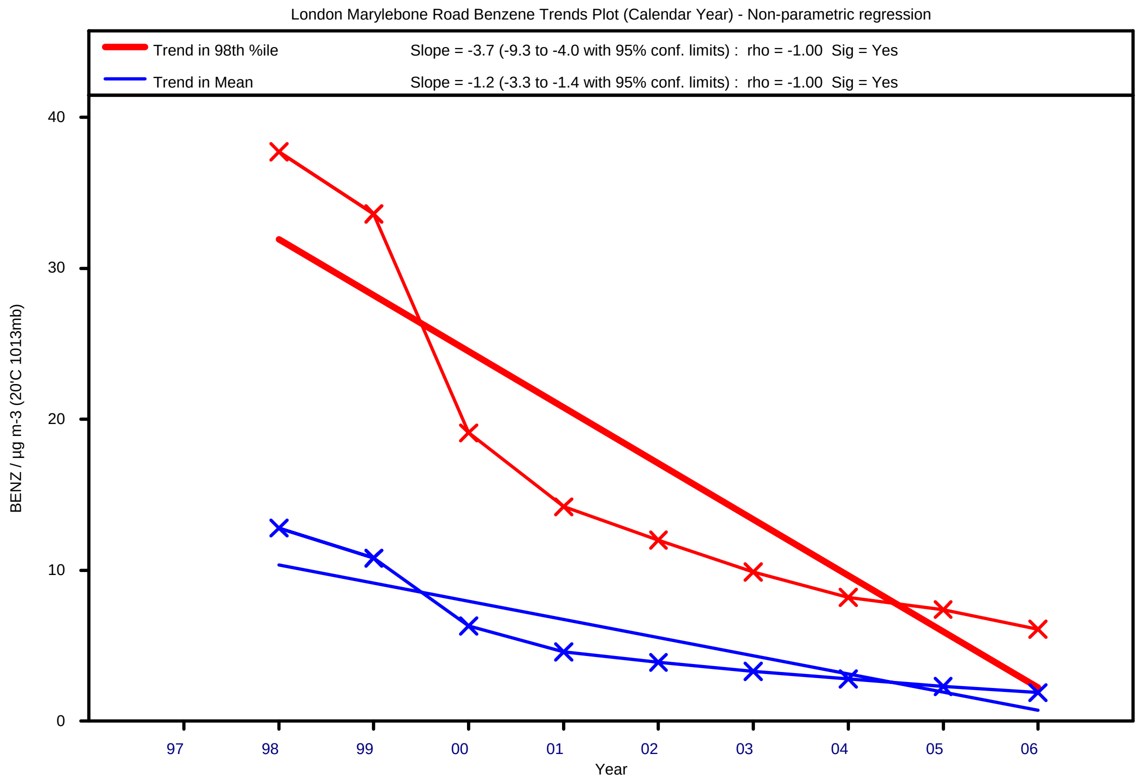


Rural Site
(*Harwell)*

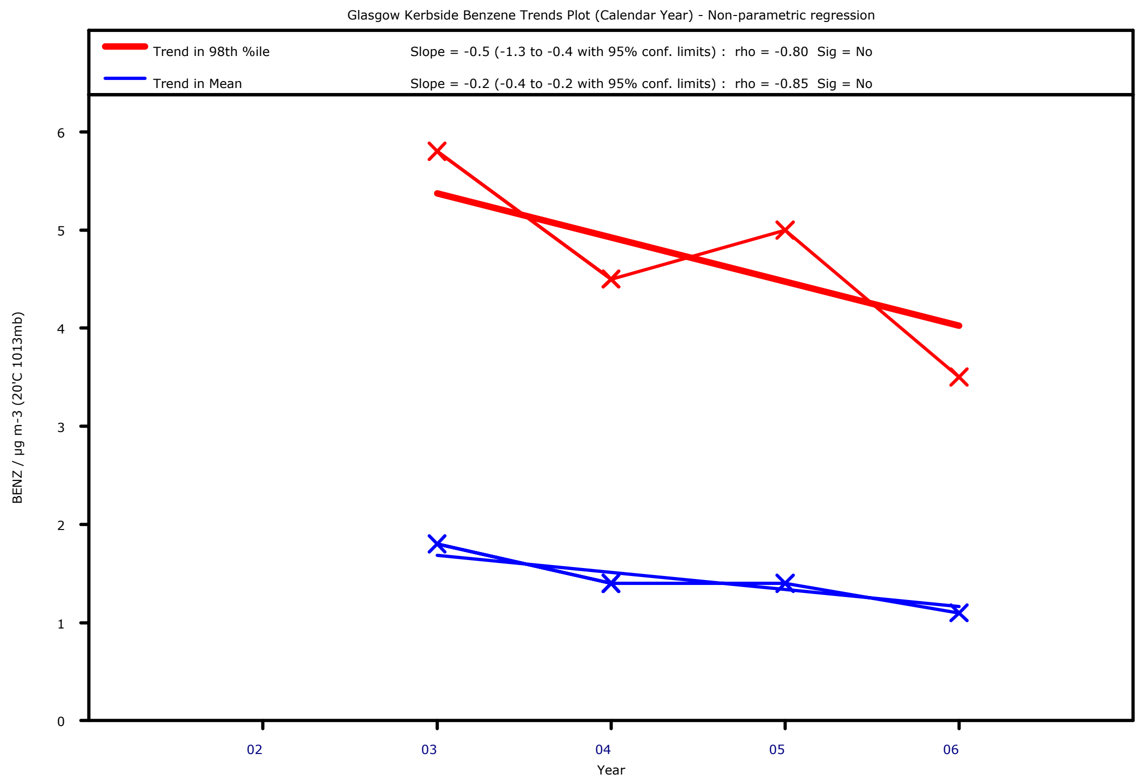
9.7 Trends in annual concentrations

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

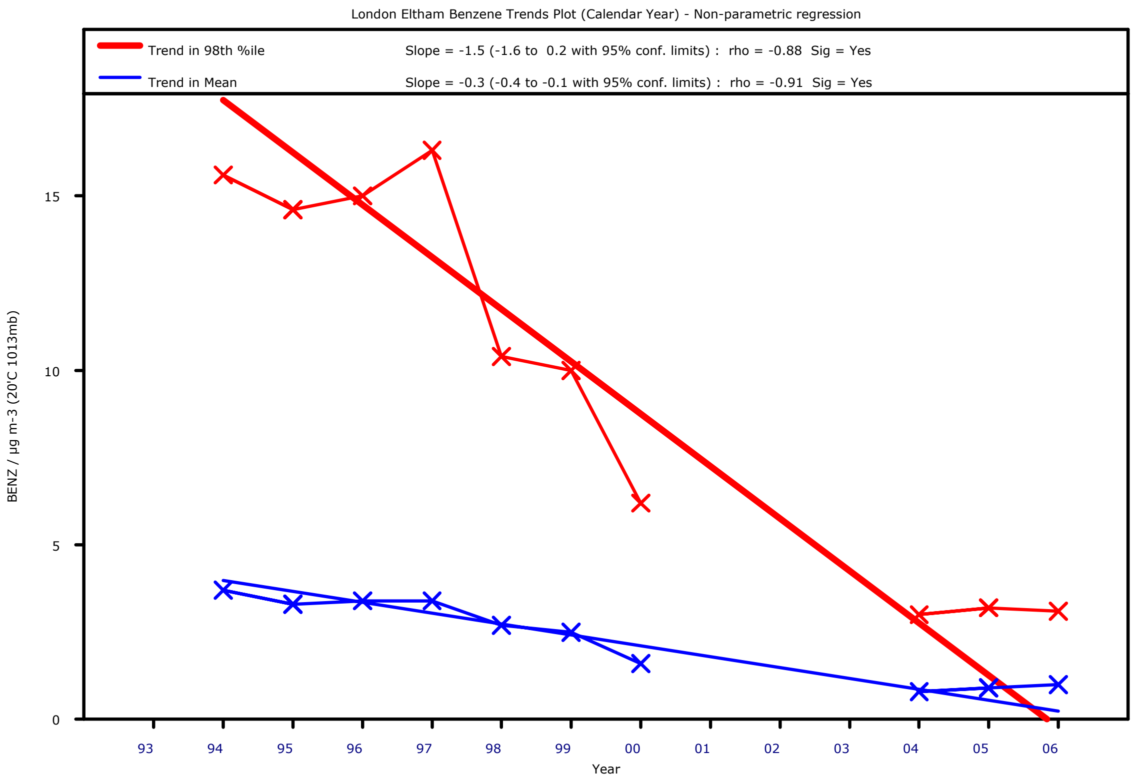
London Marylebone Road Benzene Trends Plot – Non-parametric regression



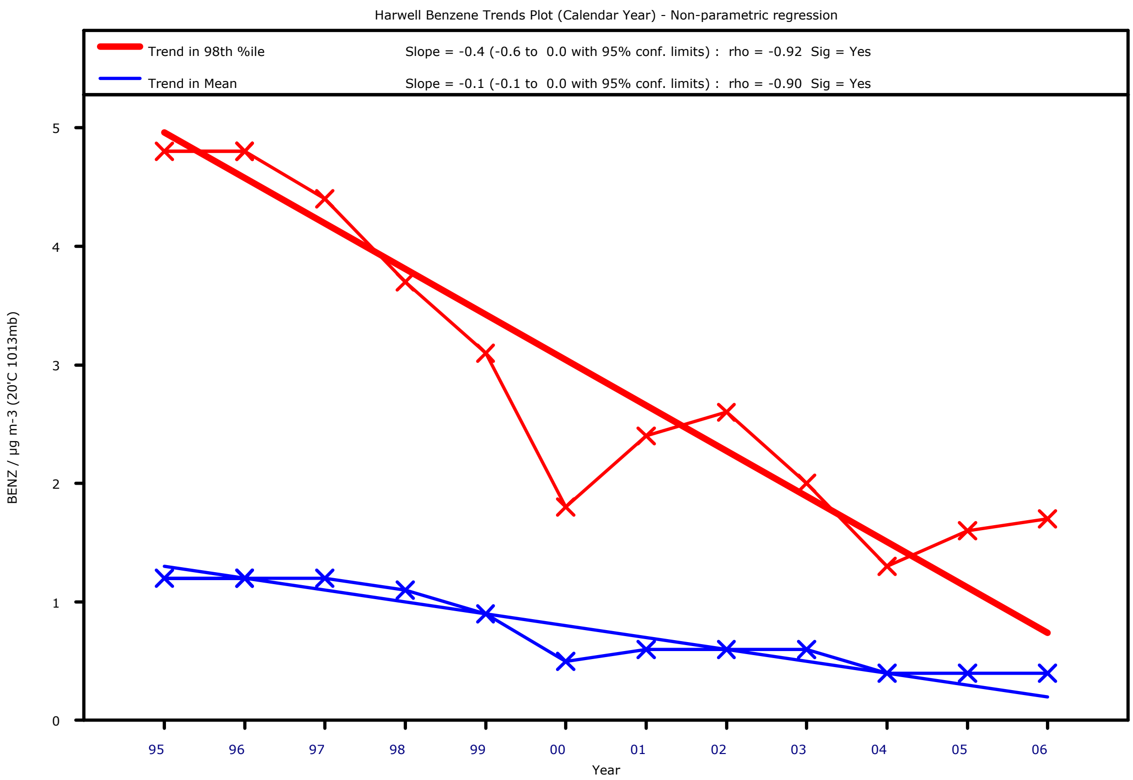
Glasgow Kerbside benzene Trends plot – Non-parametric regression



London Eltham Benzene Trends Plot – Non-parametric regression



Harwell Benzene Trends Plot – Non-parametric regression



9.8 Benzene Statistical Summary 2006

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	0.40	87.1	6.63
London Eltham	SU	0.96	80.5	9.30
London Marylebone Road	KB	1.93	77.1	14.56
Scotland				
Glasgow Kerbside	KB	1.07	92.3	14.30
Wales				
Cardiff Centre	UC	0.79	89.3	24.15

ii) Benzene Exceedence Statistics

Site	Air Quality Standard > 16.3 µg m^{-3}	Days	Daughter 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

10. 1,3-Butadiene- Measurement Sites, Instrumentation and Statistics

10.1 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.

10.2 Instrumentation

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

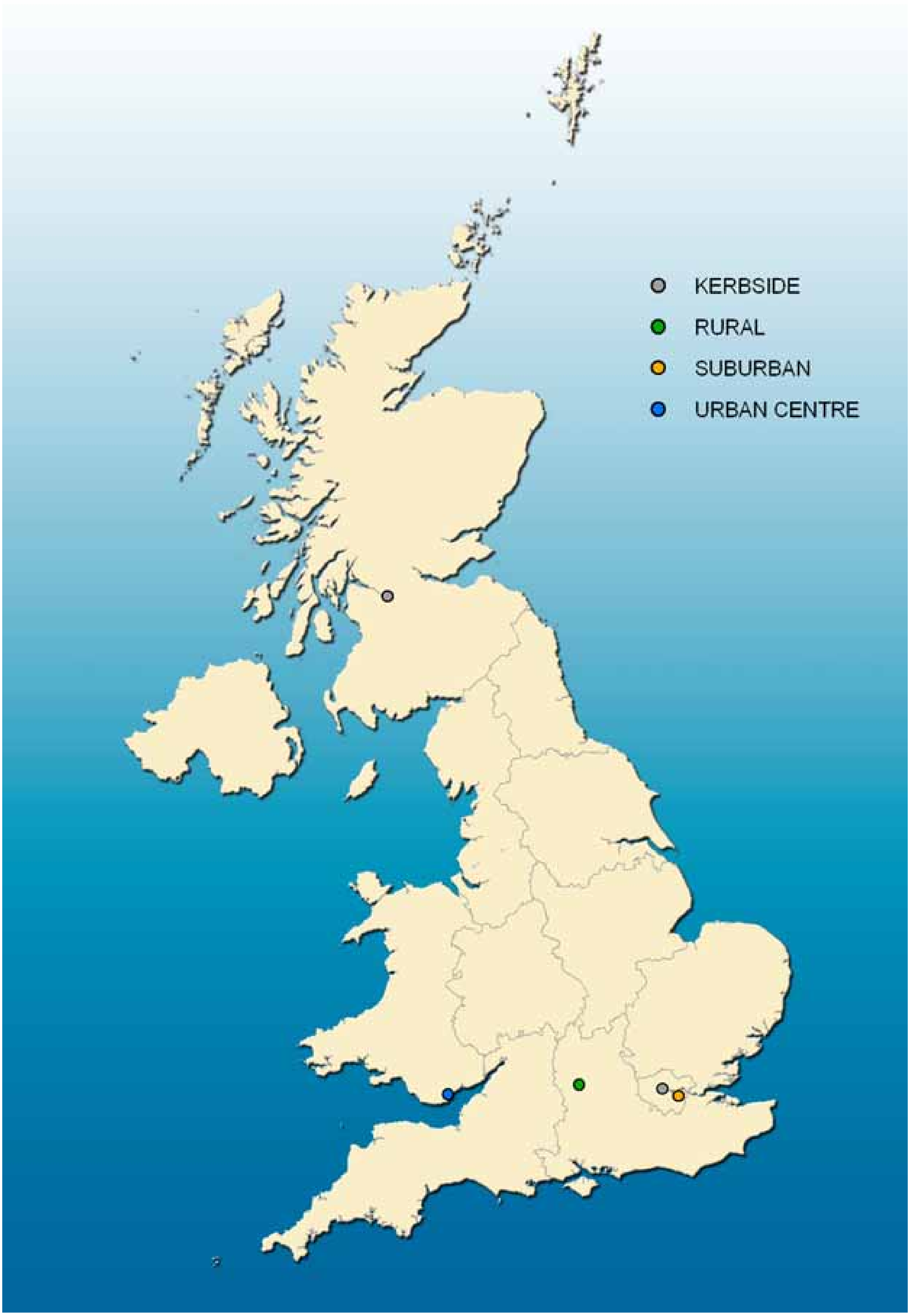
- Environnement VOC 71M
- Perkin Elmer OPA

** 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 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

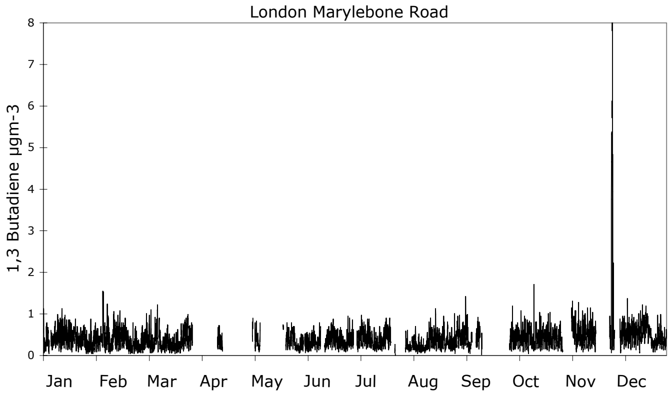
No bandings are set for 1,3-Butadiene, as there are no known short-term effects of this pollutant.



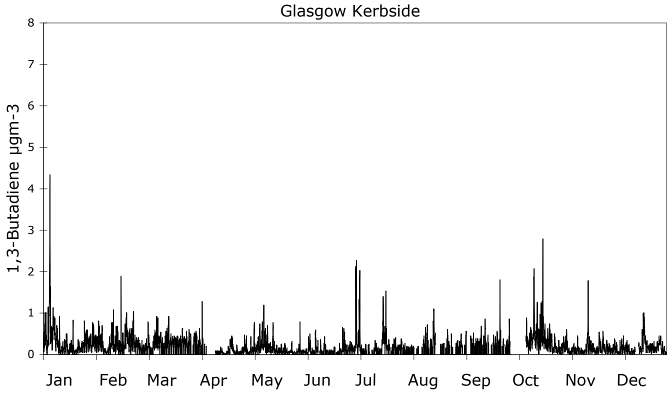
UK Automatic 1,3-Butadiene Monitoring Sites 2006

10.4 Hourly Average Concentrations

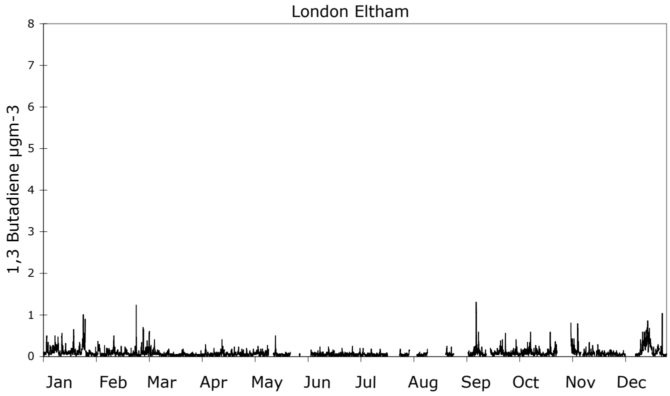
These figures show time series graphs of hourly average 1,3-Butadiene concentrations at four *typical* site types for 2006.



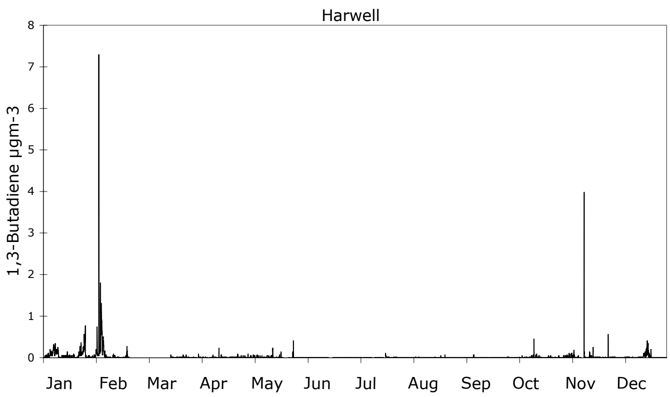
Kerbside Site
(*Marylebone Road)*



Kerbside Site
(*Glasgow)*



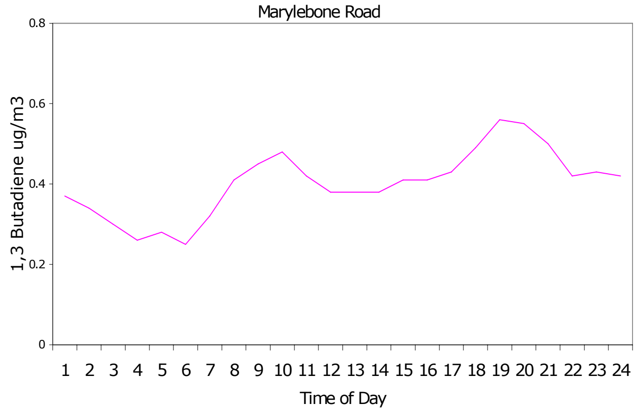
Suburban Site
(London Eltham)



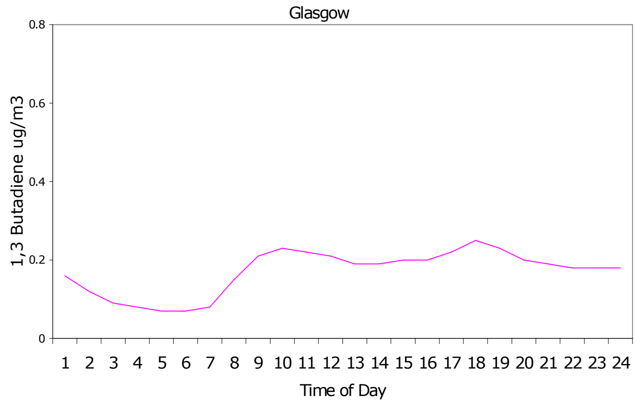
Rural Site
(Harwell)

10.5 Diurnal Variations

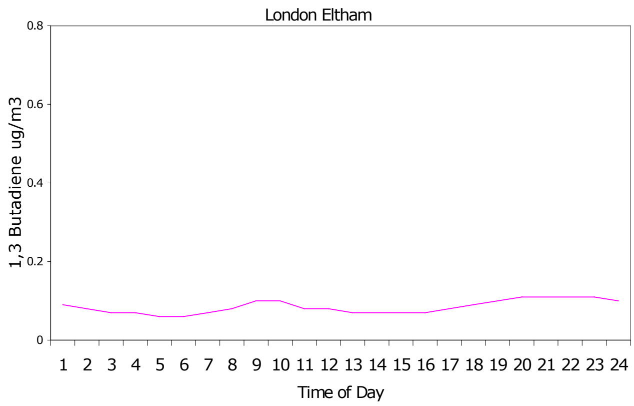
These figures show how 1,3-Butadiene concentrations vary on average for each hour of day during 2006, at a number of selected *typical* monitoring site types. Local time is used, rather than GMT, since this will more closely reflect the daily cycle of man-made emissions.



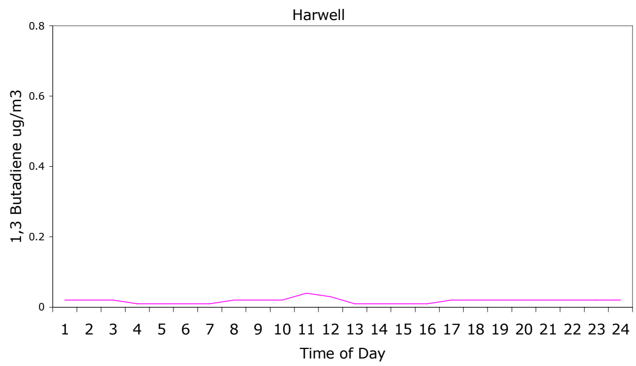
Kerbside Site
(Marylebone Road)



Kerbside Site
(Glasgow)



Suburban Site
(London Eltham)

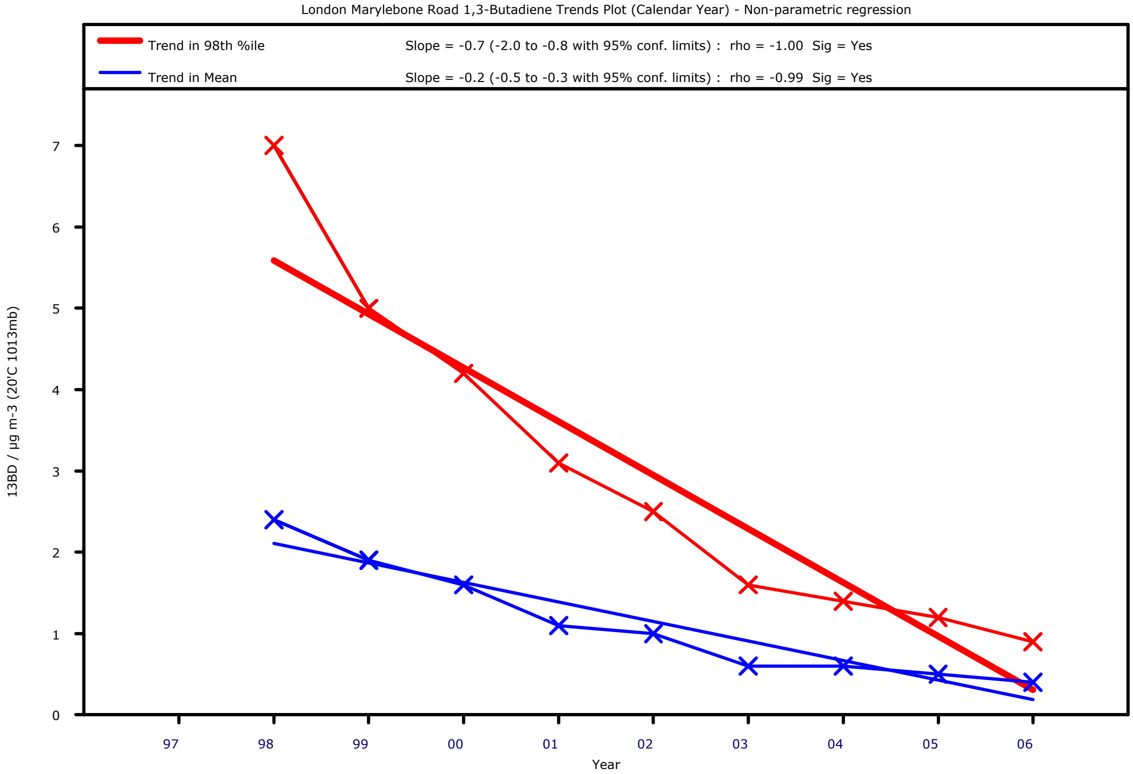


Rural Site
(Harwell)

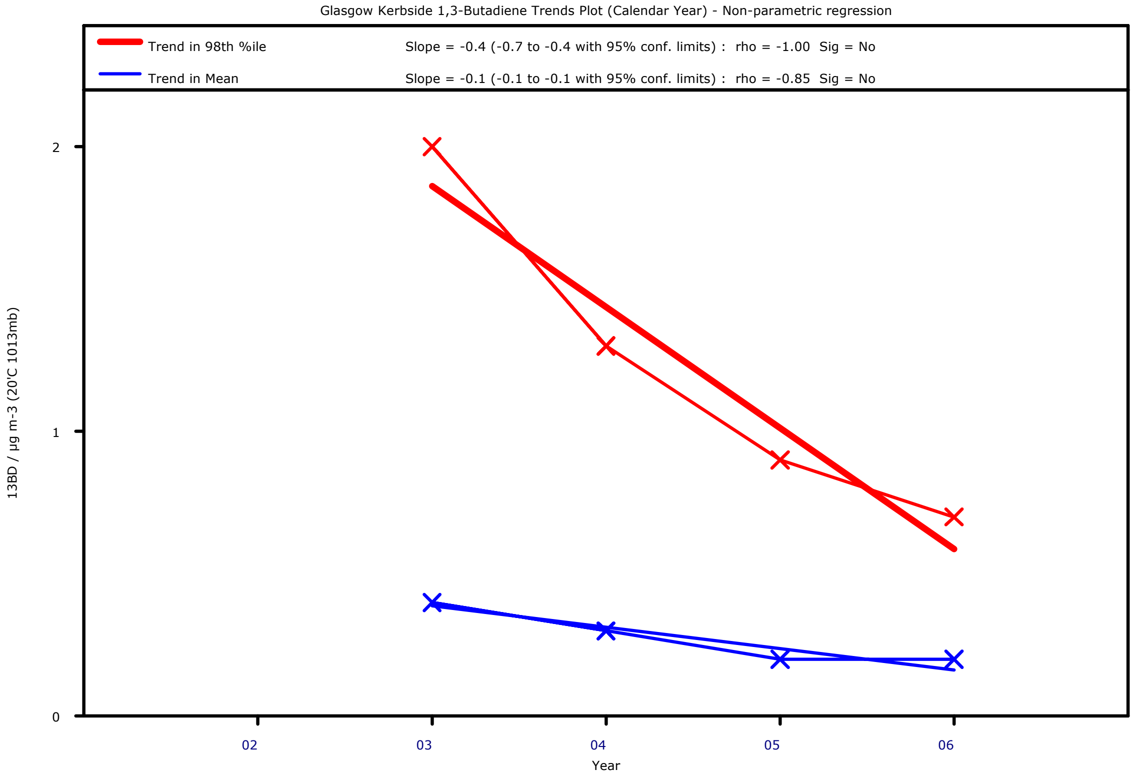
10.6 Trends in annual concentrations

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

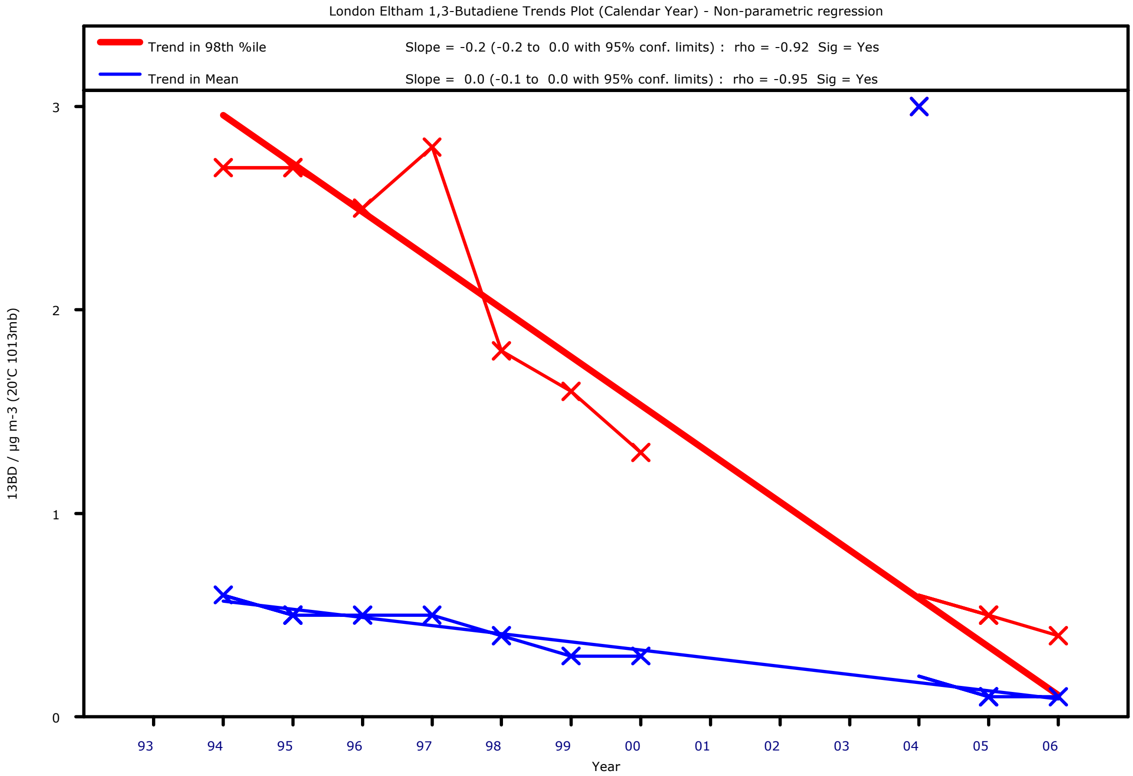
London Marylebone Road 1,3 Butadiene Trends Plot – Non-parametric regression



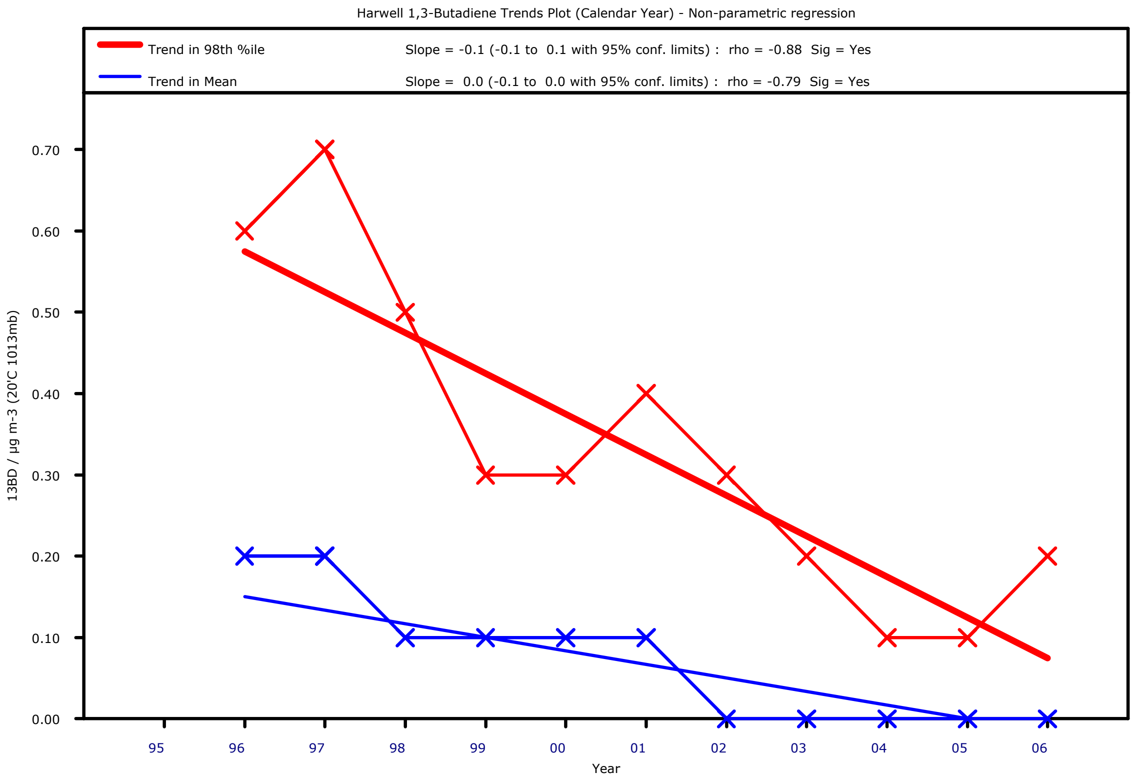
Glasgow Kerbside 1,3 Butadiene Trends plot – Non-parametric regression



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



Harwell 1,3 Butadiene Trend Plot Non-parametric regression



10.7 1,3-Butadiene Statistical Summary 2006

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	0.02	87.1	7.29
London Eltham	SU	0.09	79.7	1.31
London Marylebone Road	KB	0.40	70.7	8.75
Scotland				
Glasgow Kerbside	KB	0.17	92.4	4.34
Wales				
Cardiff Centre	UC	0.09	89.4	6.08

ii) 1,3-Butadiene Exceedence Statistics

Site	**Air Quality Standard** > 2.3 µg m^{-3}	Days
England		
Harwell	0	0
London Eltham	0	0
London Marylebone Road	0	0
Scotland	0	0
Glasgow Kerbside	0	0
Wales	0	0
Cardiff Centre	0	0

11. CO - Measurement Sites, Instrumentation and Statistics

11.1 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.

11.2 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.*

11.3 Data Quality Requirements of EC Directive 2000/69/EC

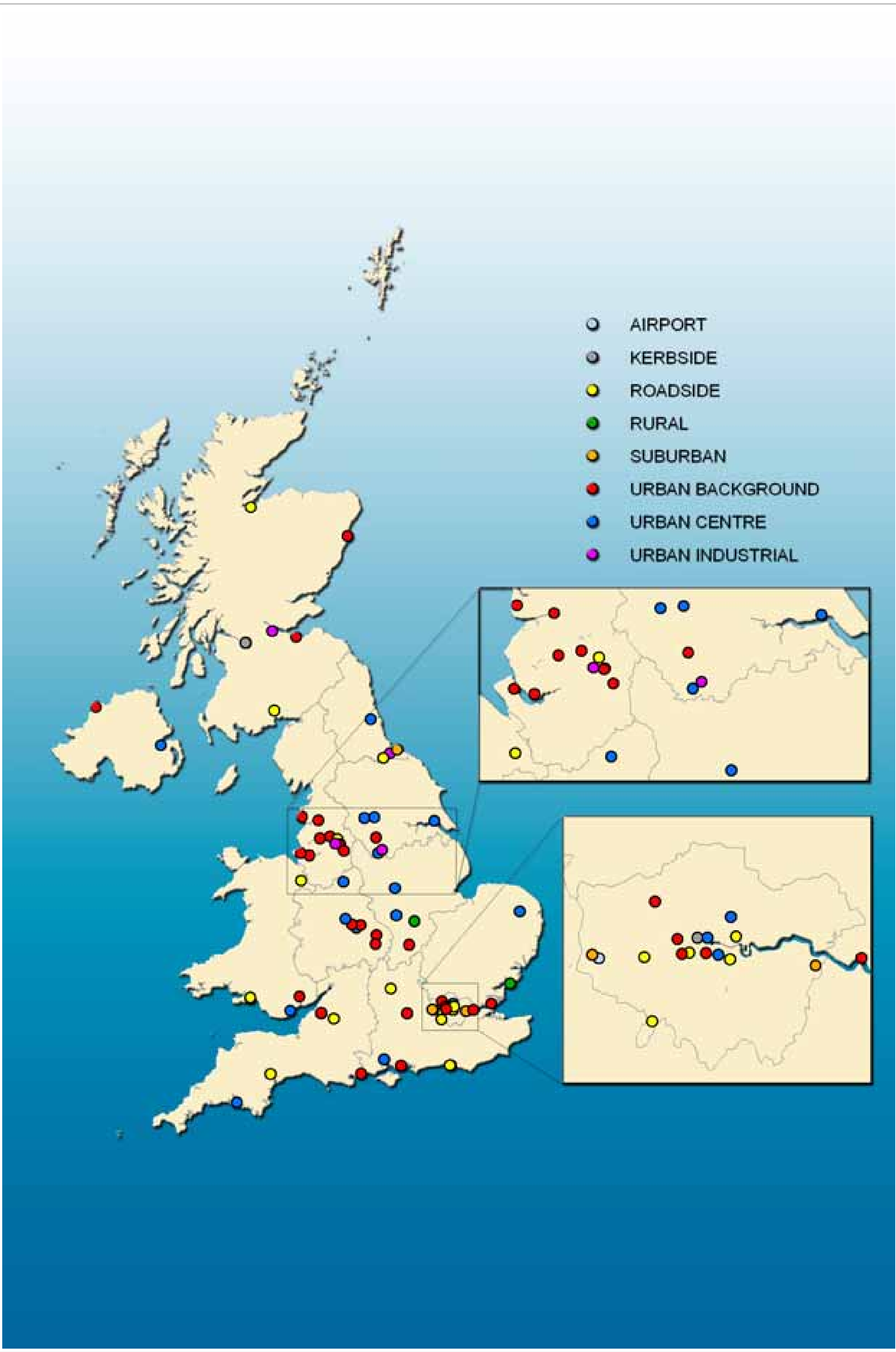
Uncertainty 15%
Minimum data capture 90%

11.4 Objectives and Bandings

Summary of objectives of the Air Quality Strategy			
	Objective	**Measured as**	**To be achieved by**
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

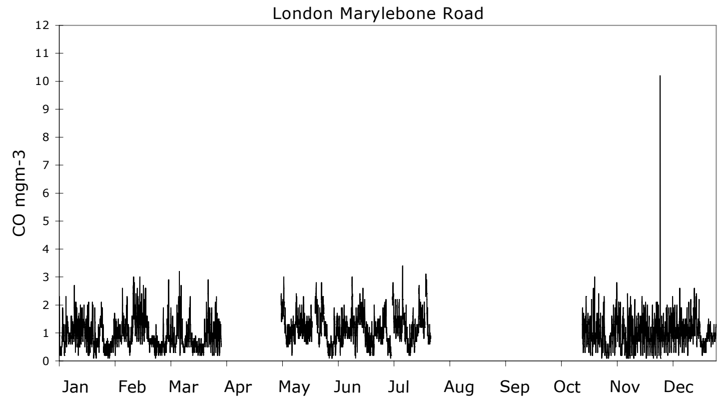
Air Quality Bands and Index Values		
Band	**Index**	**Carbon Monoxide mg m^{-3}**
Low	1	0-3.8
	2	3.9-7.6
	3	7.7-11.5
Moderate	4	11.6-13.4
	5	13.5-15.4
	6	15.5-17.3
High	7	17.4-19.2
	8	19.3-21.2
	9	21.3-23.1
Very High	10	23.2 or more



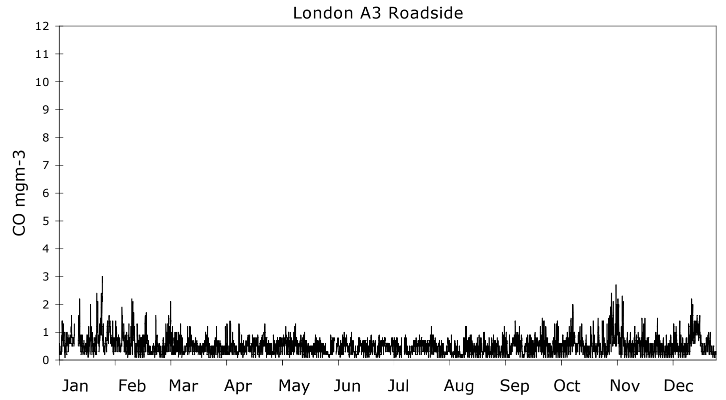
UK Automatic Carbon Monoxide Monitoring Sites 2006

11.5 Hourly Average Concentrations

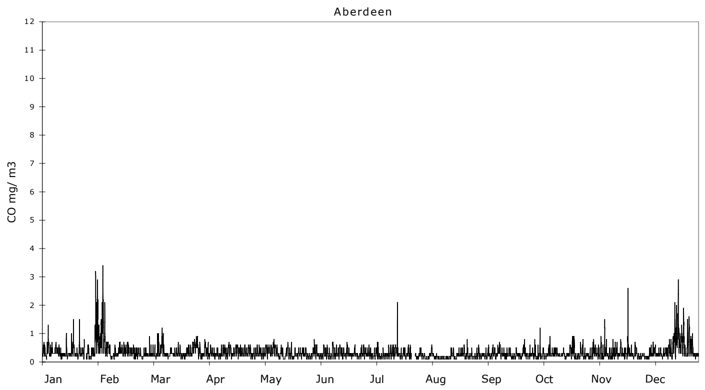
These figures show time series graphs of hourly average carbon monoxide concentrations at four *typical* site types for 2006.



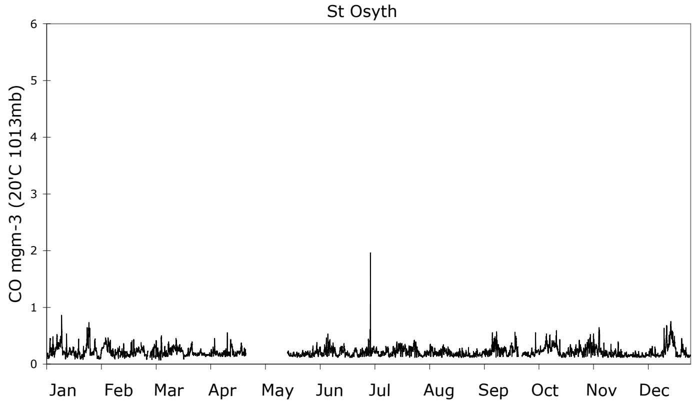
Kerbside Site
(Marylebone Road)



Roadside Site
(London A3)



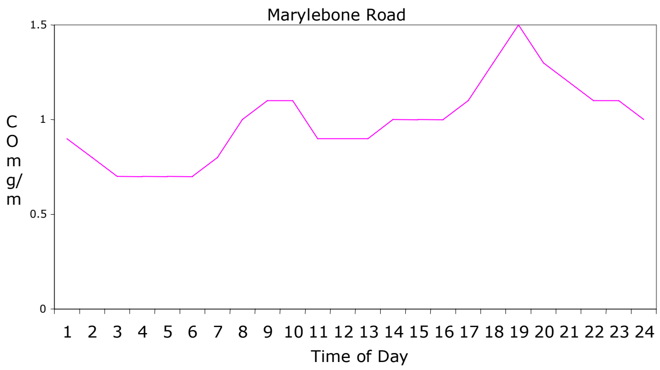
Urban Background Site
(Aberdeen)



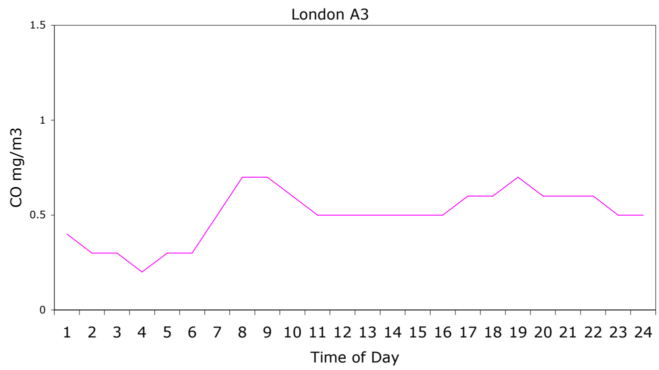
Rural Site
(St.Osyth)

11.6 Diurnal Variations

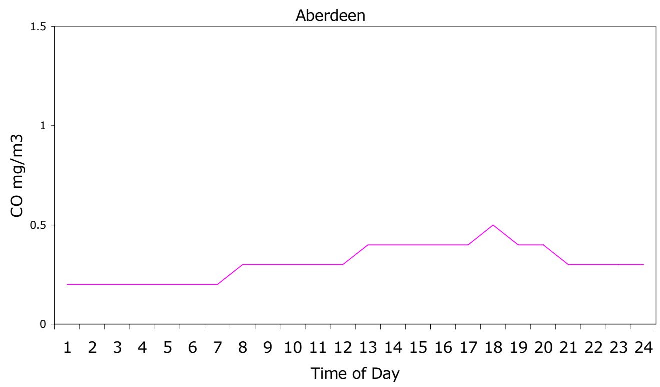
These figures show how carbon monoxide concentrations vary on average for each hour of day during 2006, at a number of selected *typical* monitoring site types. Local time is used, rather than GMT, since this will more closely reflect the daily cycle of man-made emissions.



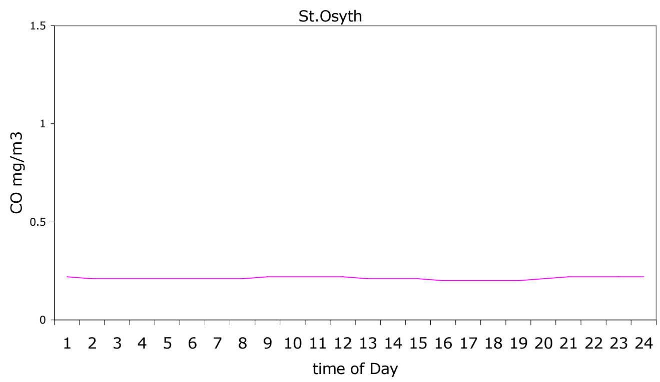
Kerbside Site
(Marylebone Road)



Roadside Site
(London A3)



Urban Background Site
(Aberdeen)

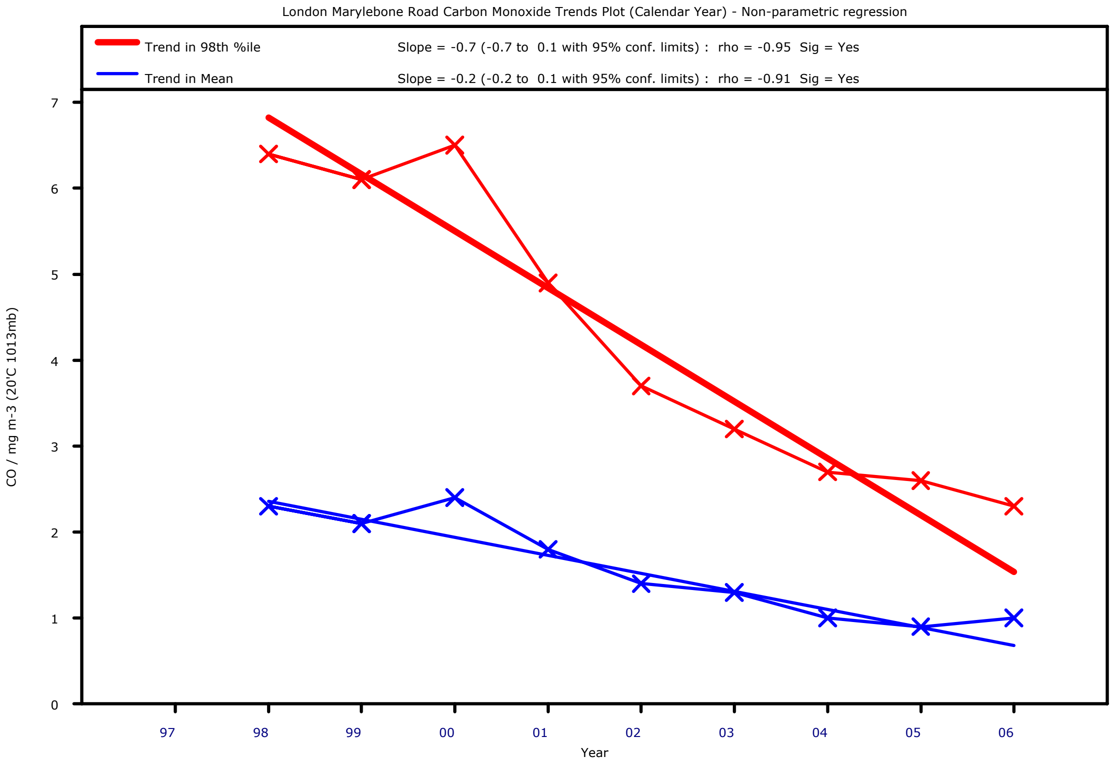


Rural Site
(St.Osyth)

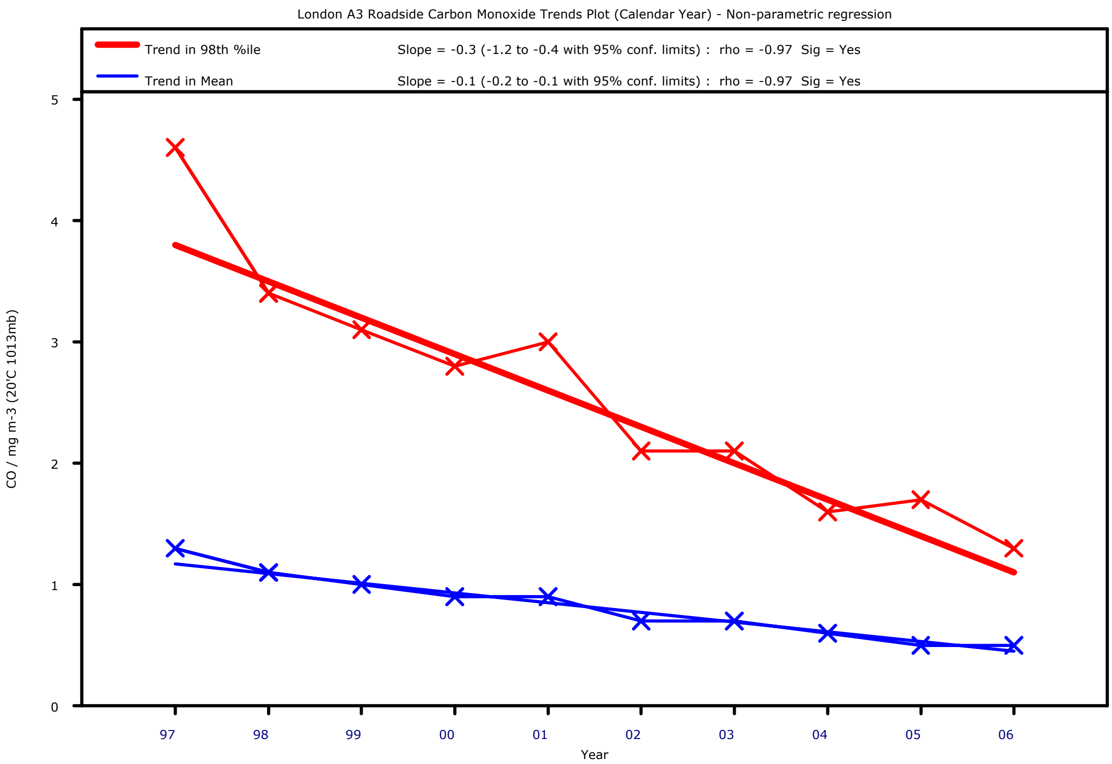
11.7 Trends in annual concentrations

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

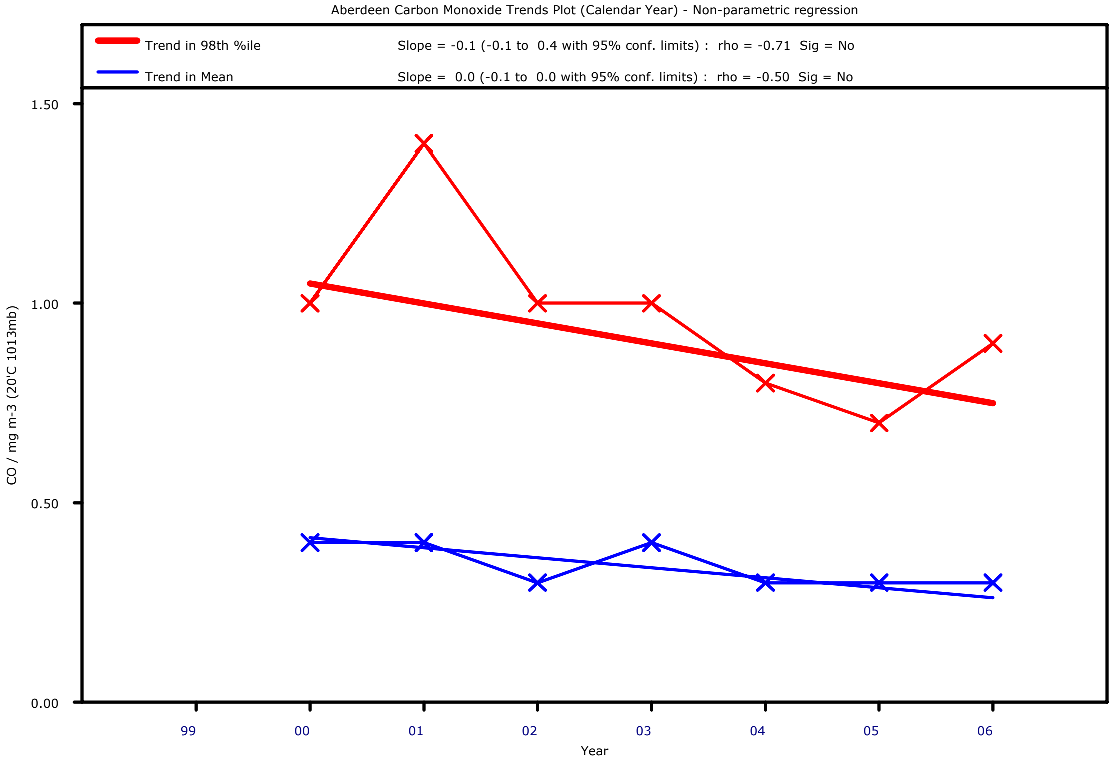
London Marylebone Road Carbon Monoxide Trends Plot – Non-parametric regression



London A3 carbon Monoxide Trends plot – Non-parametric regression



Aberdeen Carbon Monoxide Trend Plot – Non-parametric regression



11.8 Carbon Monoxide Statistical Summary 2006

i) CO annual statistics I

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						
Barnsley Gawber	UB	0.2	77.9	2.3	1.6	03/03/2006
Bath Roadside	RD	0.8	83.2	4.9	2.3	05/11/2006
Birmingham Centre	UC	0.3	95.5	3.2	2.2	22/12/2006
Birmingham Tyburn	UB	0.2	98.7	3.1	2.7	10/11/2006
Blackpool Marton	UB	0.2	93.5	2.4	1.0	02/11/2006
Bolton	UB	0.3	97.4	3.4	2.8	04/11/2006
Bournemouth	UB	0.3	97.2	3.4	2.5	12/01/2006
Bradford Centre	UC	0.3	94.2	2.8	1.7	03/01/2006
Brentford Roadside	RD	0.5	65.3	3.5	2.9	10/11/2006
Brighton Roadside	RD	0.4	98.0	4.1	1.9	05/11/2006
Bristol Old Market	UC	0.5	97.3	3.5	2.6	05/11/2006
Bristol St Paul's	UB	0.3	53.2	4.3	3.3	05/11/2006
Bury Roadside	RD	---	44.5	3.1	2.2	02/01/2006
Coventry Memorial Park	UB	0.2	99.2	1.7	1.3	20/12/2006
Exeter Roadside	RD	0.6	98.7	4.4	2.4	20/12/2006
Hove Roadside	RD	0.4	99.3	4.1	1.6	03/01/2006
Hull Freetown	UC	0.2	64.9	3.0	2.3	18/12/2006
Leamington Spa	UB	0.2	98.7	2.8	1.7	19/12/2006
Leeds Centre	UC	0.2	94.0	1.5	1.3	22/01/2006
Leicester Centre	UC	0.2	98.5	3.5	2.0	22/01/2006
Liverpool Speke	UB	0.2	94.2	2.8	1.6	24/01/2006
London A3 Roadside	RD	0.5	97.6	3.0	2.5	25/01/2006
London Bexley	SU	0.2	97.3	3.9	2.3	04/11/2006
London Bloomsbury	UC	0.4	95.3	2.7	2.2	20/12/2006
London Brent	UB	0.2	98.8	5.0	2.8	07/11/2006
London Cromwell Road 2	RD	0.7	95.0	2.3	2.0	11/02/2006
London Hackney	UC	0.4	91.7	4.6	3.5	07/11/2006
London Harlington	A	0.3	99.0	3.0	2.0	07/11/2006
London Hillingdon	SU	0.4	95.9	3.7	2.4	07/11/2006
London Marylebone Road	KB	1.0	66.4	10.2	2.8	23/07/2006
London N. Kensington	UB	0.3	96.6	2.4	2.0	10/11/2006
London Southwark	UC	0.4	68.8	2.4	1.6	21/12/2006
London Westminster	UB	---	41.4	2.1	1.6	10/11/2006
Manchester Piccadilly	UC	0.3	95.0	4.8	2.7	09/12/2006
Manchester Town Hall	UB	---	39.2	1.7	1.5	21/12/2006
Market Harborough	RU	0.2	98.3	1.2	1.0	20/12/2006
Middlesbrough	I	0.2	92.2	3.6	1.4	07/06/2006
Newcastle Centre	UC	0.1	98.2	1.7	1.0	08/03/2006
Northampton	UB	0.2	99.3	2.6	1.6	24/01/2006
Norwich Centre	UC	0.2	99.2	3.5	1.9	18/12/2006
Nottingham Centre	UC	0.2	98.2	2.6	2.2	22/12/2006
Oxford Centre Roadside	RD	0.2	96.5	4.2	1.9	10/11/2006
Plymouth Centre	UC	0.3	55.6	2.1	1.2	09/01/2006
Portsmouth	UB	0.3	99.0	5.0	1.9	29/11/2006
Preston	UB	0.3	95.0	2.0	1.5	21/12/2006
Reading New Town	UB	0.3	96.0	2.4	1.6	22/01/2006
Redcar	SU	0.4	85.3	2.0	1.1	04/01/2006
Salford Eccles	I	0.2	87.3	3.1	2.2	04/01/2006
Sandwell West Bromwich	UB	0.3	95.5	2.2	1.6	21/12/2006
Sheffield Centre	UC	0.3	97.0	2.9	2.2	21/12/2006
Sheffield Tinsley	I	0.3	92.8	2.9	2.4	23/07/2006
Southampton Centre	UC	0.3	70.0	3.9	2.2	11/02/2006
Southend-on-Sea	UB	0.2	98.9	3.8	2.1	18/12/2006
Southwark Roadside	RD	---	10.7	2.6	2.0	05/02/2006
St Osyth	RU	0.21	92.2	1.96	0.70	03/07/2006
Stockport Shaw Heath	UB	0.1	99.0	2.4	1.9	03/02/2006
Stockton-on-Tees Yarm	RD	0.4	95.8	3.6	1.9	06/01/2006
Stoke-on-Trent Centre	UC	0.4	93.9	4.3	2.9	21/12/2006

ii) CO exceedence statistics I

Site	Moderate band	Days	High band	Days	Very High band	Days	Daughter Directive and Air Quality Standard	Days	Air Quality Standard (Scotland)	Days
England										
Barnsley Gawber	0	0	0	0	0	0	0	0	0	0
Bath Roadside	0	0	0	0	0	0	0	0	0	0
Birmingham Centre	0	0	0	0	0	0	0	0	0	0
Birmingham Tyburn	0	0	0	0	0	0	0	0	0	0
Blackpool Marton	0	0	0	0	0	0	0	0	0	0
Bolton	0	0	0	0	0	0	0	0	0	0
Bournemouth	0	0	0	0	0	0	0	0	0	0
Bradford Centre	0	0	0	0	0	0	0	0	0	0
Brentford Roadside	0	0	0	0	0	0	0	0	0	0
Brighton Roadside	0	0	0	0	0	0	0	0	0	0
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
Coventry Memorial	0	0	0	0	0	0	0	0	0	0
Exeter Roadside	0	0	0	0	0	0	0	0	0	0
Hove Roadside	0	0	0	0	0	0	0	0	0	0
Hull Freetown	0	0	0	0	0	0	0	0	0	0
Leamington Spa	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 A3 Roadside	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 Brent	0	0	0	0	0	0	0	0	0	0
London Cromwell Road	0	0	0	0	0	0	0	0	0	0
London Hackney	0	0	0	0	0	0	0	0	0	0
London Harlington	0	0	0	0	0	0	0	0	0	0
London Hillingdon	0	0	0	0	0	0	0	0	0	0
London Marylebone	0	0	0	0	0	0	0	0	0	0
London N. Kensington	0	0	0	0	0	0	0	0	0	0
London Southwark	0	0	0	0	0	0	0	0	0	0
London Westminster	0	0	0	0	0	0	0	0	0	0
Manchester Piccadilly	0	0	0	0	0	0	0	0	0	0
Manchester Town Hall	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
Northampton	0	0	0	0	0	0	0	0	0	0
Norwich Centre	0	0	0	0	0	0	0	0	0	0
Nottingham Centre	0	0	0	0	0	0	0	0	0	0
Oxford Centre	0	0	0	0	0	0	0	0	0	0
Plymouth Centre	0	0	0	0	0	0	0	0	0	0
Portsmouth	0	0	0	0	0	0	0	0	0	0
Preston	0	0	0	0	0	0	0	0	0	0
Reading New Town	0	0	0	0	0	0	0	0	0	0
Redcar	0	0	0	0	0	0	0	0	0	0
Salford Eccles	0	0	0	0	0	0	0	0	0	0
Sandwell West	0	0	0	0	0	0	0	0	0	0
Sheffield Centre	0	0	0	0	0	0	0	0	0	0
Sheffield Tinsley	0	0	0	0	0	0	0	0	0	0
Southampton Centre	0	0	0	0	0	0	0	0	0	0
Southend-on-Sea	0	0	0	0	0	0	0	0	0	0
Southwark Roadside	0	0	0	0	0	0	0	0	0	0
St Osyth	0	0	0	0	0	0	0	0	0	0
Stockport Shaw Heath	0	0	0	0	0	0	0	0	0	0
Stockton-on-Tees Yarm	0	0	0	0	0	0	0	0	0	0

iii) CO annual statistics II

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 *(continued)*						
Thurrock	UB	0.3	98.2	2.4	1.8	04/11/2006
Tower Hamlets Roadside	RD	0.5	88.1	1.9	1.5	09/11/2006
West London	UC	0.4	84.1	2.4	1.8	10/11/2006
Wigan Centre	UB	0.2	96.5	2.6	1.6	04/11/2006
Wirral Tranmere	UB	0.2	95.8	2.4	1.1	04/01/2006
Wolverhampton Centre	UC	0.4	93.2	2.8	1.8	21/12/2006
N Ireland						
Belfast Centre	UC	0.2	82.4	2.9	2.0	19/02/2006
Derry	UB	0.2	95.3	2.0	1.3	30/01/2006
Scotland						
Aberdeen	UB	0.3	99.1	3.4	2.2	03/02/2006
Dumfries	RD	0.6	84.6	4.9	2.3	04/01/2006
Edinburgh St Leonards	UC	0.3	97.2	2.2	1.3	03/02/2006
Glasgow Centre	UC	0.3	88.7	3.0	2.0	04/01/2006
Glasgow City Chambers	UB	0.4	98.9	2.8	2.0	04/01/2006
Glasgow Kerbside	KB	0.4	95.8	3.2	2.2	04/01/2006
Grangemouth	I	0.2	95.7	1.7	1.4	18/12/2006
Inverness	RD	0.4	99.2	3.2	2.4	04/01/2006
Wales						
Cardiff Centre	UC	0.2	97.8	2.3	1.6	12/01/2006
Cwmbran	UB	0.3	99.3	3.2	2.2	03/11/2006
Swansea	UC	0.2	51.8	2.4	1.1	11/01/2006
Swansea Roadside	RD	---	27.9	2.6	1.8	20/12/2006
Wrexham	UC	0.5	95.5	2.7	1.8	07/11/2006

iv) CO exceedence statistics II

Site	Moderate band	Days	High band	Days	Very High band	Days	Daughter Directive and Air Quality Standard	Days	Air Quality Standard (Scotland)	Days
England *(continued)*										
Stoke-on-Trent Centre	0	0	0	0	0	0	0	0	0	0
Thurrock	0	0	0	0	0	0	0	0	0	0
Tower Hamlets	0	0	0	0	0	0	0	0	0	0
West London	0	0	0	0	0	0	0	0	0	0
Wigan Centre	0	0	0	0	0	0	0	0	0	0
Wirral Tranmere	0	0	0	0	0	0	0	0	0	0
Wolverhampton Centre	0	0	0	0	0	0	0	0	0	0
N Ireland										
Belfast Centre	0	0	0	0	0	0	0	0	0	0
Derry	0	0	0	0	0	0	0	0	0	0
Scotland										
Aberdeen	0	0	0	0	0	0	0	0	0	0
Dumfries	0	0	0	0	0	0	0	0	0	0
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
Glasgow City	0	0	0	0	0	0	0	0	0	0
Glasgow Kerbside	0	0	0	0	0	0	0	0	0	0
Grangemouth	0	0	0	0	0	0	0	0	0	0
Inverness	0	0	0	0	0	0	0	0	0	0
Wales										
Cardiff Centre	0	0	0	0	0	0	0	0	0	0
Cwmbran	0	0	0	0	0	0	0	0	0	0
Swansea	0	0	0	0	0	0	0	0	0	0
Swansea Roadside	0	0	0	0	0	0	0	0	0	0
Wrexham	0	0	0	0	0	0	0	0	0	0

12. NO_2 - Measurement Sites, Instrumentation and Statistics

12.1 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).

12.2 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.*

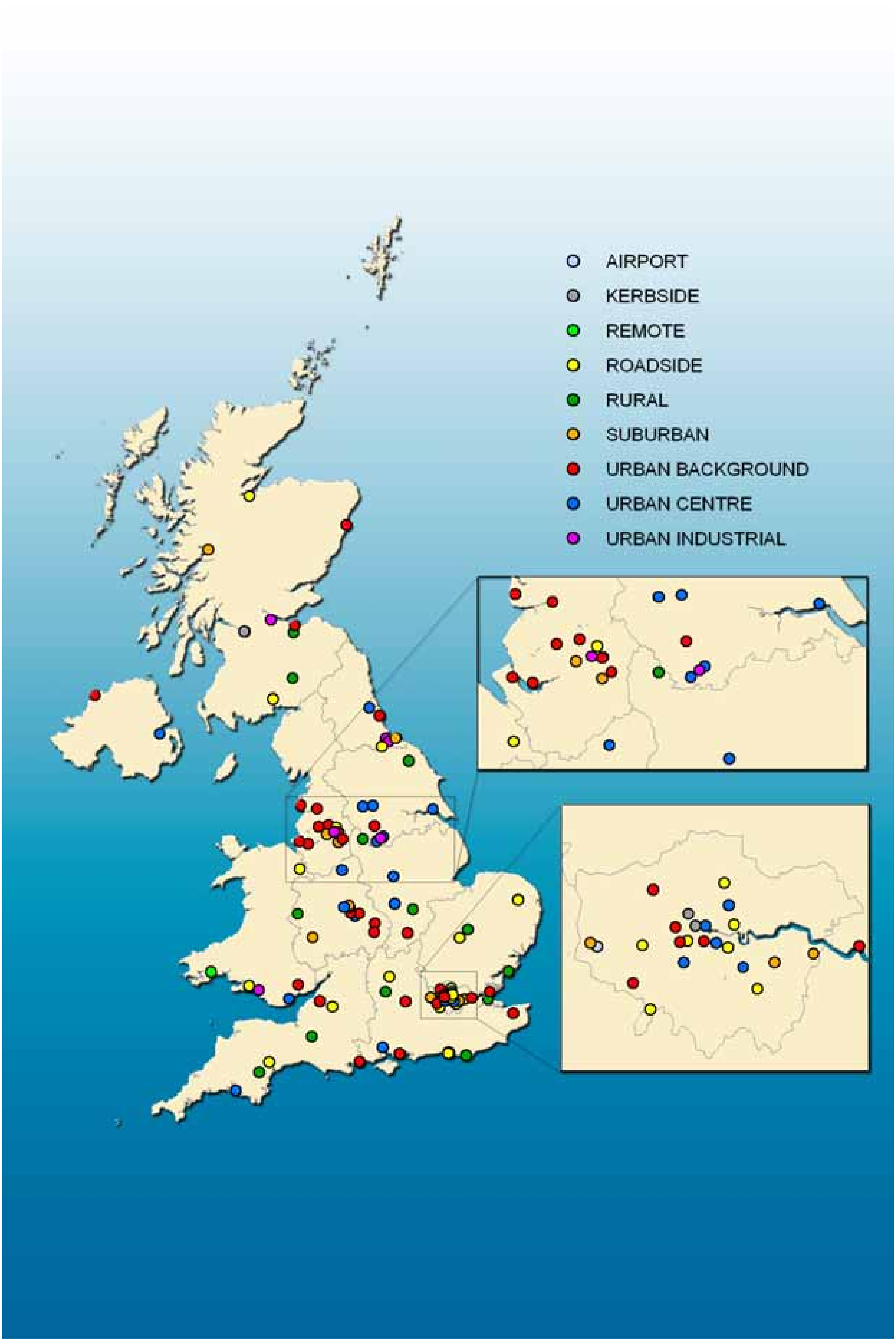
12.3 Data Quality Requirements of EC Directive 1999/30/EC

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**
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

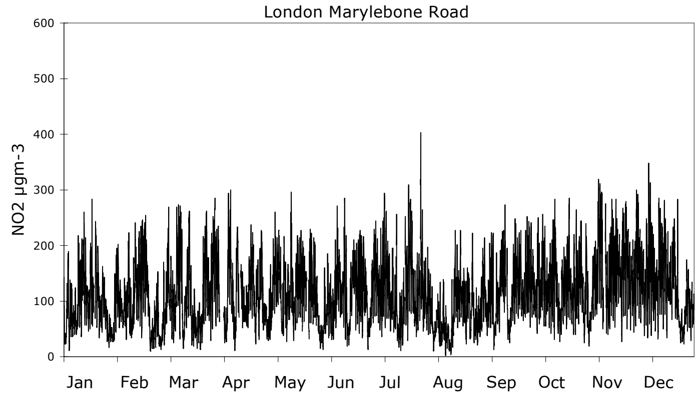
Air Quality Bands and Index Values		
Band	**Index**	**Nitrogen Dioxide µg m^{-3}**
Low	1	0-95
	2	96-190
	3	191-286
Moderate	4	287-381
	5	382-477
	6	478-572
High	7	573-635
	8	363-700
	9	701-763
Very High	10	764 or more



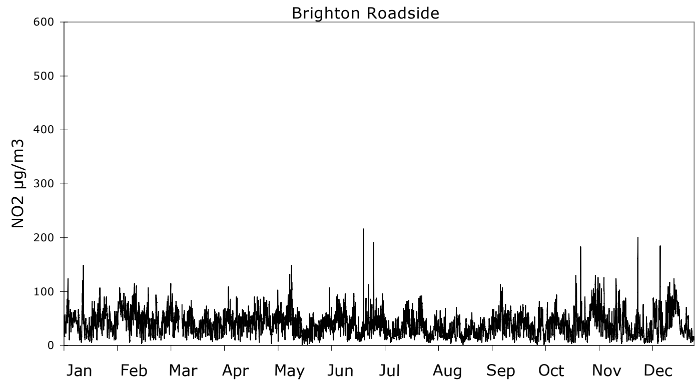
UK Automatic Nitrogen Dioxide Monitoring Sites 2006

12.5 Hourly Average Concentrations

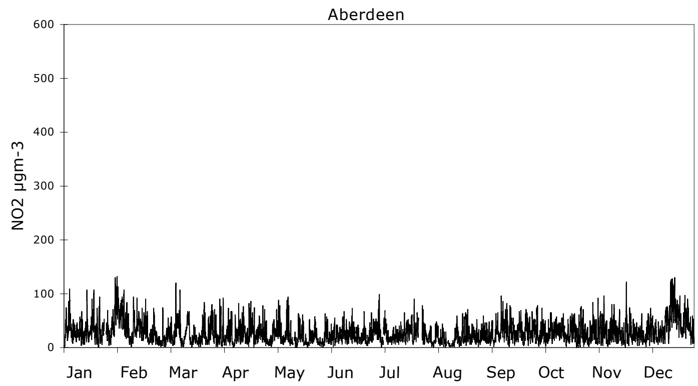
These figures show time series graphs of hourly average nitrogen dioxide concentrations at four *typical* site types for 2006.



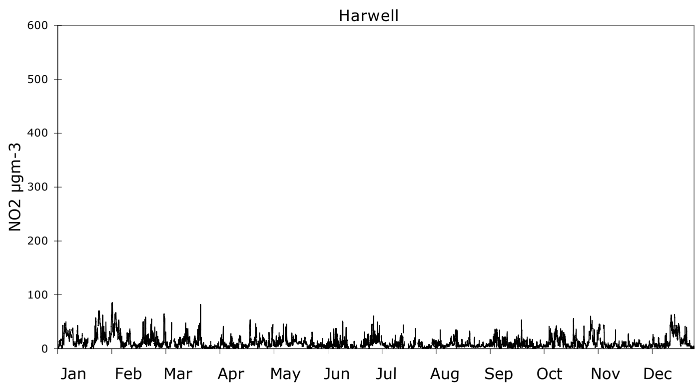
Kerbside Site
(*Marylebone Road)*



Roadside Site
(*Brighton Roadside)*



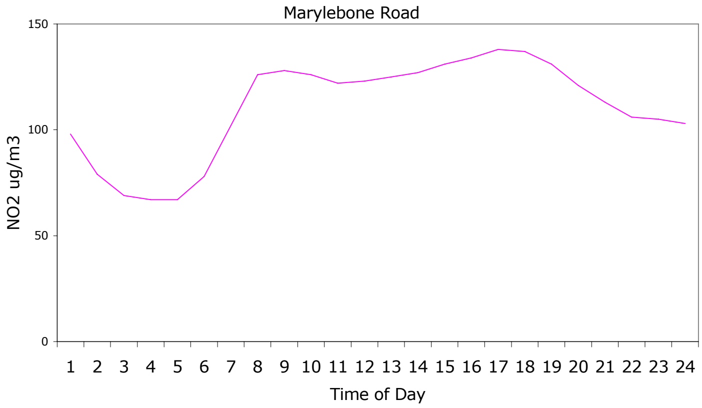
Urban Background Site
(*Aberdeen)*



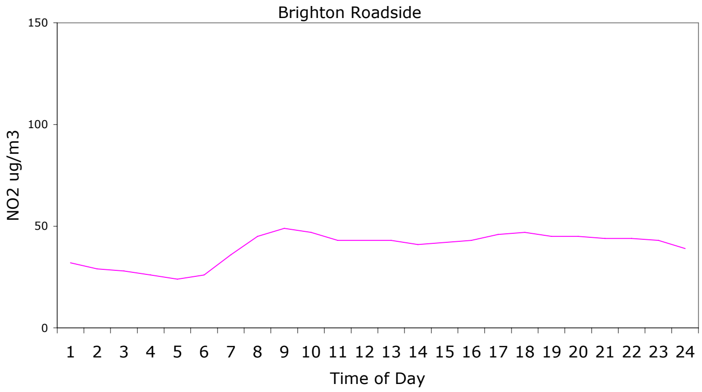
Rural Site
(Harwell)

12.6 Diurnal Variations

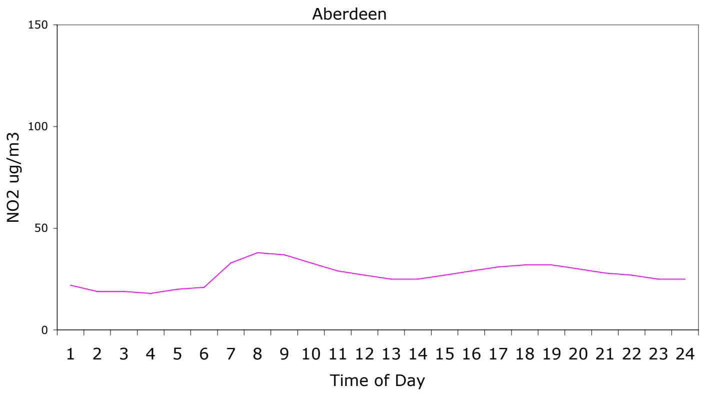
These figures show how nitrogen dioxide concentrations vary on average for each hour of day during 2006, at a number of selected *typical* monitoring site types. Local time is used, rather than GMT, since this will more closely reflect the daily cycle of man-made emissions.



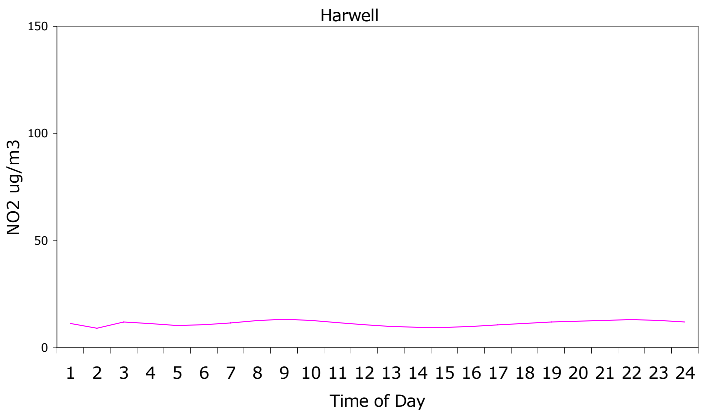
Kerbside Site
(*Marylebone Road)*



Roadside Site
(*Brighton)*



Urban Background Site
(*Aberdeen)*

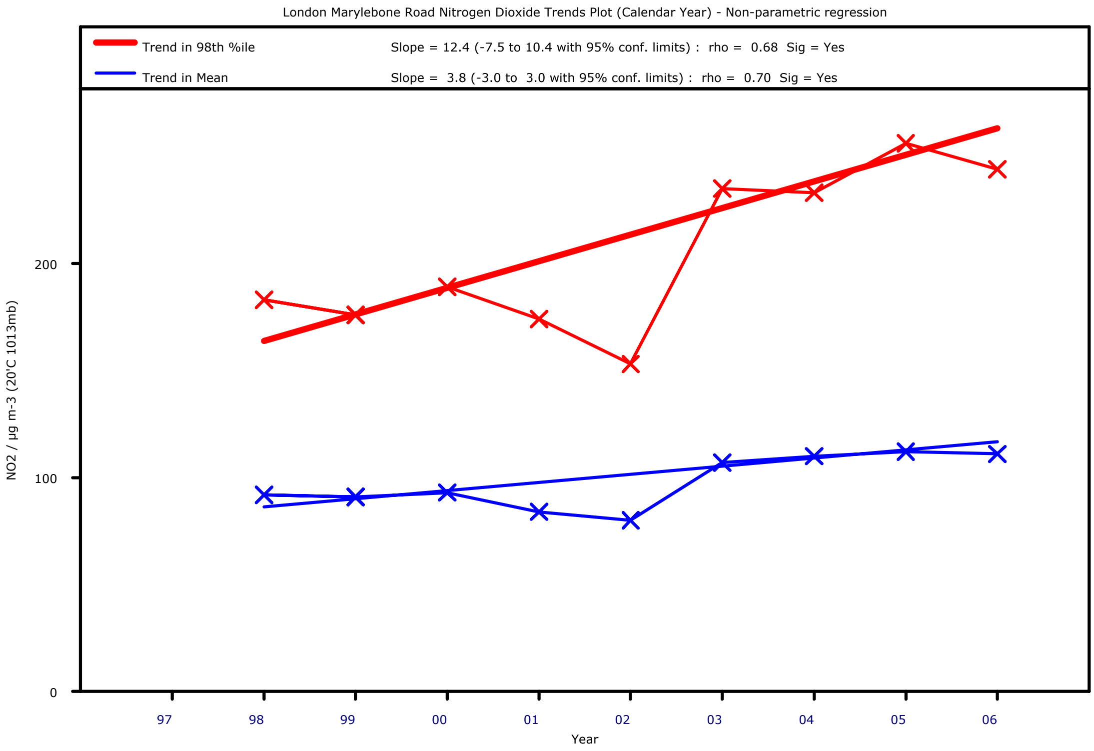


Rural Site
(Harwell)

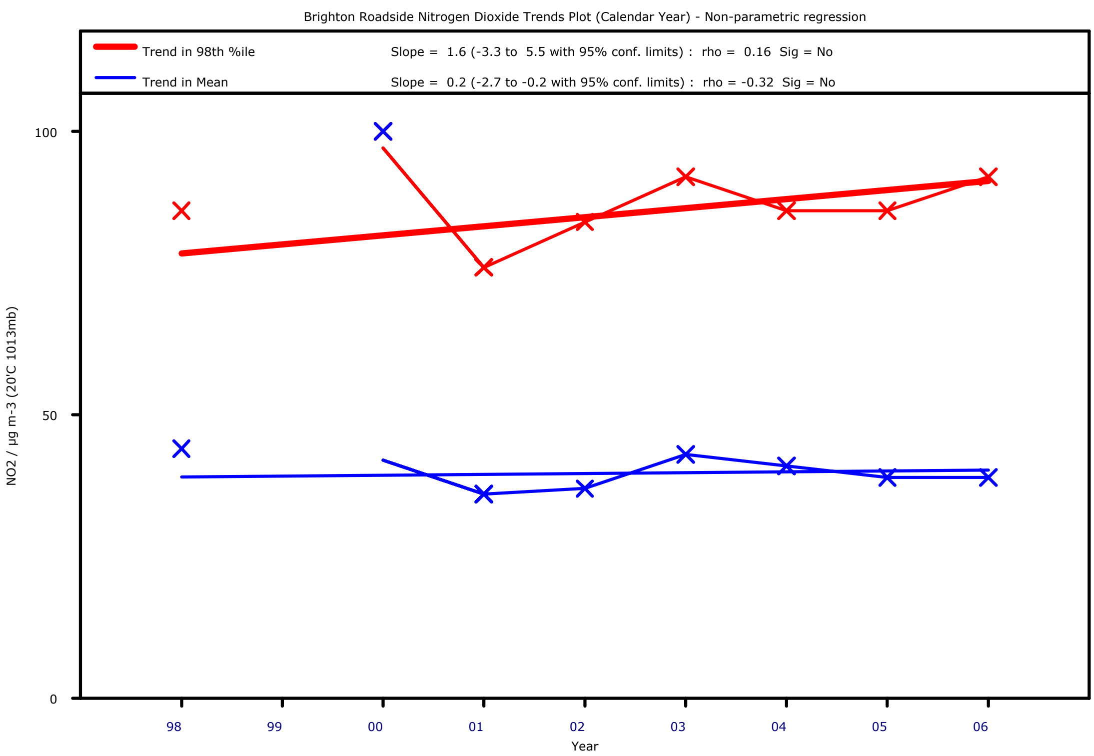
12.7 Trends in annual concentrations

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

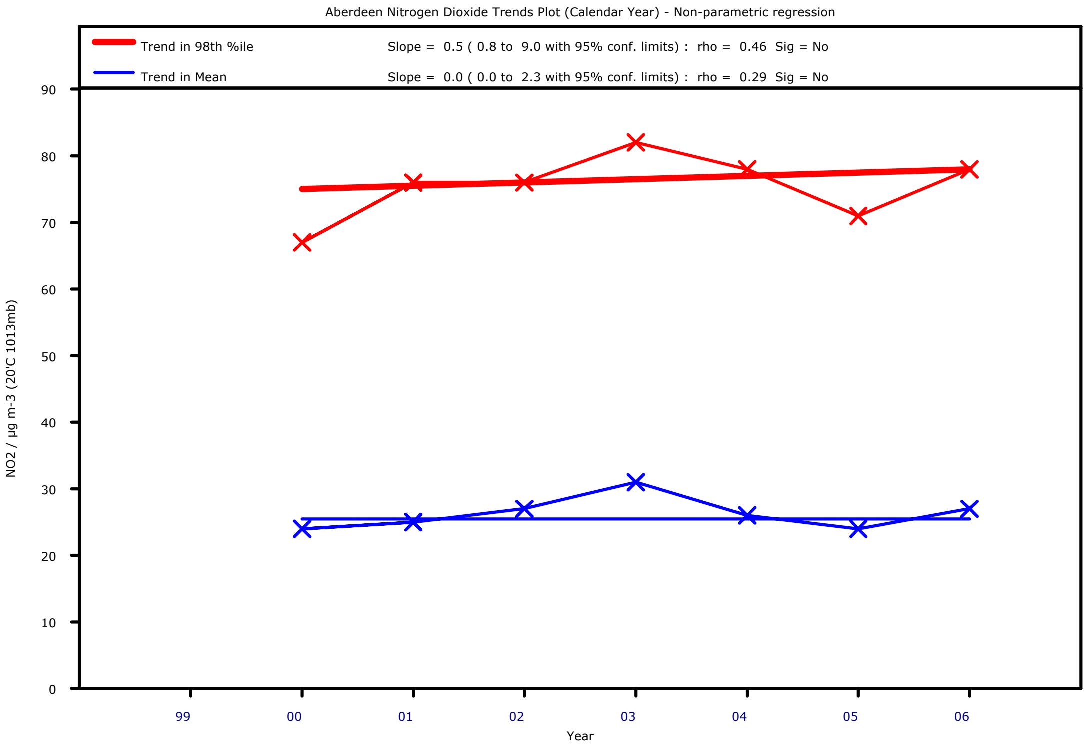
London Marylebone Road Nitrogen Dioxide Trends Plot – Non-parametric regression



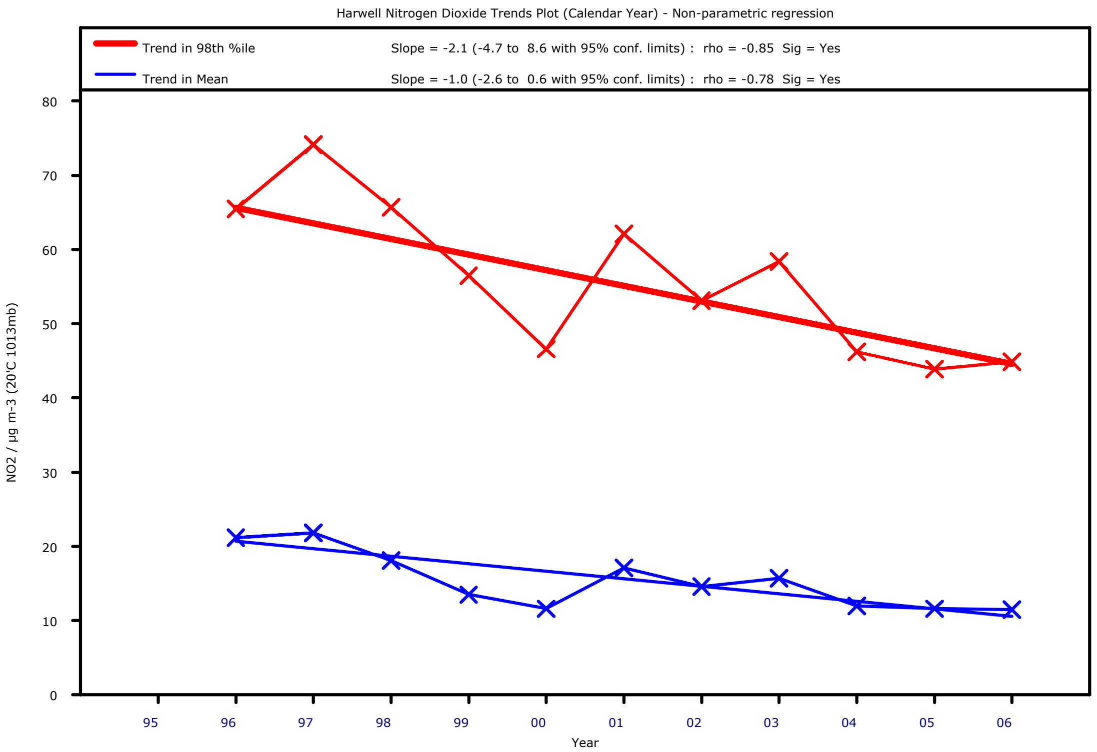
Brighton Roadside Nitrogen Dioxide Trends Plot – Non-parametric regression



Aberdeen Nitrogen Dioxide Trends Plot – Non-parametric regression



Harwell Nitrogen Dioxide Trends Plot – Non-parametric regression



12.8 Nitrogen Dioxide Statistical Summary 2006

i) NO_2 annual statistics I

Site	Site Type	Annual average of hourly means µg m^{-3}	Annual data capture of hourly means %	Maximum hourly mean µg m^{-3}	99.8%ile of hourly means µg m^{-3}
England					
Barnsley Gawber	UB	19	77.0	118	86
Bath Roadside	RD	69	98.2	222	191
Billingham	I	29	97.8	298	149
Birmingham Centre	UC	34	93.9	136	115
Birmingham Tyburn	UB	37	87.1	170	136
Blackpool Marton	UB	18	94.5	120	88
Bolton	UB	23	67.5	132	107
Bournemouth	UB	17	93.1	109	92
Bradford Centre	UC	32	94.0	115	99
Brentford Roadside	RD	54	86.5	208	176
Brighton Preston Park	UB	21	98.2	128	92
Brighton Roadside	RD	39	99.1	216	126
Bristol Old Market	RD	67	99.0	265	193
Bristol St Paul's	UB	31	53.5	164	120
Bury Roadside	RD	73	81.2	235	195
Cambridge Roadside	RD	45	89.7	138	109
Camden Kerbside	KB	72	96.9	290	218
Canterbury	UB	18	97.5	84	73
Coventry Memorial Park	UB	18	99.3	139	103
Exeter Roadside	RD	39	97.3	195	141
Glazebury	SU	17.0	96.6	101.2	84.0
Haringey Roadside	RD	44	85.1	162	130
Harwell	RU	11.5	92.6	85.6	68.0
High Muffles	RU	7.5	87.7	69.5	61.3
Hove Roadside	RD	34	88.5	162	117
Hull Freetown	UC	24	86.7	105	82
Ladybower	RU	---	46.4	68.8	---
Leamington Spa	UB	20	72.8	117	88
Leeds Centre	UC	39	91.5	176	115
Leicester Centre	UC	30	98.4	130	97
Leominster	SU	12	91.7	82	63
Liverpool Speke	UB	22	92.0	136	111
London A3 Roadside	RD	60	97.8	193	162
London Bexley	SU	36	92.4	145	126
London Bloomsbury	UC	57	93.3	180	145
London Brent	UB	30	98.2	151	118
London Bromley	RD	51	59.9	212	162
London Cromwell Road 2	RD	83	90.8	229	185
London Eltham	SU	30	99.0	136	105
London Hackney	UC	49	83.4	273	168
London Harlington	A	37	98.3	350	122
London Hillingdon	SU	49	94.3	164	147
London Lewisham	UC	55	92.0	172	159
London Marylebone Road	KB	111	97.2	403	294
London N. Kensington	UB	38	99.2	176	141
London Southwark	UC	42	86.1	153	134
London Teddington	UB	23.2	98.6	117.1	101.4
London Wandsworth	UC	51	97.8	160	138
London Westminster	UB	51	96.0	329	122
Lullington Heath	RU	10.8	85.7	81.9	68.8
Manchester Piccadilly	UC	44	97.4	273	134
Manchester South	SU	16	88.1	128	86
Manchester Town Hall	UB	42	86.9	229	130
Market Harborough	RU	10.9	95.8	76.2	60.4
Middlesbrough	I	22	96.3	105	86
Newcastle Centre	UC	29	62.9	118	94
Northampton	UB	21	98.4	107	86
Norwich Centre	UC	21	99.1	113	74

ii) NO_2 exceedence statistics I

Site	Moderate band	Days	High band	Days	Very High band	Days	Air Quality Standard (Annual Mean)	Daughter Directive Hourly Mean Standard	Days
England									
Barnsley Gawber	0	0	0	0	0	0	0	0	0
Bath Roadside	0	0	0	0	0	0	**1**	**11**	**10**
Billingham	1	1	0	0	0	0	0	**5**	**5**
Birmingham Centre	0	0	0	0	0	0	0	0	0
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	0
Bournemouth	0	0	0	0	0	0	0	0	0
Bradford Centre	0	0	0	0	0	0	0	0	0
Brentford Roadside	0	0	0	0	0	0	**1**	**2**	**2**
Brighton Preston Park	0	0	0	0	0	0	0	0	0
Brighton Roadside	0	0	0	0	0	0	0	**2**	**2**
Bristol Old Market	0	0	0	0	0	0	**1**	**13**	**9**
Bristol St Paul's	0	0	0	0	0	0	0	0	0
Bury Roadside	0	0	0	0	0	0	**1**	**10**	**6**
Cambridge Roadside	0	0	0	0	0	0	**1**	0	0
Camden Kerbside	1	1	0	0	0	0	**1**	**40**	**19**
Canterbury	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	0
Haringey Roadside	0	0	0	0	0	0	**1**	0	0
Harwell	0	0	0	0	0	0	0	0	0
High Muffles	0	0	0	0	0	0	0	0	0
Hove Roadside	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
Leamington Spa	0	0	0	0	0	0	0	0	0
Leeds Centre	0	0	0	0	0	0	0	0	0
Leicester Centre	0	0	0	0	0	0	0	0	0
Leominster	0	0	0	0	0	0	0	0	0
Liverpool Speke	0	0	0	0	0	0	0	0	0
London A3 Roadside	0	0	0	0	0	0	**1**	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 Brent	0	0	0	0	0	0	0	0	0
London Bromley	0	0	0	0	0	0	**1**	**1**	**1**
London Cromwell Road 2	0	0	0	0	0	0	**1**	**4**	**3**
London Eltham	0	0	0	0	0	0	0	0	0
London Hackney	0	0	0	0	0	0	**1**	**8**	**3**
London Harlington	2	2	0	0	0	0	0	**2**	**2**
London Hillingdon	0	0	0	0	0	0	**1**	0	0
London Lewisham	0	0	0	0	0	0	**1**	0	0
London Marylebone Road	27	13	0	0	0	0	**1**	**686**	**147**
London N. Kensington	0	0	0	0	0	0	0	0	0
London Southwark	0	0	0	0	0	0	**1**	0	0
London Teddington	0	0	0	0	0	0	0	0	0
London Wandsworth	0	0	0	0	0	0	**1**	0	0
London Westminster	3	2	0	0	0	0	**1**	**5**	**2**
Lullington Heath	0	0	0	0	0	0	0	0	0
Manchester Piccadilly	0	0	0	0	0	0	**1**	**2**	**1**
Manchester South	0	0	0	0	0	0	0	0	0
Manchester Town Hall	0	0	0	0	0	0	**1**	**3**	**1**
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
Northampton	0	0	0	0	0	0	0	0	0
Norwich Centre	0	0	0	0	0	0	0	0	0

iii) NO_2 annual statistics II

Site	Site Type	Annual average of hourly means µg m^{-3}	Annual data capture of hourly means %	Maximum hourly mean µg m^{-3}	99.8%ile of hourly means µg m^{-3}
England *(continued)*					
Norwich Forum Roadside	RD	35	88.8	202	109
Nottingham Centre	UC	34	98.1	136	107
Oxford Centre Roadside	RD	66	95.2	244	199
Plymouth Centre	UC	---	44.5	99	---
Portsmouth	UB	22	99.1	132	82
Preston	UB	22	90.3	118	90
Reading New Town	UB	21	71.2	88	74
Redcar	SU	22	83.7	94	76
Rochester Stoke	RU	19.8	92.9	127.2	84.6
Rotherham Centre	UC	37	77.8	206	166
Salford Eccles	I	35	96.5	178	120
Sandwell West Bromwich	UB	25	69.4	136	111
Sheffield Centre	UC	36	52.5	185	124
Sheffield Tinsley	I	40	98.6	216	141
Somerton	RU	8.3	80.5	61.9	50.8
Southampton Centre	UC	28	90.0	143	105
Southend-on-Sea	UB	20	97.7	120	90
Southwark Roadside	RD	---	14.0	185	---
St Osyth	RU	15.6	95.0	107.3	71.6
Stockport Shaw Heath	UB	31	83.2	183	117
Stockton-on-Tees Yarm	RD	38	98.9	351	118
Stoke-on-Trent Centre	UC	32	93.4	160	134
Sunderland Silksworth	UB	18	91.2	122	84
Thurrock	UB	33	92.7	141	113
Tower Hamlets Roadside	RD	61	99.5	239	181
Walsall Alumwell	UB	38	98.0	174	134
Walsall Willenhall	SU	31	89.3	231	136
West London	UB	51	94.5	197	138
Wicken Fen	RU	10.2	97.3	59.6	55.4
Wigan Centre	UB	26	97.4	130	90
Wirral Tranmere	UB	19	93.5	126	96
Wolverhampton Centre	UC	27	94.6	157	99
Yarner Wood	RU	5.2	87.8	57.7	47.9
N Ireland					
Belfast Centre	UC	34	90.7	254	134
Derry	UB	12	88.1	82	63
Scotland					
Aberdeen	UB	27	96.7	132	113
Bush Estate	RU	10.0	86.8	65.9	51.0
Dumfries	RD	37	94.3	199	132
Edinburgh St Leonards	UC	27	93.8	113	97
Eskdalemuir	RU	3.7	89.1	54.2	27.5
Fort William	SU	---	42.6	61	---
Glasgow Centre	UC	31	96.1	246	111
Glasgow City Chambers	UB	47	98.2	168	124
Glasgow Kerbside	KB	68	92.5	254	174
Grangemouth	I	18	98.0	111	90
Inverness	RD	21	99.0	126	101
Wales					
Aston Hill	RU	5.5	69.5	58.4	49.3
Cardiff Centre	UC	31	97.1	134	99
Cwmbran	UB	14	95.5	92	76
Narberth	RU	5.3	94.0	61.9	44.5
Port Talbot	UB	18	97.2	96	78
Swansea	UC	31	54.5	126	101
Swansea Roadside	RD	---	27.6	138	---
Wrexham	UC	21	94.4	126	84

iv) NO_2 exceedence statistics II

Site	Moderate band	Days	High band	Days	Very High band	Days	Air Quality Standard (Annual Mean)	Daughter Directive Hourly Mean Standard	Days
England *(continued)*									
Norwich Forum Roadside	0	0	0	0	0	0	0	**1**	**1**
Nottingham Centre	0	0	0	0	0	0	0	0	0
Oxford Centre Roadside	0	0	0	0	0	0	**1**	**17**	**9**
Plymouth Centre	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
Redcar	0	0	0	0	0	0	0	0	0
Rochester Stoke	0	0	0	0	0	0	0	0	0
Rotherham Centre	0	0	0	0	0	0	0	**2**	**2**
Salford Eccles	0	0	0	0	0	0	0	0	0
Sandwell West Bromwich	0	0	0	0	0	0	0	0	0
Sheffield Centre	0	0	0	0	0	0	0	0	0
Sheffield Tinsley	0	0	0	0	0	0	0	**1**	**1**
Somerton	0	0	0	0	0	0	0	0	0
Southampton Centre	0	0	0	0	0	0	0	0	0
Southend-on-Sea	0	0	0	0	0	0	0	0	0
Southwark Roadside	0	0	0	0	0	0	---	0	0
St Osyth	0	0	0	0	0	0	0	0	0
Stockport Shaw Heath	0	0	0	0	0	0	0	0	0
Stockton-on-Tees Yarm	1	1	0	0	0	0	0	**2**	**2**
Stoke-on-Trent Centre	0	0	0	0	0	0	0	0	0
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**	**7**	**3**
Walsall Alumwell	0	0	0	0	0	0	0	0	0
Walsall Willenhall	0	0	0	0	0	0	0	**4**	**1**
West London	0	0	0	0	0	0	**1**	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
Wolverhampton Centre	0	0	0	0	0	0	0	0	0
Yarner Wood	0	0	0	0	0	0	0	0	0
N Ireland									
Belfast Centre	0	0	0	0	0	0	0	**5**	**3**
Derry	0	0	0	0	0	0	0	0	0
Scotland									
Aberdeen	0	0	0	0	0	0	0	0	0
Bush Estate	0	0	0	0	0	0	0	0	0
Dumfries	0	0	0	0	0	0	0	0	0
Edinburgh St Leonards	0	0	0	0	0	0	0	0	0
Eskdalemuir	0	0	0	0	0	0	0	0	0
Fort William	0	0	0	0	0	0	---	0	0
Glasgow Centre	0	0	0	0	0	0	0	**2**	**2**
Glasgow City Chambers	0	0	0	0	0	0	**1**	0	0
Glasgow Kerbside	0	0	0	0	0	0	**1**	**3**	**3**
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
Cwmbran	0	0	0	0	0	0	0	0	0
Narberth	0	0	0	0	0	0	0	0	0
Port Talbot	0	0	0	0	0	0	0	0	0
Swansea	0	0	0	0	0	0	0	0	0
Swansea Roadside	0	0	0	0	0	0	---	0	0
Wrexham	0	0	0	0	0	0	0	0	0

13. NO_x- 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 1999/30/EC

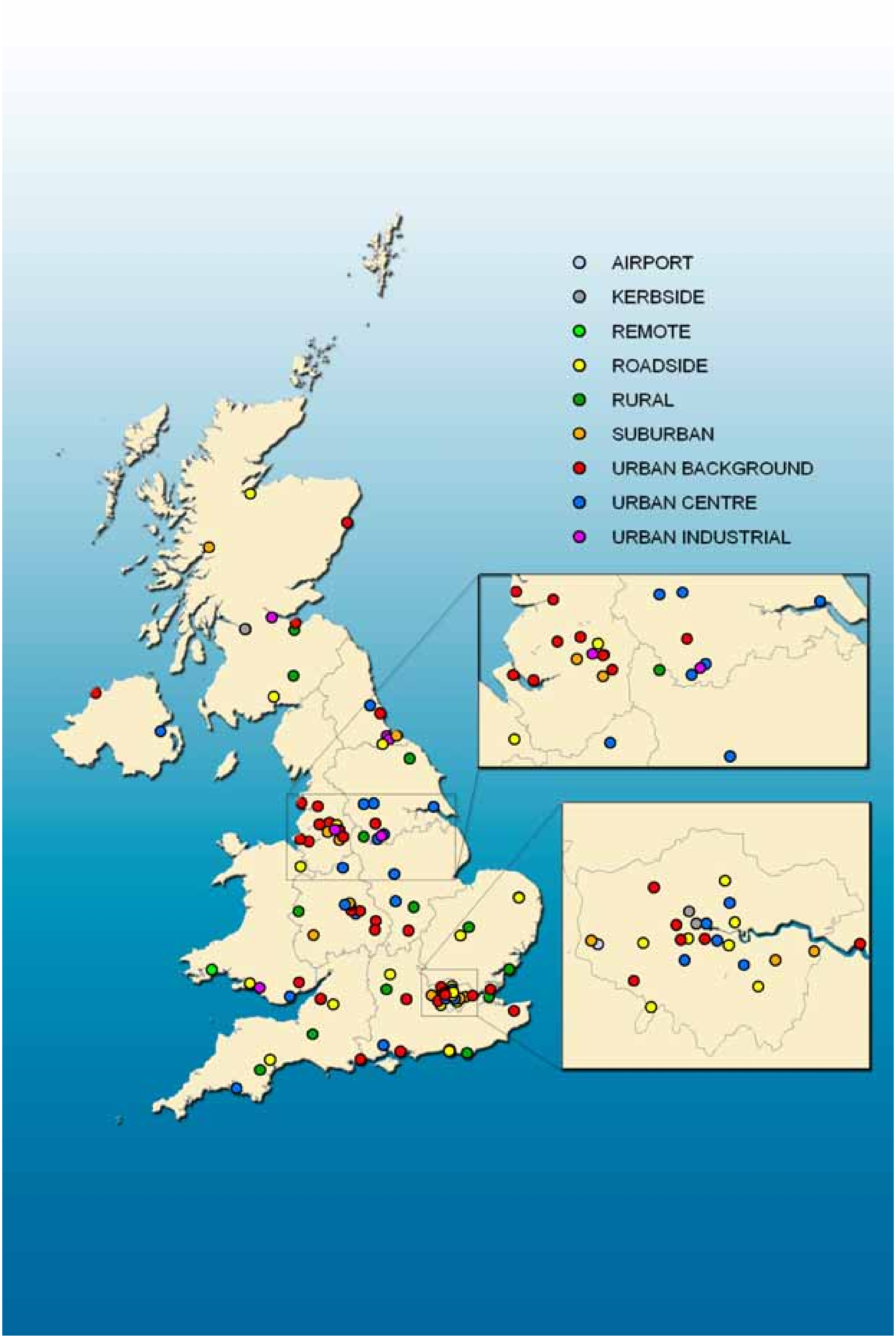
Uncertainty 15%
Minimum data capture 90%

13.4 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

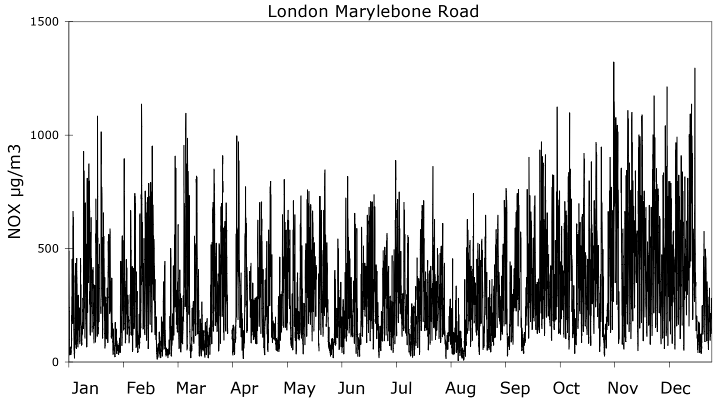
No bandings are set for oxides of nitrogen, as there are no known short-term effects of this pollutant.



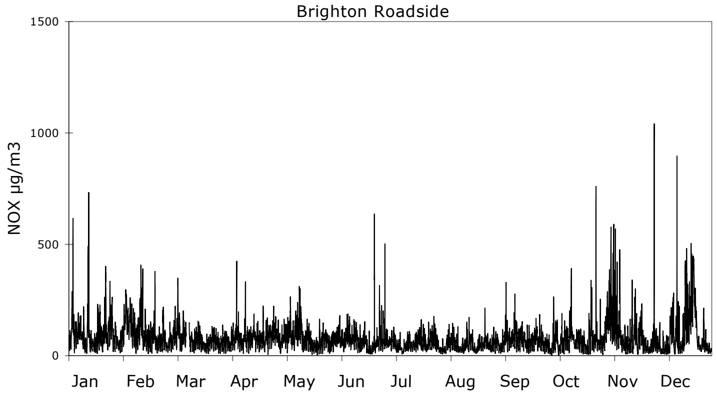
UK Automatic Nitrogen Oxides Monitoring Sites 2006

13.5 Hourly Average Concentrations

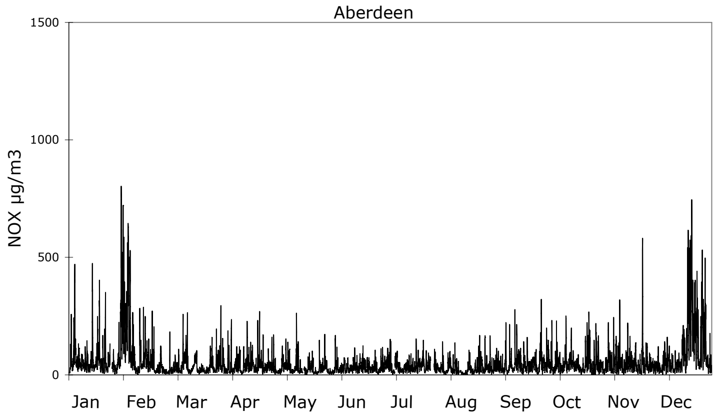
These figures show time series graphs of hourly average nitrogen oxides concentrations at four *typical* site types for 2006.



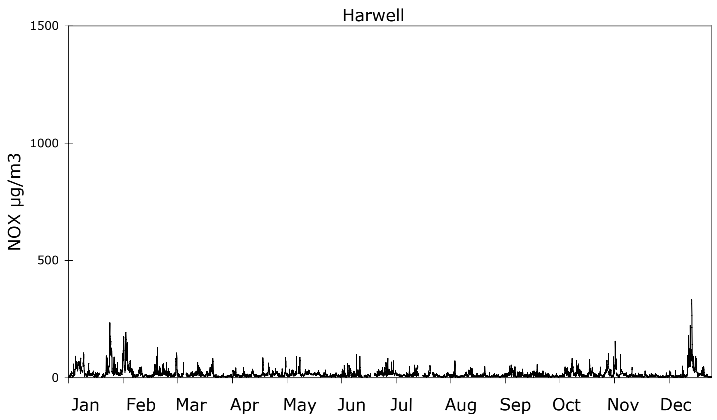
Kerbside Site
(*Marylebone Road)*



Roadside Site
(Brighton)



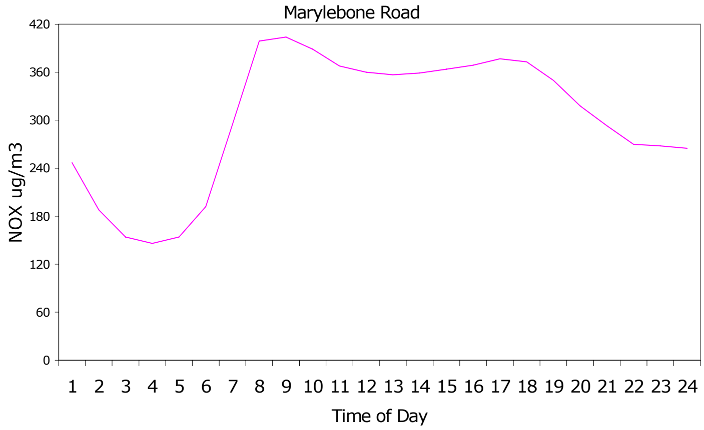
Urban Background Site
(*Aberdeen***)**



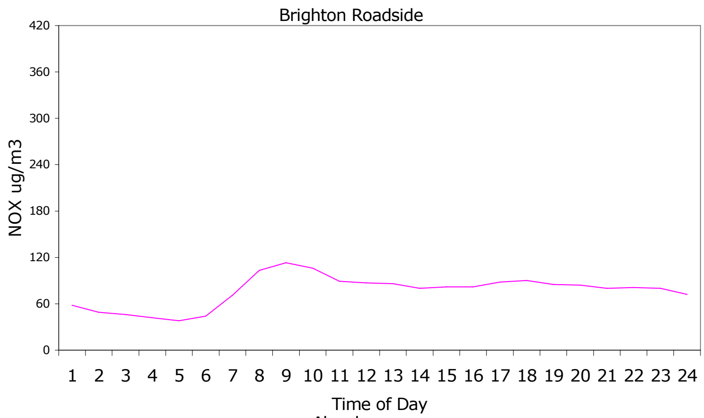
Rural Site
(Harwell)

13.6 Diurnal Variations

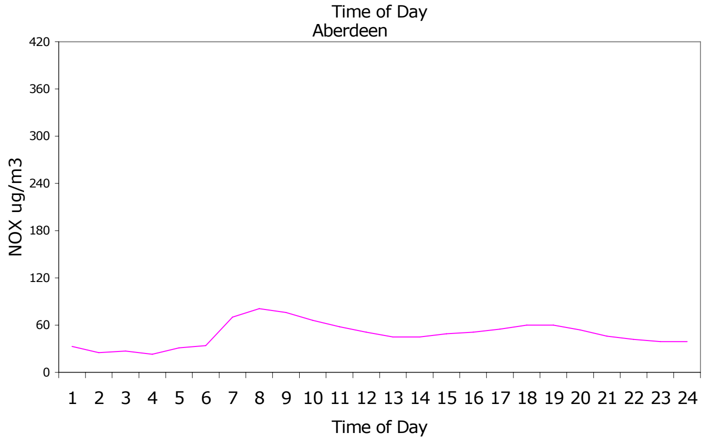
These figures show how nitrogen oxides concentrations vary on average for each hour of day during the year, at a number of selected *typical* monitoring site types. Local time is used, rather than GMT, since this will more closely reflect the daily cycle of man-made emissions.



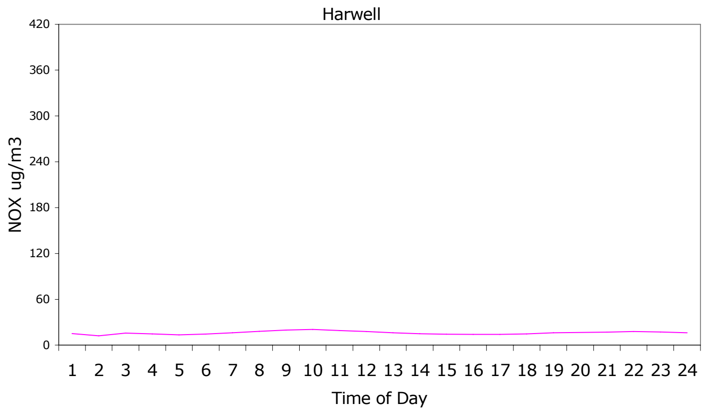
Kerbside Site
(Marylebone Road)



Roadside Site
(Brighton)



Urban Background Site
(Aberdeen)

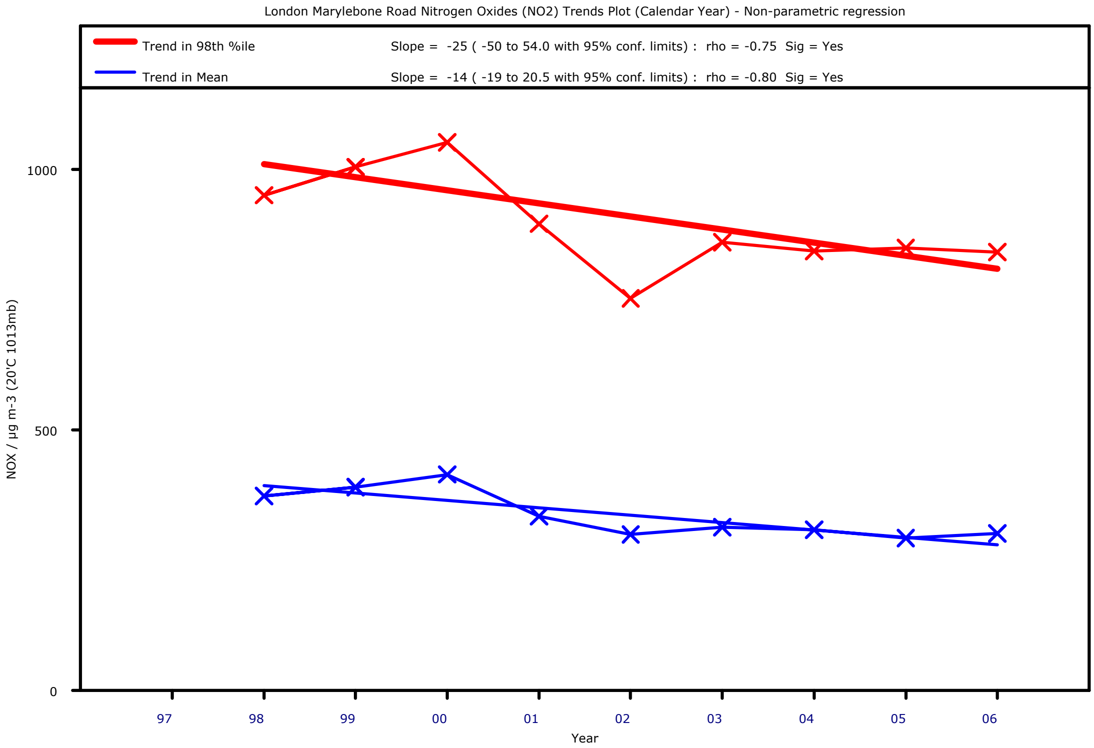


Rural Site
(Harwell)

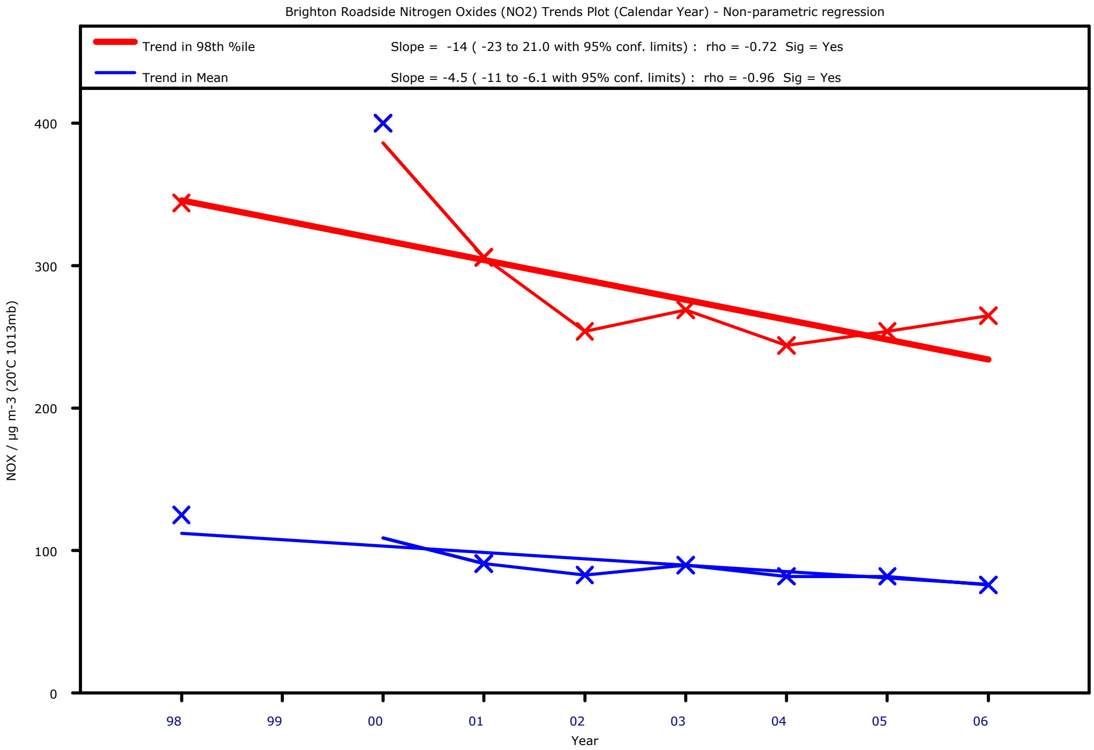
13.7 Trends in annual concentrations

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

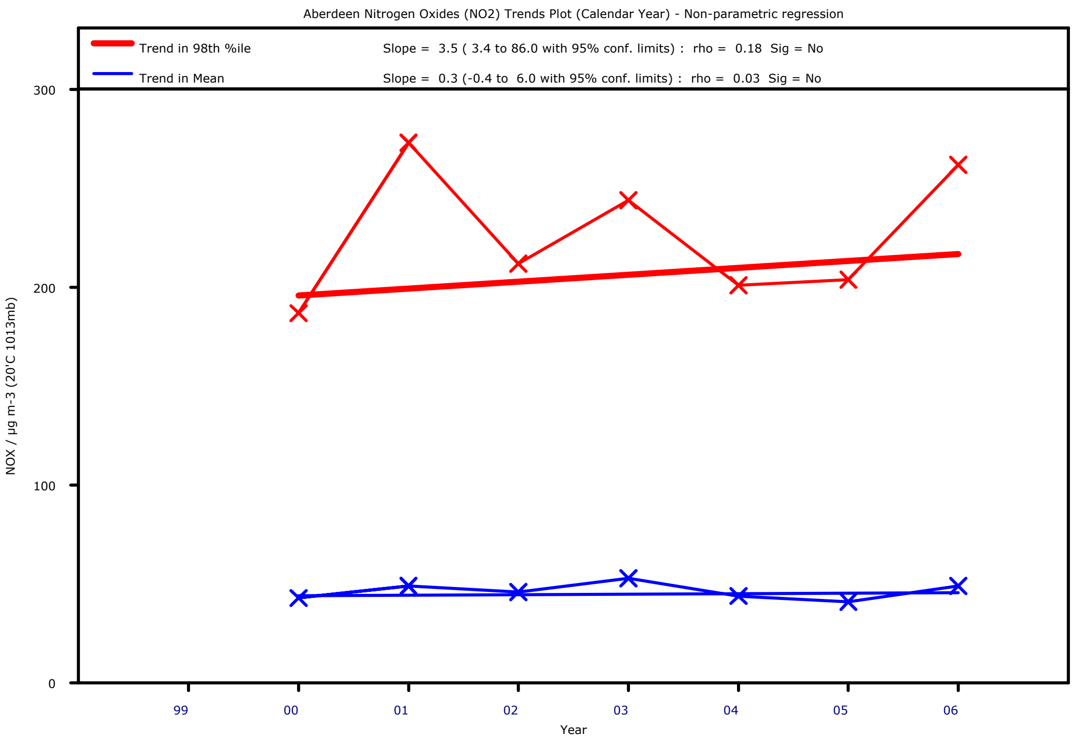
London Marylebone Road Nitrogen Oxides Trends Plot – Non-parametric regression



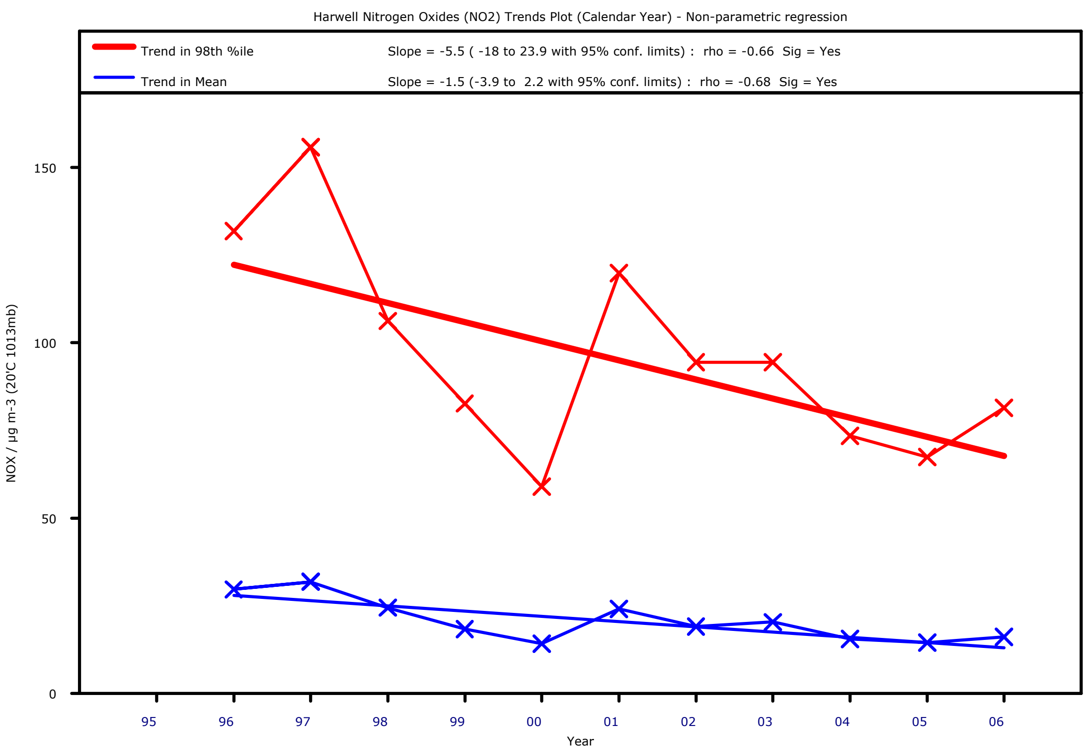
Brighton Roadside Nitrogen Oxides Trends Plot – Non-parametric regression



Aberdeen Nitrogen Oxides Trends Plot – Non-parametric



Harwell Nitrogen Oxides Trends Plot – Non-parametric regression



13.8 Nitrogen Oxides Statistical Summary 2006

i) NOx annual statistics I

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	29	77.0	464
Bath Roadside	RD	187	98.2	995
Billingham	I	51	97.8	846
Birmingham Centre	UC	58	93.9	892
Birmingham Tyburn	UB	74	87.1	1446
Blackpool Marton	UB	28	94.5	441
Bolton	UB	37	67.5	688
Bournemouth	UB	24	93.1	575
Bradford Centre	UC	57	94.0	842
Brentford Roadside	RD	142	86.5	1045
Brighton Preston Park	UB	31	98.2	630
Brighton Roadside	RD	76	99.1	1041
Bristol Old Market	RD	182	99.0	1507
Bristol St Paul's	UB	53	53.5	940
Bury Roadside	RD	197	81.2	1089
Cambridge Roadside	RD	111	89.7	840
Camden Kerbside	KB	181	96.9	1255
Canterbury	UB	28	97.5	432
Coventry Memorial Park	UB	27	99.3	644
Exeter Roadside	RD	101	97.3	825
Glazebury	SU	30.0	96.6	631.1
Haringey Roadside	RD	84	85.1	900
Harwell	RU	16.2	92.6	333.9
High Muffles	RU	9.1	87.7	158.3
Hove Roadside	RD	61	88.5	754
Hull Freetown	UC	42	86.7	537
Ladybower	RU	---	46.4	200.9
Leamington Spa	UB	29	72.8	518
Leeds Centre	UC	71	91.5	1186
Leicester Centre	UC	53	98.4	944
Leominster	SU	17	91.7	374
Liverpool Speke	UB	36	92.0	754
London A3 Roadside	RD	143	97.8	955
London Bexley	SU	60	92.4	772
London Bloomsbury	UC	97	93.3	852
London Brent	UB	51	98.2	984
London Bromley	RD	95	59.9	623
London Cromwell Road 2	RD	181	90.8	831
London Eltham	SU	45	99.0	796
London Hackney	UC	92	83.4	1350
London Harlington	A	65	98.3	966
London Hillingdon	SU	107	94.3	982
London Lewisham	UC	104	92.0	812
London Marylebone Road	KB	302	97.2	1322
London N. Kensington	UB	60	99.2	844
London Southwark	UC	74	86.1	686
London Teddington	UB	37.6	98.6	510.5
London Wandsworth	UC	101	97.8	707
London Westminster	UB	84	96.0	833
Lullington Heath	RU	14.2	85.7	324.3
Manchester Piccadilly	UC	81	97.4	1566
Manchester South	SU	26	88.1	500
Manchester Town Hall	UB	66	86.9	1282
Market Harborough	RU	13.6	95.8	385.2
Middlesbrough	I	31	96.3	456
Newcastle Centre	UC	49	62.9	583
Northampton	UB	33	98.4	707
Norwich Centre	UC	33	99.1	829
Norwich Forum Roadside	RD	69	88.8	1041
Nottingham Centre	UC	63	98.1	802
Oxford Centre Roadside	RD	175	95.2	999
Plymouth Centre	UC	---	44.5	302

ii) NOx exceedence statistics I

Site	Daughter Directive Ecosystem and Air Quality Standard (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	1
Bournemouth	0
Bradford Centre	1
Brentford Roadside	1
Brighton Preston Park	1
Brighton Roadside	1
Bristol Old Market	1
Bristol St Paul's	1
Bury Roadside	1
Cambridge Roadside	1
Camden Kerbside	1
Canterbury	0
Coventry Memorial Park	0
Exeter Roadside	1
Glazebury	0
Haringey Roadside	1
Harwell	0
High Muffles	0
Hove Roadside	1
Hull Freetown	1
Ladybower	---
Leamington Spa	0
Leeds Centre	1
Leicester Centre	1
Leominster	0
Liverpool Speke	1
London A3 Roadside	1
London Bexley	1
London Bloomsbury	1
London Brent	1
London Bromley	1
London Cromwell Road 2	1
London Eltham	1
London Hackney	1
London Harlington	1
London Hillingdon	1
London Lewisham	1
London Marylebone Road	1
London N. Kensington	1
London Southwark	1
London Teddington	1
London Wandsworth	1
London Westminster	1
Lullington Heath	0
Manchester Piccadilly	1
Manchester South	0
Manchester Town Hall	1
Market Harborough	0
Middlesbrough	1
Newcastle Centre	1
Northampton	1
Norwich Centre	1
Norwich Forum Roadside	1
Nottingham Centre	1
Oxford Centre Roadside	1
Plymouth Centre	---

iii) NOx annual statistics II

Site	Site Type	Annual average of hourly means µg m^{-3}	Annual data capture of hourly means %	Maximum hourly mean µg m^{-3}
England - *continued*				
Portsmouth	UB	33	99.1	1318
Preston	UB	38	90.3	529
Reading New Town	UB	33	71.2	604
Redcar	SU	29	83.7	521
Rochester Stoke	RU	26.5	92.9	571.1
Rotherham Centre	UC	74	77.8	1161
Salford Eccles	I	62	96.5	1159
Sandwell West Bromwich	UB	40	69.4	1003
Sheffield Centre	UC	77	52.5	1421
Sheffield Tinsley	I	80	98.6	1396
Somerton	RU	10.4	80.5	157.4
Southampton Centre	UC	59	90.0	896
Southend-on-Sea	UB	31	97.7	785
Southwark Roadside	RD	---	14.0	856
St Osyth	RU	18.3	95.0	219.7
Stockport Shaw Heath	UB	49	83.2	890
Stockton-on-Tees Yarm	RD	114	98.9	2059
Stoke-on-Trent Centre	UC	57	93.4	1129
Sunderland Silksworth	UB	27	91.2	372
Thurrock	UB	57	92.7	781
Tower Hamlets Roadside	RD	141	99.5	1131
Walsall Alumwell	UB	69	98.0	1100
Walsall Willenhall	SU	48	89.3	1998
West London	UB	85	94.5	1763
Wicken Fen	RU	14.5	97.3	275.2
Wigan Centre	UB	45	97.4	802
Wirral Tranmere	UB	29	93.5	392
Wolverhampton Centre	UC	50	94.6	554
Yarner Wood	RU	6.3	87.8	150.7
N Ireland				
Belfast Centre	UC	61	90.7	1417
Derry	UB	19	88.1	359
Scotland				
Aberdeen	UB	49	96.7	802
Bush Estate	RU	14.7	86.8	238.0
Dumfries	RD	93	94.3	817
Edinburgh St Leonards	UC	40	93.8	563
Eskdalemuir	RU	5.8	89.1	56.2
Fort William	SU	---	42.6	172
Glasgow Centre	UC	57	96.1	972
Glasgow City Chambers	UB	89	98.2	995
Glasgow Kerbside	KB	246	92.5	1513
Grangemouth	I	30	98.0	775
Inverness	RD	45	99.0	672
Wales				
Aston Hill	RU	7.9	69.5	90.9
Cardiff Centre	UC	49	97.1	569
Cwmbran	UB	20	95.5	541
Narberth	RU	7.2	94.0	98.0
Port Talbot	UB	29	97.2	554
Swansea	UC	54	54.5	502
Swansea Roadside	RD	---	27.6	745
Wrexham	UC	41	94.4	474

iv) NOx exceedence statistics II

Site	Daughter Directive Ecosystem and Air Quality Standard (Annual Mean) > 30 µg m^{-3}
England - *continued*	
Portsmouth	**1**
Preston	**1**
Reading New Town	**1**
Redcar	0
Rochester Stoke	0
Rotherham Centre	**1**
Salford Eccles	**1**
Sandwell West Bromwich	**1**
Sheffield Centre	**1**
Sheffield Tinsley	**1**
Somerton	0
Southampton Centre	**1**
Southend-on-Sea	**1**
Southwark Roadside	---
St Osyth	0
Stockport Shaw Heath	**1**
Stockton-on-Tees Yarm	**1**
Stoke-on-Trent Centre	**1**
Sunderland Silksworth	0
Thurrock	**1**
Tower Hamlets Roadside	**1**
Walsall Alumwell	**1**
Walsall Willenhall	**1**
West London	**1**
Wicken Fen	0
Wigan Centre	**1**
Wirral Tranmere	0
Wolverhampton Centre	**1**
Yarner Wood	0
N Ireland	
Belfast Centre	**1**
Derry	0
Scotland	
Aberdeen	**1**
Bush Estate	0
Dumfries	**1**
Edinburgh St Leonards	**1**
Eskdalemuir	0
Fort William	---
Glasgow Centre	**1**
Glasgow City Chambers	**1**
Glasgow Kerbside	**1**
Grangemouth	0
Inverness	**1**
Wales	
Aston Hill	0
Cardiff Centre	**1**
Cwmbran	0
Narberth	0
Port Talbot	0
Swansea	**1**
Swansea Roadside	---
Wrexham	**1**

14. PM_{10} - Measurement Sites, Instrumentation and Statistics

14.1 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.

14.2 Instrumentation

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

- R&P TEOM 1400
- R&P Partisol
- Met One BAM 1020

** 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).

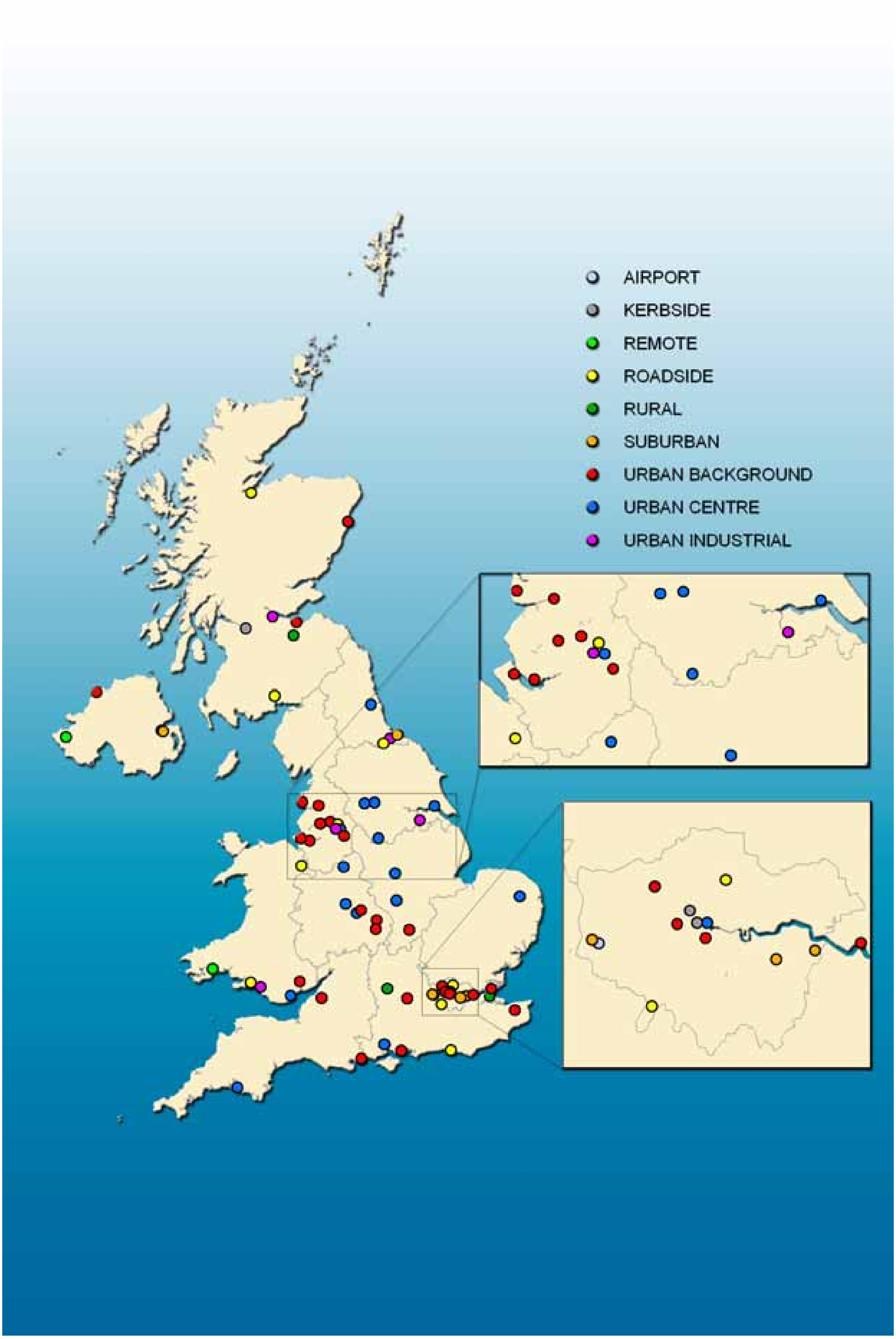
14.3 Data Quality Requirements of EC Directive 1999/30/EC

Uncertainty 25%
Minimum data capture 90%

14.4 Objectives and Bandings

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

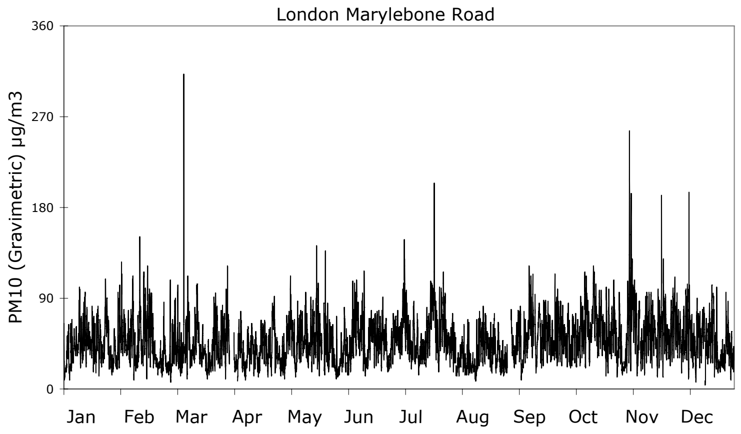
Air Quality Bands and Index Values		
Band	**Index**	**PM_{10} µg m^{-3} (Gravimetric)**
Low	1	0-16
	2	17-32
	3	33-49
Moderate	4	50-57
	5	58-66
	6	67-74
High	7	75-82
	8	83-91
	9	92-99
Very High	10	100 or more



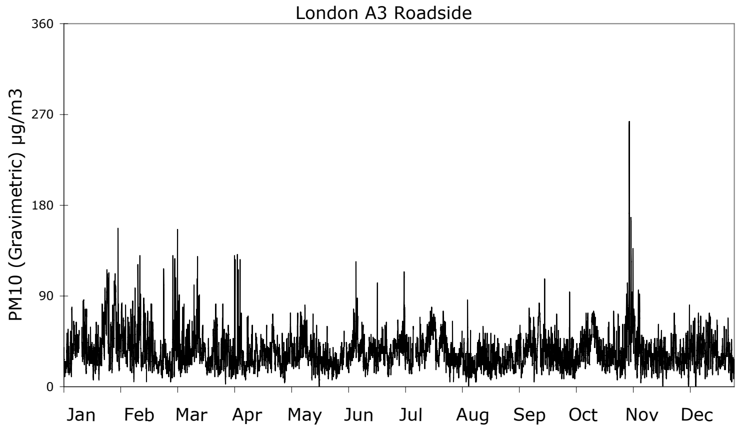
UK Automatic Gravimetric PM_{10} particles Monitoring Sites 2006

14.5 Hourly Average Concentrations

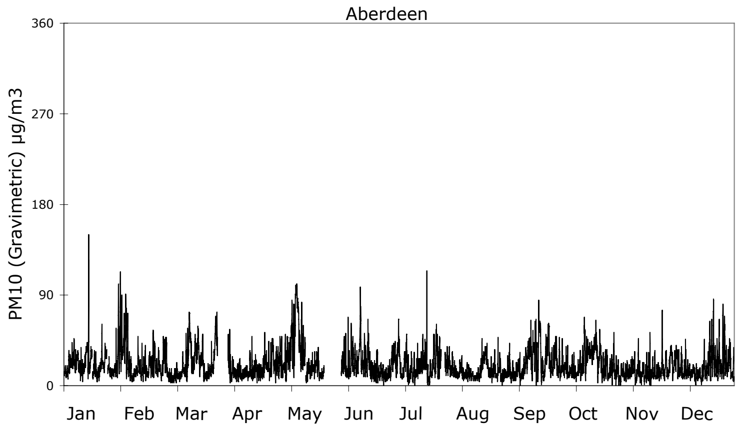
These figures show time series graphs of hourly average PM_{10} concentrations at four *typical* site types for 2006. Units are gravimetric equivalent (TEOM*1.3).



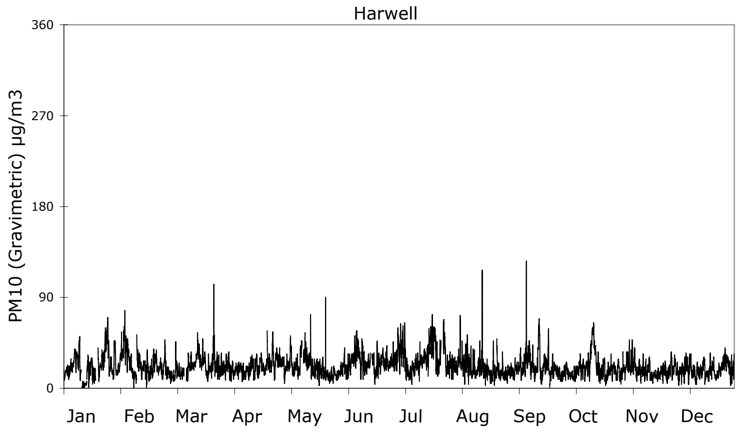
Kerbside Site
(Marylebone Road)



Roadside Site
(London A3)



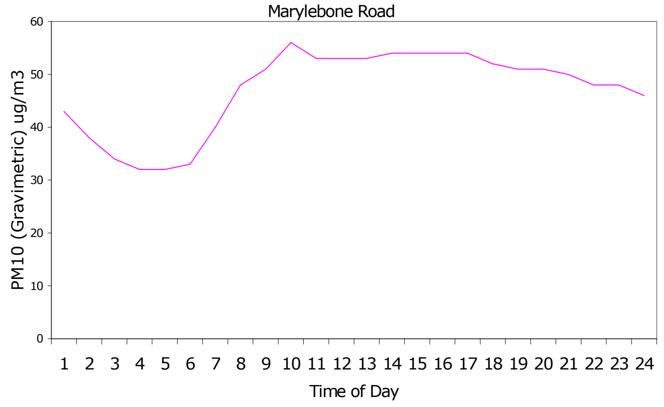
Urban Background Site
(Aberdeen)



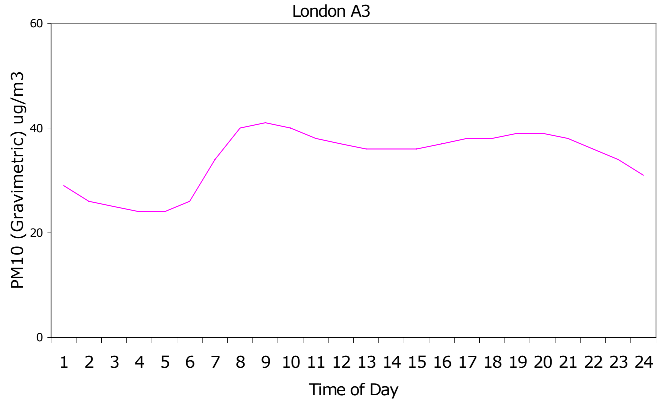
Rural Site
(Harwell)

14.6 Diurnal Variations

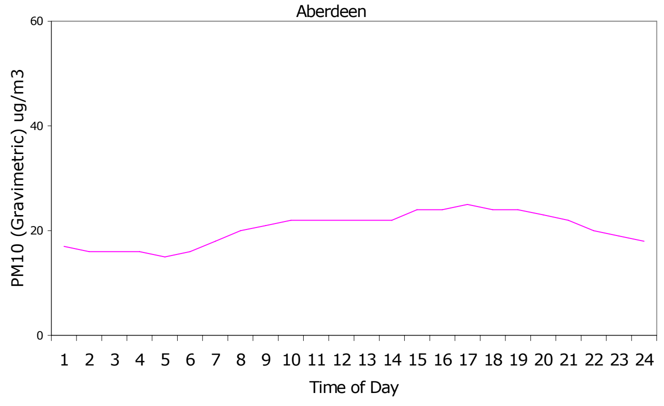
These figures show how PM_{10} concentrations vary on average for each hour of day during the year, at a number of selected *typical* monitoring site types. Local time is used, rather than GMT, since this will more closely reflect the daily cycle of man-made emissions.



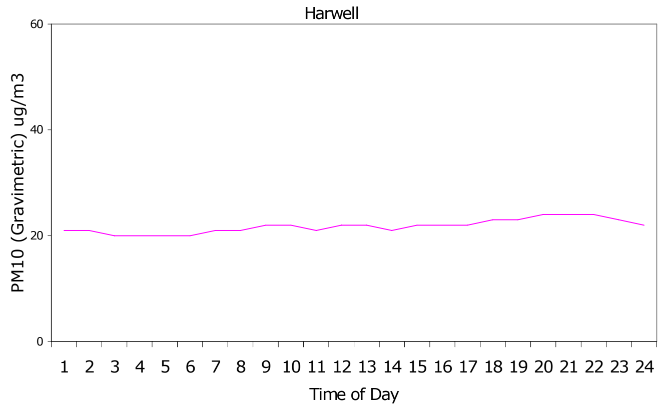
Kerbside Site
(Marylebone Road)



Roadside Site
(London A3)



Urban Background Site
(Aberdeen)

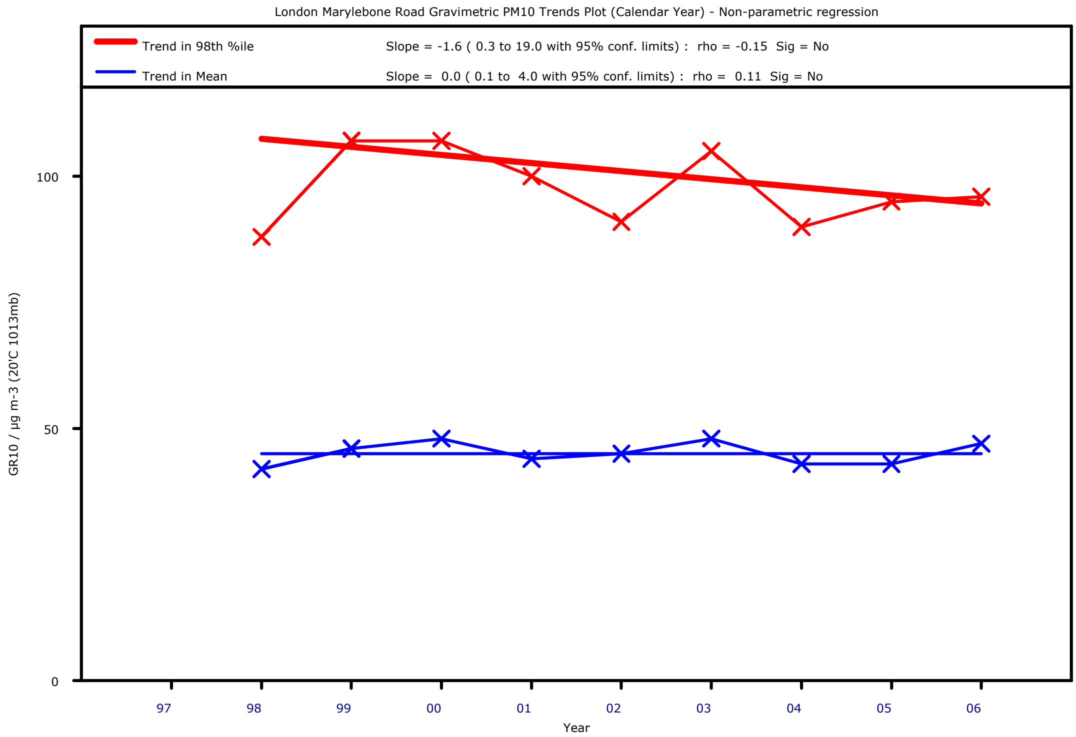


Rural Site
(Harwell)

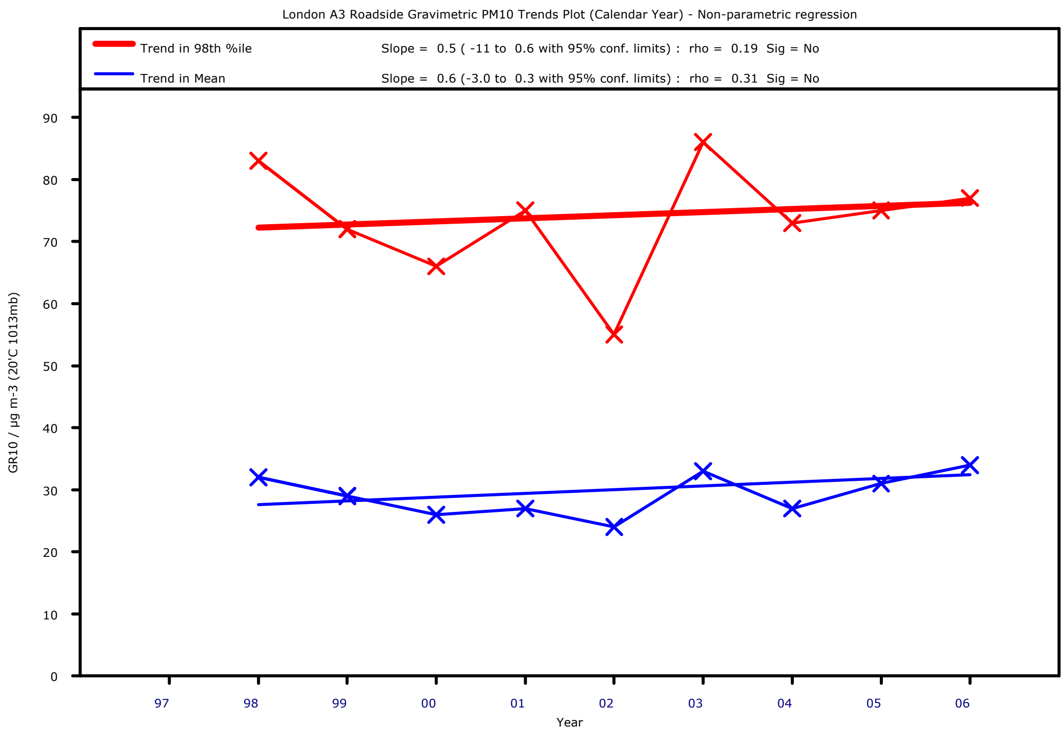
14.7 Trends in annual concentrations

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

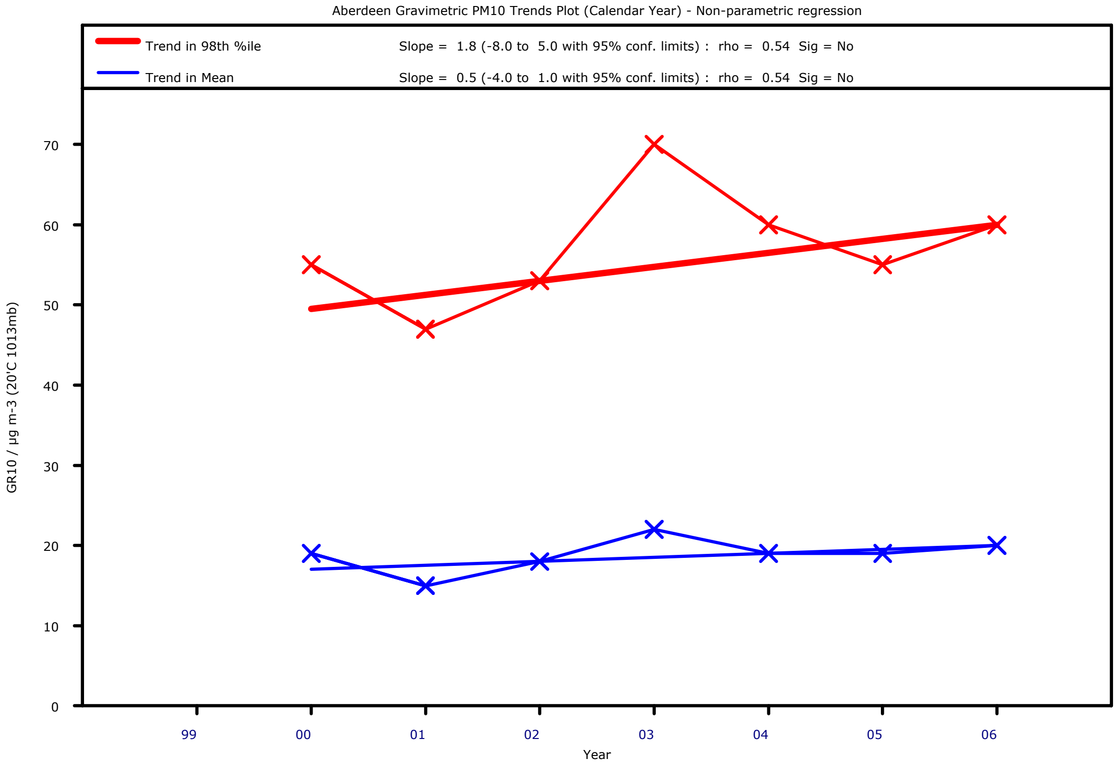
London Marylebone Road Gravimetric PM10 Trends Plot – Non-parametric regression



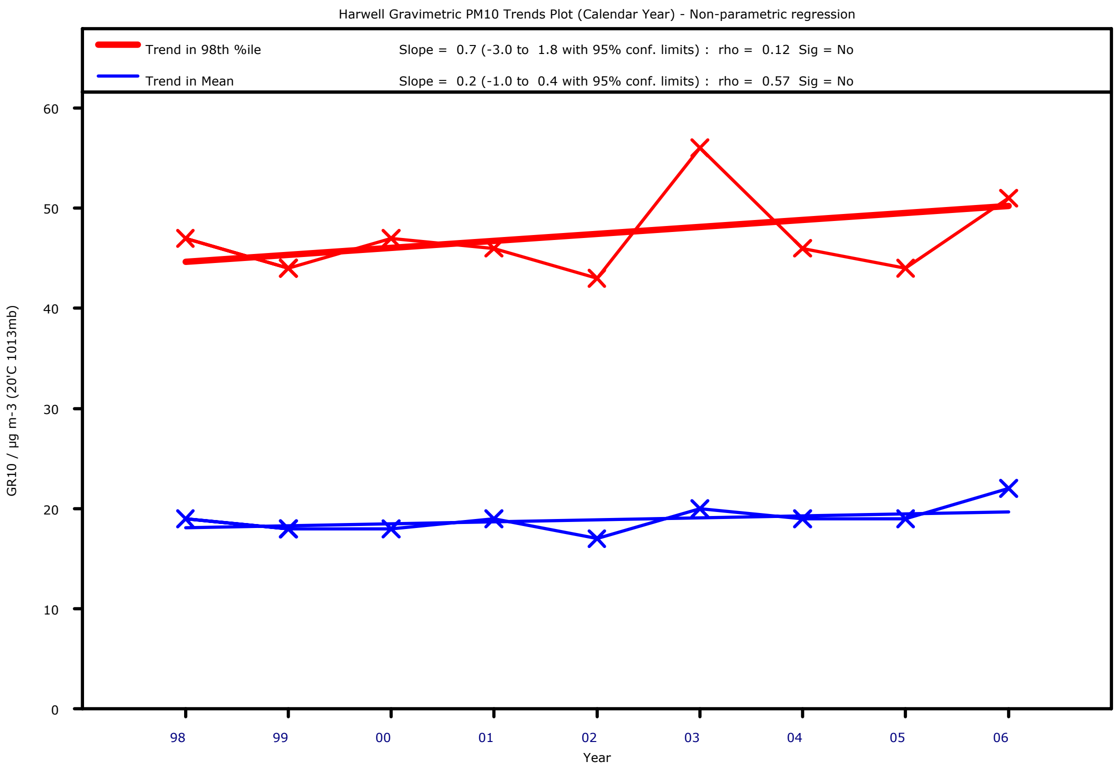
London A3 Roadside Gravimetric PM10 Trends Plot – Non-parametric regression



Aberdeen Gravimetric PM10 Trends Plot – Non-parametric regression



Harwell Gravimetric PM10 Trends Plot – Non-parametric regression



14.8 PM_{10} Statistical Summary 2006

i) PM_{10} annual statistics I

Site	Site Type	Annual average µg m^{-3}	Annual data capture of hourly means % (for Partisol, capture of daily means)	Maximum hourly mean µg m^{-3}	Maximum running 24-hour mean µg m^{-3}	Date of maximum running 24-hour mean	90%ile of daily means µg m^{-3}	98%ile of daily means µg m^{-3}
England								
Birmingham Centre	UC	27	97.4	537	86	03/02/2006	42	57
Birmingham Tyburn	UB	24	94.7	352	105	04/11/2006	38	53
Blackpool Marton	UB	27	95.5	109	66	01/02/2006	39	48
Bolton	UB	22	97.0	195	90	04/11/2006	34	49
Bournemouth	UB	29 *	98.9	---	---	---	44	65
Bradford Centre	UC	34	94.5	686	169	25/01/2006	59	94
Brighton Roadside PM_{10}	RD	38 *	97.0	---	---	---	53	70
Bristol St Paul's	UB	23	53.0	476	190	05/11/2006	35	53
Bury Roadside	RD	31	86.6	159	84	03/02/2006	49	65
Camden Kerbside	KB	37	86.0	298	109	05/11/2006	57	74
Canterbury	UB	24	99.0	165	63	16/09/2006	34	51
Coventry Memorial Park	UB	19	99.2	157	85	02/02/2006	30	44
Haringey Roadside	RD	28	86.5	714	84	04/11/2006	40	56
Harwell	RU	22	98.0	126	58	16/10/2006	32	44
Hull Freetown	UC	25	97.6	208	78	08/05/2006	37	50
Leamington Spa	UB	24	98.7	657	101	06/12/2006	36	54
Leeds Centre	UC	24	99.1	608	75	20/09/2006	40	52
Leicester Centre	UC	23	98.3	269	96	05/11/2006	34	50
Liverpool Speke	UB	22	96.0	164	83	09/05/2006	35	51
London A3 Roadside	RD	34	98.5	263	95	05/11/2006	48	64
London Bexley	SU	26	91.0	629	149	04/11/2006	39	51
London Bloomsbury	UC	30	98.0	225	81	05/11/2006	44	58
London Brent	UB	23	99.0	261	96	05/11/2006	36	50
London Eltham	SU	24	96.9	335	99	05/11/2006	36	52
London Harlington	A	27	98.8	152	68	05/11/2006	41	53
London Hillingdon	SU	29	96.9	888	163	05/11/2006	42	58
London Marylebone Road	KB	47	97.1	312	109	05/11/2006	66	83
London N. Kensington	UB	26	99.1	264	107	05/11/2006	40	56
London Westminster	UB	31 *	95.6	---	---	---	49	71
Manchester Piccadilly	UC	26	96.3	701	75	03/02/2006	41	55
Middlesbrough	I	23	98.1	276	102	08/05/2006	37	53
Newcastle Centre	UC	20	97.9	96	80	08/05/2006	31	43
Northampton	UB	20	95.8	105	66	02/02/2006	29	47
Northampton PM_{10}	UB	28 *	91.5	---	---	---	45	65
Norwich Centre	UC	24	65.5	113	57	08/05/2006	35	46
Nottingham Centre	UC	24	98.2	143	70	02/02/2006	36	51
Plymouth Centre	UC	---	44.9	74	54	11/05/2006	---	---
Portsmouth	UB	24	98.5	281	88	05/11/2006	35	48
Preston	UB	22	98.0	140	61	09/05/2006	33	46
Reading New Town	UB	23	93.9	185	64	05/11/2006	33	45
Redcar	UB	24	86.9	386	86	08/05/2006	39	50
Rochester Stoke	SU	22	92.3	389	64	05/11/2006	34	47
Salford Eccles	RU	23	95.9	289	74	01/02/2006	38	55
Scunthorpe Town	I	30	96.1	276	136	10/06/2006	51	87
Sheffield Centre	UC	25	97.2	218	75	08/05/2006	42	58
Southampton Centre	UC	26	89.2	389	119	05/11/2006	39	51
Southend-on-Sea	UB	24	96.6	282	110	05/11/2006	36	50
Stockport Shaw Heath	UB	19	98.9	324	76	04/02/2006	30	43
Stockton-on-Tees Yarm	RD	28	98.0	205	88	08/05/2006	41	53
Stoke-on-Trent Centre	UC	27	96.4	250	90	22/12/2006	39	55
Thurrock	UB	23	98.2	329	101	05/11/2006	36	50
Wigan Centre	UB	24	94.9	143	76	04/11/2006	36	53
Wirral Tranmere	UB	21	94.3	96	59	02/02/2006	32	43

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

ii) PM_{10} exceedence statistics I

Site	Moderate band	Days	High band	Days	Very High band	Days	Daughter Directive Limit Value Daily Mean & Air Quality Standard	Days	Daughter Directive Limit Value Annual Mean and Air Quality Standard	Annual Mean Standard (Scotland)
England										
Birmingham Centre	55	7	0	0	0	0	**14**	**14**	0	**1**
Birmingham Tyburn	81	6	**4**	**1**	0	0	**8**	**8**	0	**1**
Blackpool Marton	16	2	0	0	0	0	**6**	**6**	0	**1**
Bolton	25	2	0	0	0	0	**7**	**7**	0	**1**
Bournemouth	-	-	-	-	-	-	**19**	**19**	0	**1**
Bradford Centre	518	46	**130**	**14**	**24**	**2**	**47**	**47**	0	**1**
Brighton Roadside	-	-	-	-	-	-	**51**	**51**	0	**1**
Bristol St Paul's	24	4	**17**	**3**	**29**	**2**	**6**	**6**	0	**1**
Bury Roadside	162	15	0	0	0	0	**31**	**31**	0	**1**
Camden Kerbside	350	31	**36**	**3**	0	0	**52**	**52**	0	**1**
Canterbury	0	0	0	0	0	0	**9**	**9**	0	**1**
Coventry Memorial Park	25	2	0	0	0	0	**3**	**3**	0	**1**
Haringey Roadside	64	6	0	0	0	0	**16**	**16**	0	**1**
Harwell	0	0	0	0	0	0	**3**	**3**	0	**1**
Hull Freetown	46	6	0	0	0	0	**6**	**6**	0	**1**
Leamington Spa	66	8	**18**	**2**	0	0	**10**	**10**	0	**1**
Leeds Centre	48	6	0	0	0	0	**10**	**10**	0	**1**
Leicester Centre	77	7	0	0	0	0	**7**	**7**	0	**1**
Liverpool Speke	21	2	0	0	0	0	**8**	**8**	0	**1**
London A3 Roadside	202	14	0	0	0	0	**29**	**29**	0	**1**
London Bexley	36	6	**20**	**2**	**22**	**2**	**8**	**8**	0	**1**
London Bloomsbury	95	9	0	0	0	0	**20**	**20**	0	**1**
London Brent	44	4	0	0	0	0	**7**	**7**	0	**1**
London Eltham	28	3	**5**	**2**	0	0	**11**	**11**	0	**1**
London Harlington	21	4	0	0	0	0	**10**	**10**	0	**1**
London Hillingdon	13	4	**2**	**2**	**23**	**2**	**21**	**21**	0	**1**
London Marylebone	933	83	**31**	**2**	0	0	**149**	**149**	**1**	**1**
London N. Kensington	62	7	**22**	**1**	0	0	**15**	**15**	0	**1**
London Westminster	-	-	-	-	-	-	**34**	**34**	0	**1**
Manchester Piccadilly	87	11	0	0	0	0	**15**	**15**	0	**1**
Middlesbrough	65	6	**15**	**2**	0	0	**9**	**9**	0	**1**
Newcastle Centre	28	2	0	0	0	0	**2**	**2**	0	**1**
Northampton	4	2	0	0	0	0	**3**	**3**	0	**1**
Northampton PM_{10}	-	-	-	-	-	-	**18**	**18**	0	**1**
Norwich Centre	0	0	0	0	0	0	**2**	**2**	0	**1**
Nottingham Centre	21	2	0	0	0	0	**8**	**8**	0	**1**
Plymouth Centre	0	0	0	0	0	0	0	0	---	---
Portsmouth	44	2	0	0	0	0	**7**	**7**	0	**1**
Preston	0	0	0	0	0	0	**3**	**3**	0	**1**
Reading New Town	0	0	0	0	0	0	**6**	**6**	0	**1**
Redcar	42	4	0	0	0	0	**6**	**6**	0	**1**
Rochester Stoke	0	0	0	0	0	0	**6**	**6**	0	**1**
Salford Eccles	59	8	0	0	0	0	**10**	**10**	0	**1**
Scunthorpe Town	316	29	**100**	**9**	**10**	**1**	**37**	**37**	0	**1**
Sheffield Centre	62	6	0	0	0	0	**17**	**17**	0	**1**
Southampton Centre	44	5	**21**	**1**	0	0	**7**	**7**	0	**1**
Southend-on-Sea	36	6	**21**	**1**	0	0	**7**	**7**	0	**1**
Stockport Shaw Heath	59	6	0	0	0	0	**3**	**3**	0	**1**
Stockton-on-Tees Yarm	80	5	0	0	0	0	**12**	**12**	0	**1**
Stoke-on-Trent Centre	77	7	0	0	0	0	**13**	**13**	0	**1**
Thurrock	33	3	**6**	**2**	0	0	**7**	**7**	0	**1**
Wigan Centre	50	6	0	0	0	0	**10**	**10**	0	**1**
Wirral Tranmere	0	0	0	0	0	0	**2**	**2**	0	**1**

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

iii) PM_{10} annual statistics II

Site	Site Type	Annual average µg m^{-3}	Annual data capture of hourly means % (for Partisol, capture of daily means)	Maximum hourly mean µg m^{-3}	Maximum running 24-hour mean µg m^{-3}	Date of maximum running 24-hour mean	90%ile of daily means µg m^{-3}	98%ile of daily means µg m^{-3}
England - *continued*								
Wolverhampton Centre	UC	22	97.9	490	85	03/02/2006	36	49
N Ireland								
Belfast Centre	UC	18	94.6	203	75	30/01/2006	33	49
Belfast Clara St	SU	22	99.2	144	61	30/01/2006	34	45
Derry	UB	23	96.8	213	78	29/01/2006	36	53
Lough Navar	RE	11	98.6	65	38	09/05/2006	18	27
Scotland								
Aberdeen	UB	20	94.9	150	94	07/05/2006	34	47
Auchencorth Moss	RU	12 *	88.8	---	---	---	23	33
Dumfries	RD	24 *	88.5	---	---	---	37	53
Edinburgh St Leonards	UC	20	98.2	131	81	08/05/2006	30	40
Glasgow Centre	UC	21	93.0	374	78	03/02/2006	32	43
Glasgow Kerbside	KB	38	84.9	326	120	25/02/2006	62	79
Grangemouth	I	18	96.9	133	88	08/05/2006	26	39
Inverness	RD	19 *	91.0	---	---	---	29	46
Wales								
Cardiff Centre	UC	27	94.9	293	92	06/11/2006	38	47
Cwmbran	UB	19	98.3	935	119	06/01/2006	29	40
Narberth	RU	18	90.3	181	56	10/06/2006	26	33
Port Talbot	UB	31	90.0	411	119	10/07/2006	52	70
Swansea	UC	28	56.0	173	83	10/06/2006	39	51
Swansea Roadside	RD	---	21.8	487 *	145 *	06/11/2006	---	---
Wrexham	UC	24 *	95.3	---	---	---	39	52

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

iv) PM_{10} exceedence statistics - II

Site	Moderate band	Days	High band	Days	Very High band	Days	Daughter Directive Limit Value Daily Mean & Air Quality Standard	Days	Daughter Directive Limit Value Annual Mean and Air Quality Standard	Annual Mean Standard (Scotland)
England - *continued*										
Wolverhampton Centre	50	4	0	0	0	0	**7**	**7**	0	**1**
N Ireland										
Belfast Centre	19	3	0	0	0	0	**7**	**7**	0	0
Belfast Clara St	0	0	0	0	0	0	**4**	**4**	0	**1**
Derry	62	6	0	0	0	0	**8**	**8**	0	**1**
Lough Navar	0	0	0	0	0	0	0	0	0	0
Scotland										
Aberdeen	44	3	0	0	0	0	**5**	**5**	0	**1**
Auchencorth Moss	-	-	-	-	-	-	**2**	**2**	0	0
Dumfries	-	-	-	-	-	-	**9**	**9**	0	**1**
Edinburgh St Leonards	32	2	0	0	0	0	**2**	**2**	0	**1**
Glasgow Centre	39	4	0	0	0	0	**2**	**2**	0	**1**
Glasgow Kerbside	594	55	**40**	**5**	0	0	**66**	**66**	0	**1**
Grangemouth	32	2	0	0	0	0	**2**	**2**	0	0
Inverness	-	-	-	-	-	-	**5**	**5**	0	**1**
Wales										
Cardiff Centre	42	4	0	0	0	0	**5**	**5**	0	**1**
Cwmbran	22	4	**23**	**2**	0	0	**5**	**5**	0	**1**
Narberth	0	0	0	0	0	0	**1**	**1**	0	0
Port Talbot	305	36	**34**	**4**	0	0	**35**	**35**	0	**1**
Swansea	37	3	0	0	0	0	**6**	**6**	0	**1**
Swansea Roadside	27	4	**5**	**2**	**24**	**2**	**3**	**3**	---	---
Wrexham	-	-	-	-	-	-	**10**	**10**	0	**1**

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

15. $PM_{2.5}$ - Measurement Sites, Instrumentation and Statistics

15.1 Measurement Method

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

15.2 Instrumentation

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

- R&P TEOM 1400

** 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.*

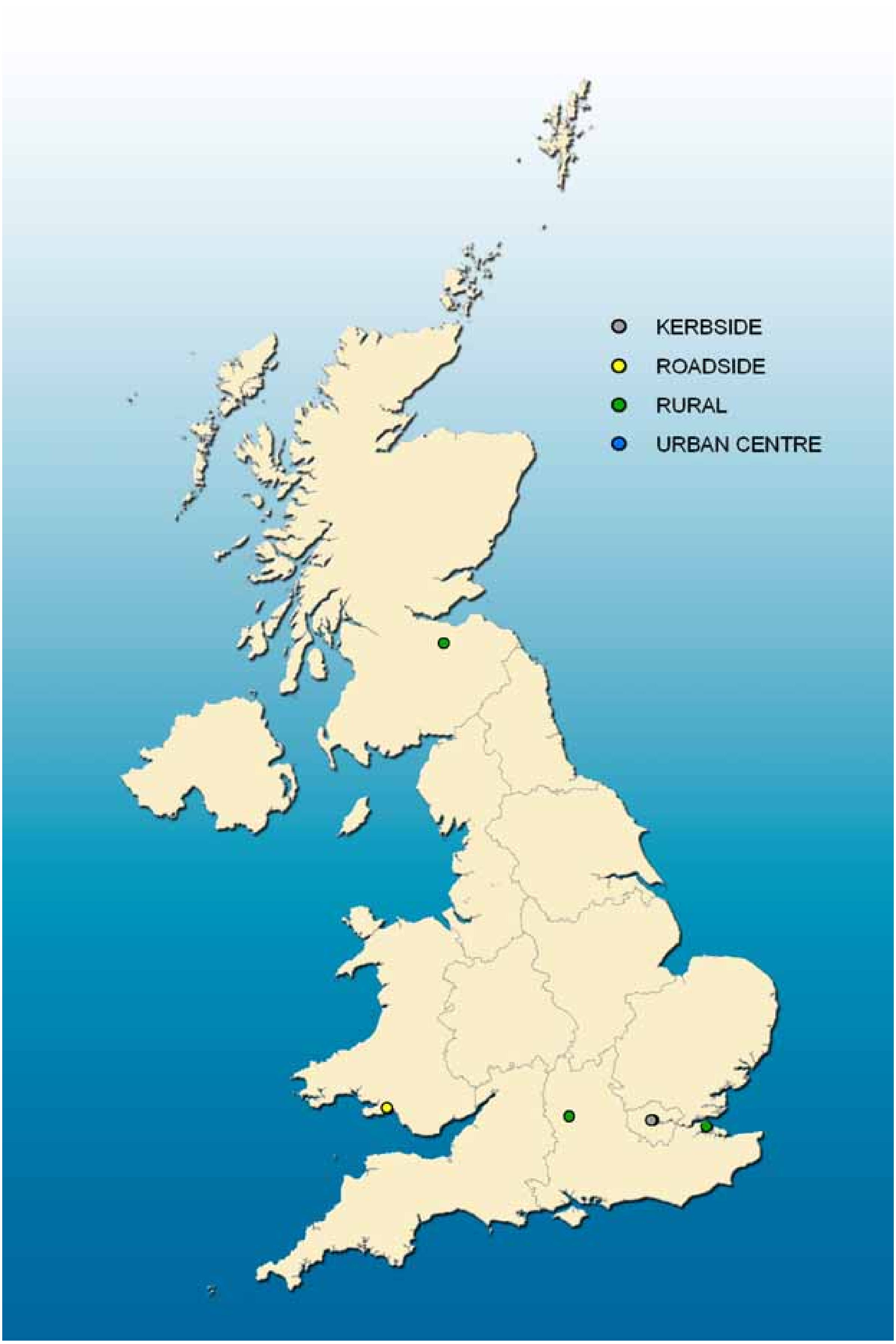
Please also see detailed information on particle measurements and conversion factors used in this report (Appendix 6).

15.3 Data Quality Requirements of EC Directive 1999/30/EC

Uncertainty 25%
Minimum data capture 90%

15.4 Objectives and Bandings

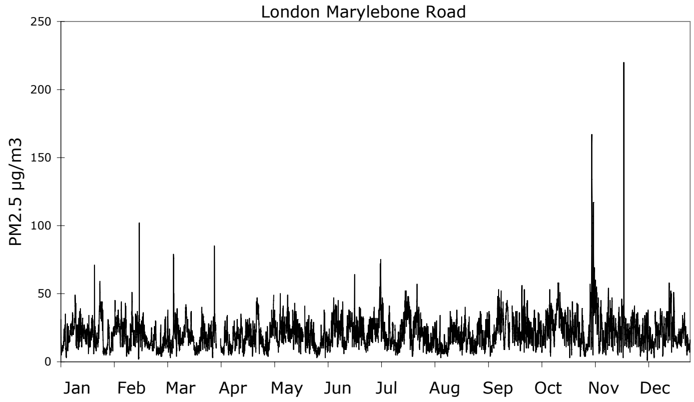
Summary of objectives of the Air Quality Strategy			
	Objective	**Measured as**	**To be achieved by**
Particles ($PM_{2.5}$) (gravimetric) All authorities	25 µg m^{-3}	Annual Mean	2020
	20% reduction in exposure reduction in urban background areas	Annual Mean	2010-2020
Particles ($PM_{2.5}$) Authorities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



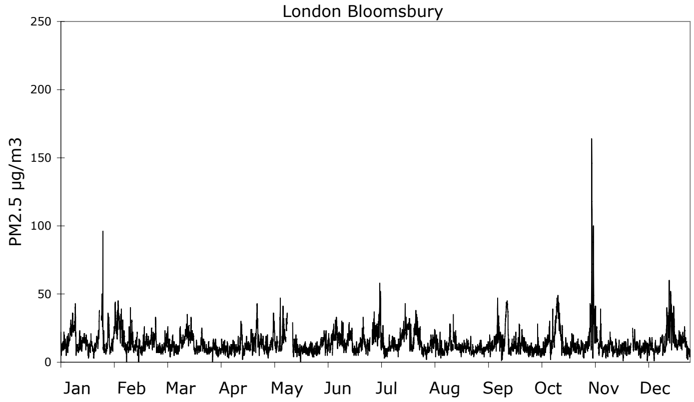
UK Automatic Gravimetric $PM_{2.5}$ particles Monitoring Sites 2006

15.5 Hourly Average Concentrations

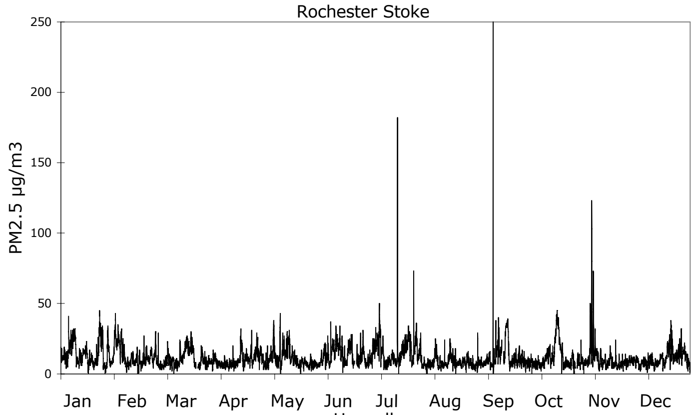
These figures show time series graphs of hourly average $PM_{2.5}$ concentrations at four *typical* site types for 2006.



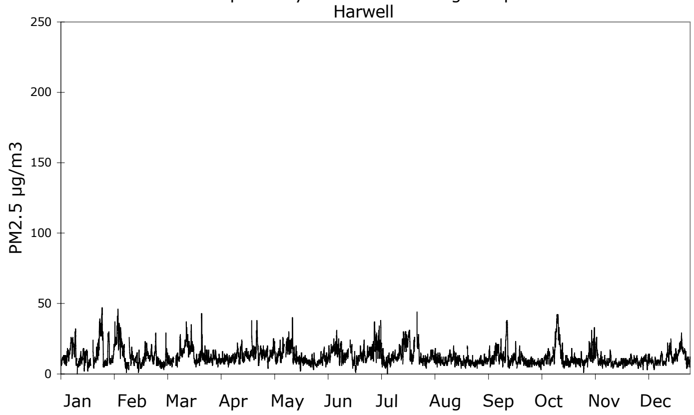
Kerbside Site
(*Marylebone Road)*



Urban Centre Site
(*Bloomsbury)*



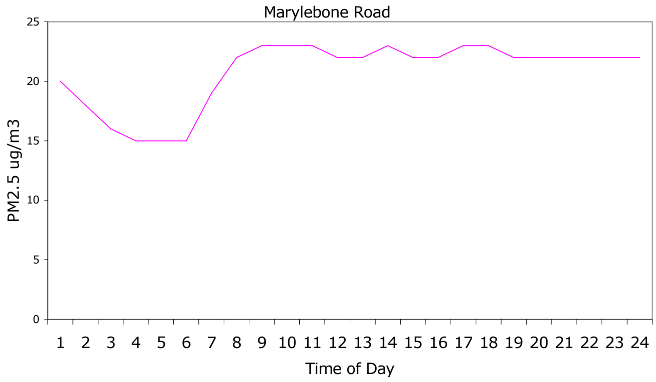
Rural Site
(*Rochester)*



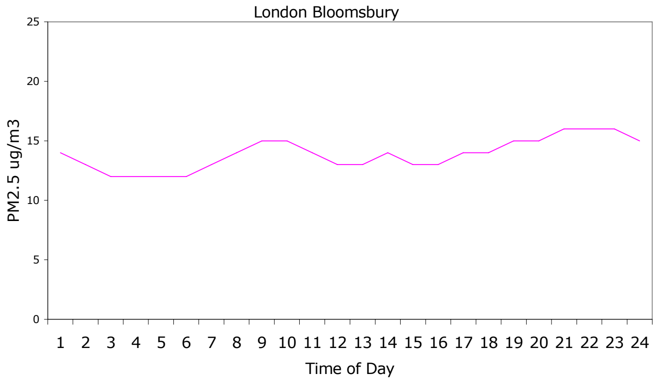
Rural Site
(Harwell)

15.6 Diurnal Variations

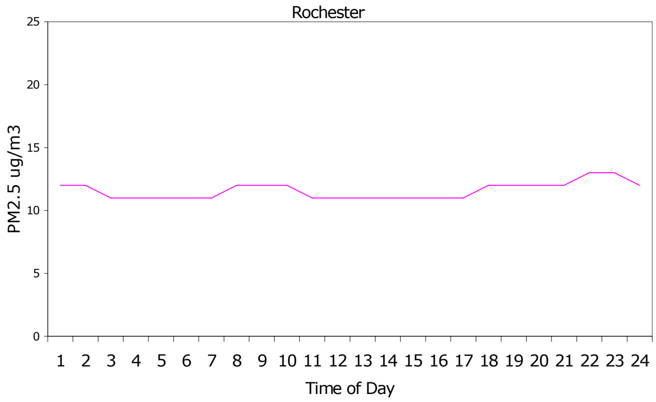
These figures show how $PM_{2.5}$ concentrations vary on average for each hour of day during 2006, at a number of selected *typical* monitoring site types. Local time is used, rather than GMT, since this will more closely reflect the daily cycle of man-made emissions.



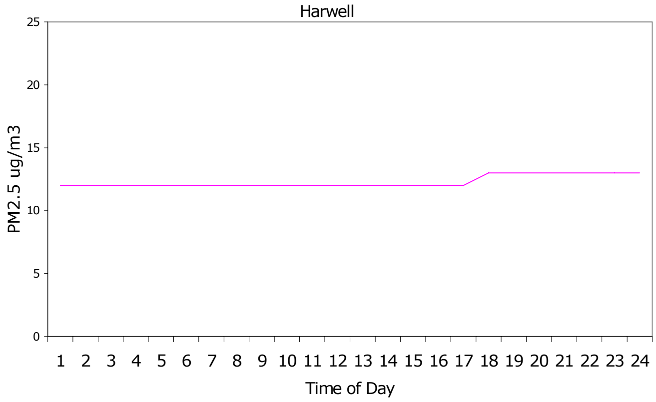
Kerbside Site
(*Marylebone Road)*



Urban Centre Site
(*Bloomsbury)*



Rural Site
(*Rochester)*

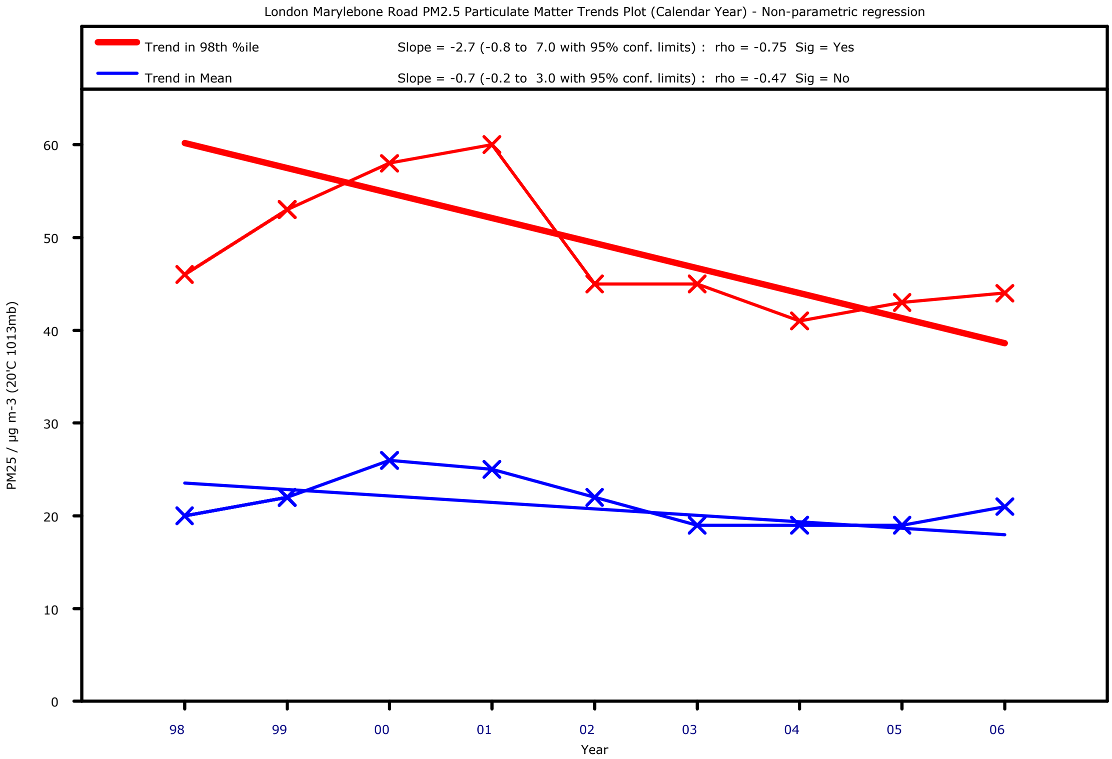


Rural Site
(Harwell)

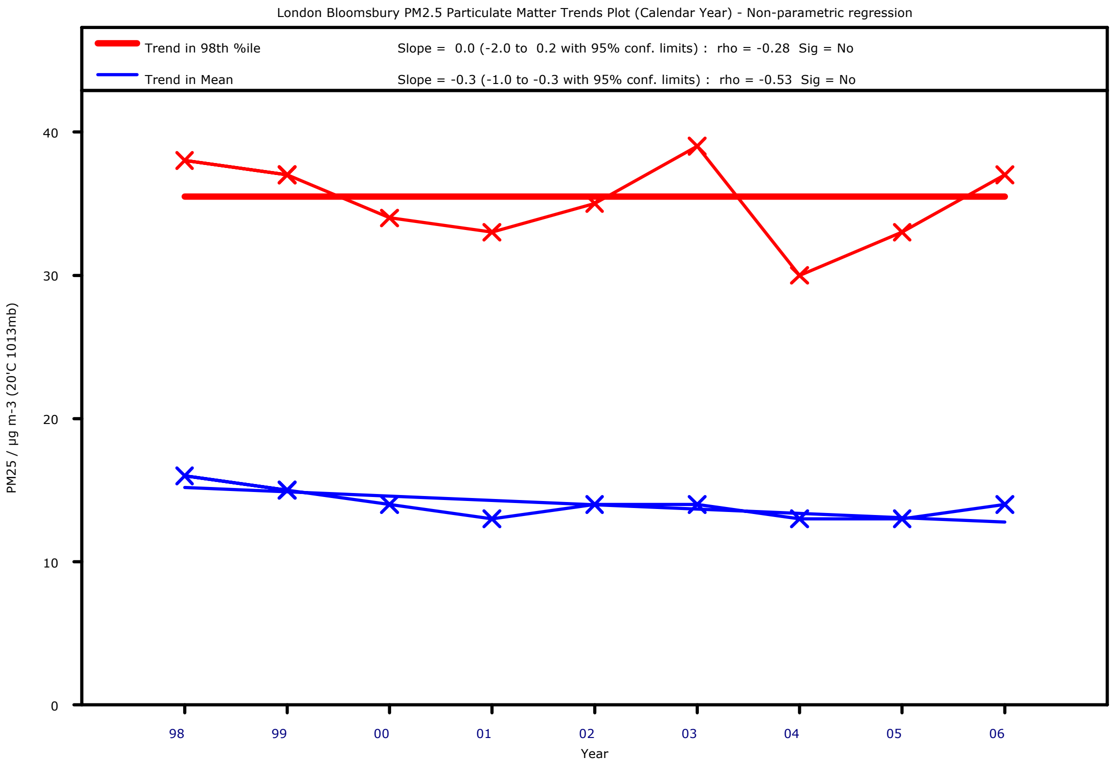
15.7 Trends in annual concentrations

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

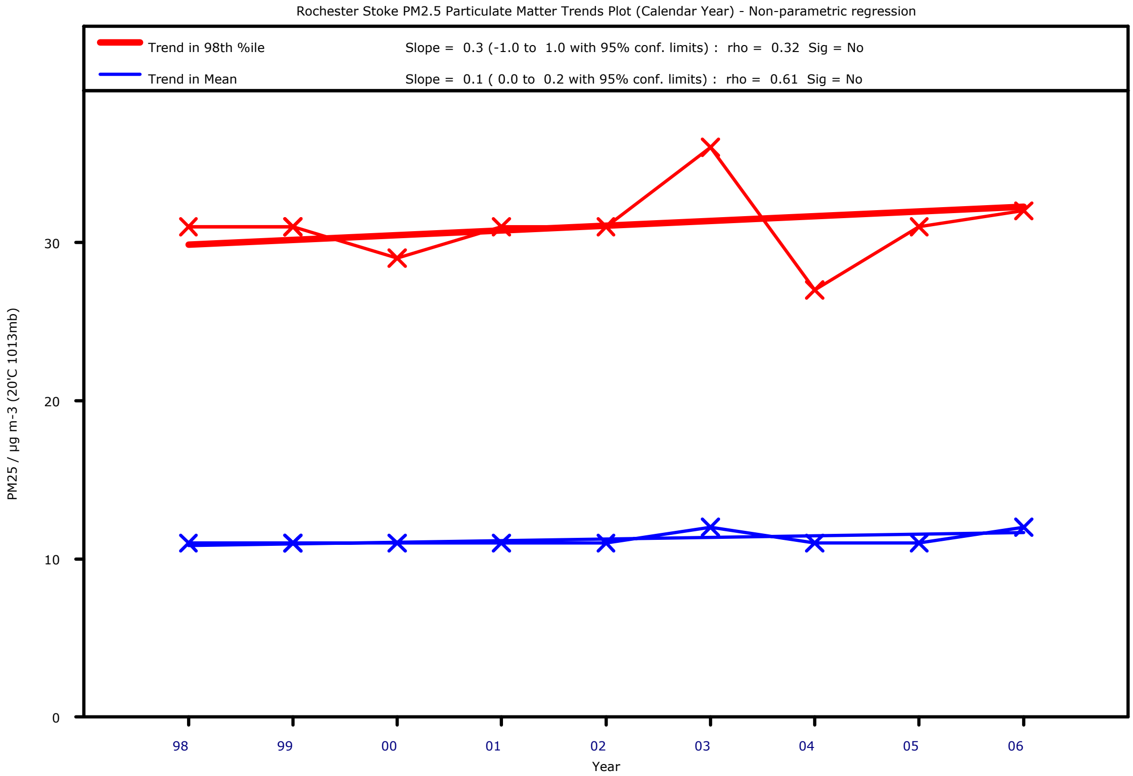
London Marylebone Road PM2.5 Particulate Matter Trends Plot –Non-parametric regression



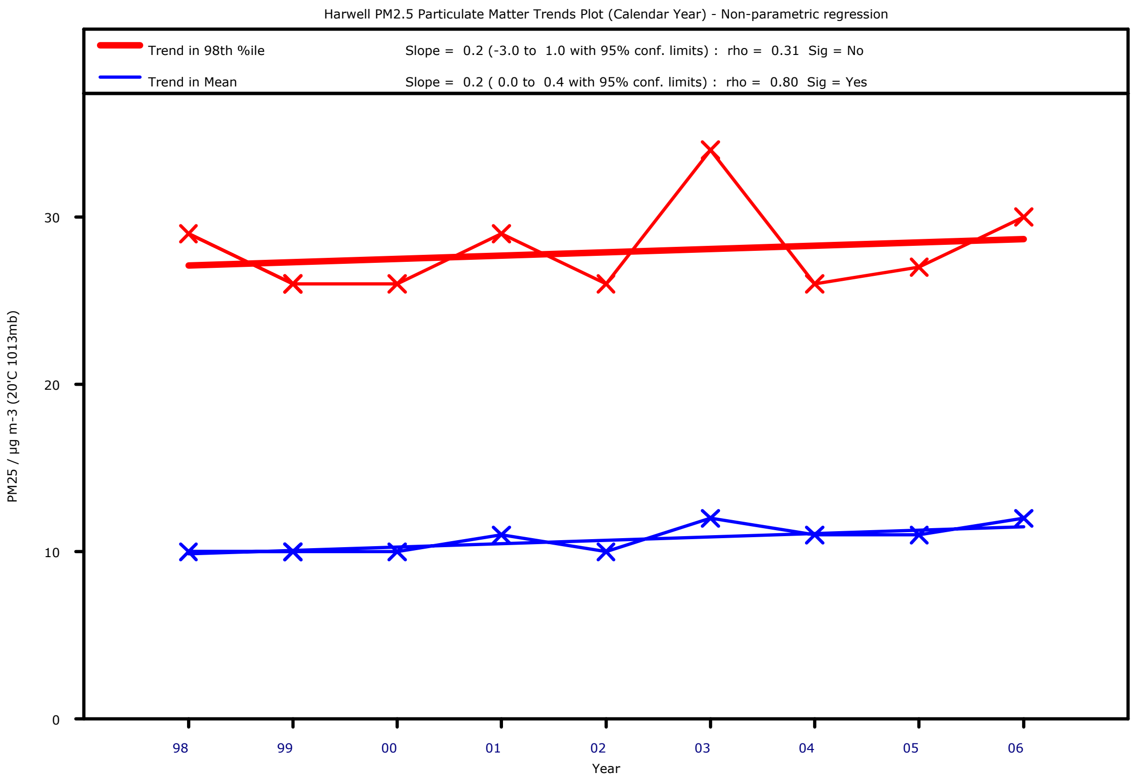
London Bloomsbury PM2.5 Particulate Matter Trends Plot – Non-parametric regression



Rochester PM2.5 particulate Matter Trends plot – Non-parametric regression



Harwell PM2.5 Particulate Matter Trends Plot – Non-parametric regression



15.8 $PM_{2.5}$ Statistical Summary 2006

i) $PM_{2.5}$ Annual statistics

Site	Annual average of hourly means µg m^{-3}	Annual data capture of hourly means %	Maximum hourly mean µg m^{-3}
England			
Harwell	12	97.9	47
London Bloomsbury	14	97.6	164
London Marylebone Road	21	97.8	220
Rochester Stoke	12	98.3	290
Scotland			
Auchencorth Moss	14	52.3	38
Wales			
Swansea Roadside	---	15.2	78

ii) Exceedence Statistics-

There are no exceedence statistics for $PM_{2.5}$ Particulate Matter

16. SO_2 - Measurement Sites, Instrumentation and Statistics

16.1 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.

16.2 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.*

16.3 Data Quality Requirements of EC Directive 1999/30/EC

Uncertainty 15%
Minimum data capture 90%

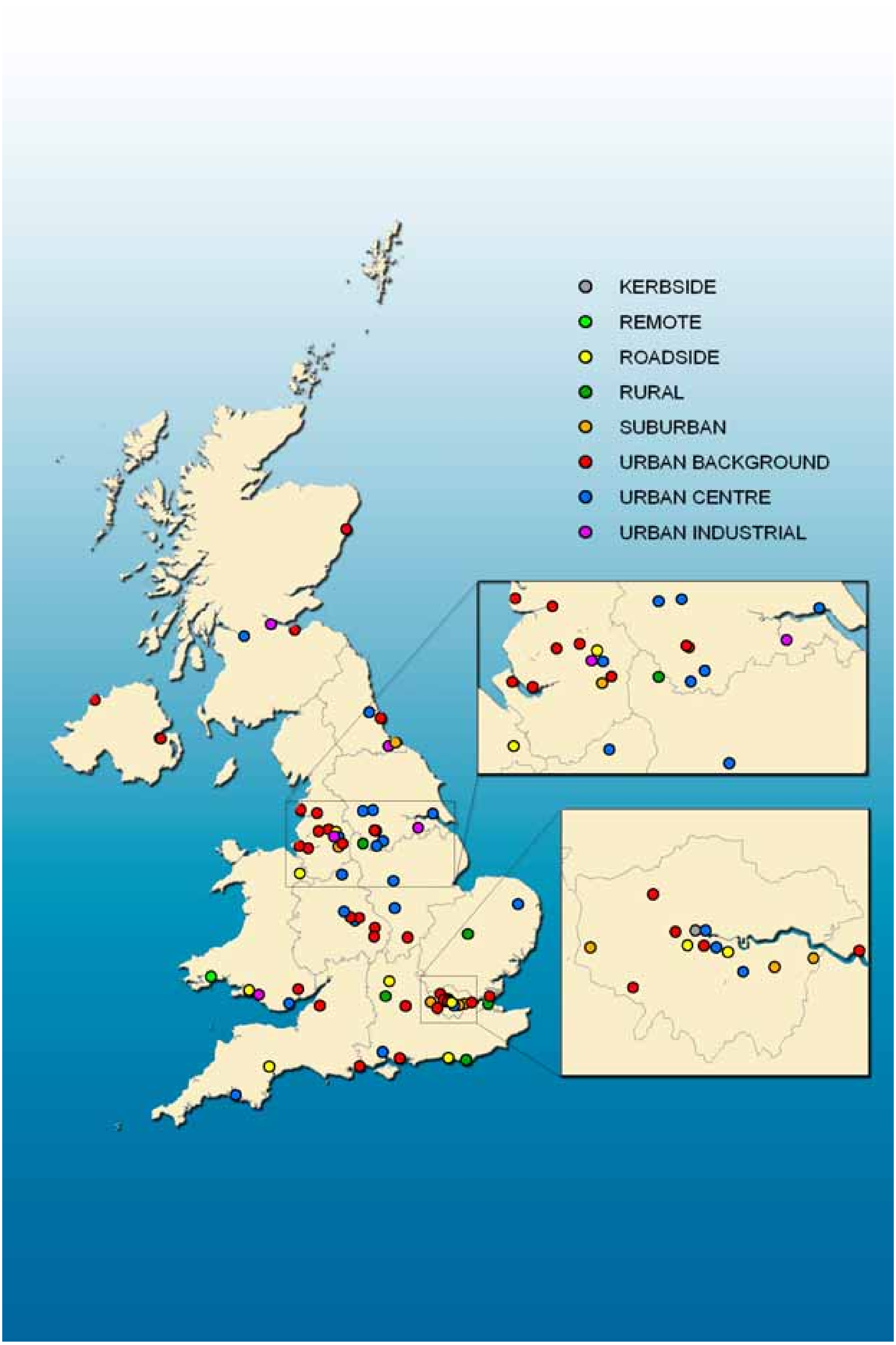
16.4 Objectives and Bandings

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

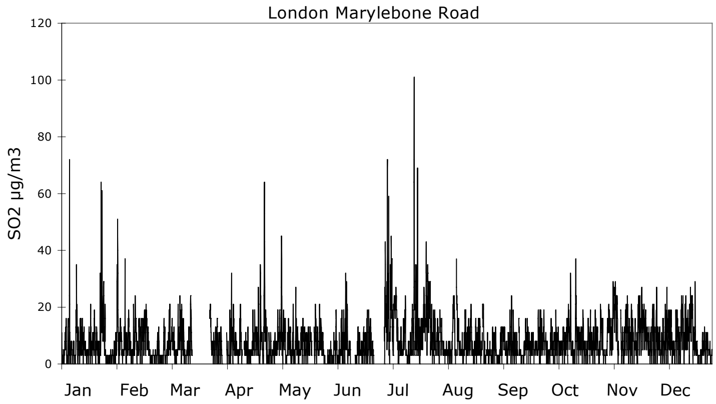
Band	Index	Sulphur Dioxide µg m^{-3}
Low	1	0-88
	2	89-176
	3	177-265
Moderate	4	266-354
	5	355-442
	6	443-531
High	7	532-708
	8	709-886
	9	887-1063
Very High	10	1064 or more



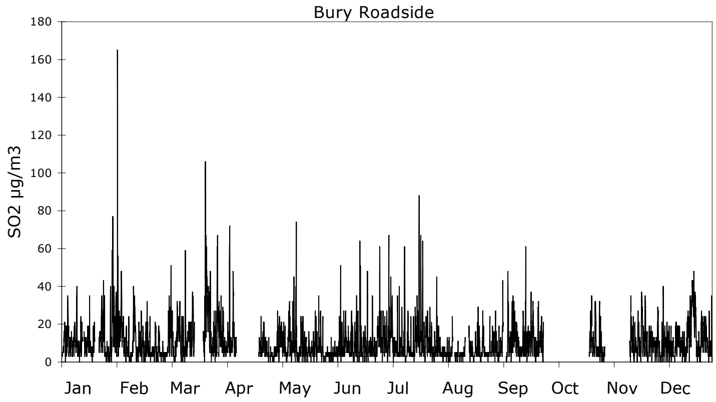
UK Automatic Sulphur Dioxide Monitoring Sites 2006

16.5 Hourly Average Concentrations

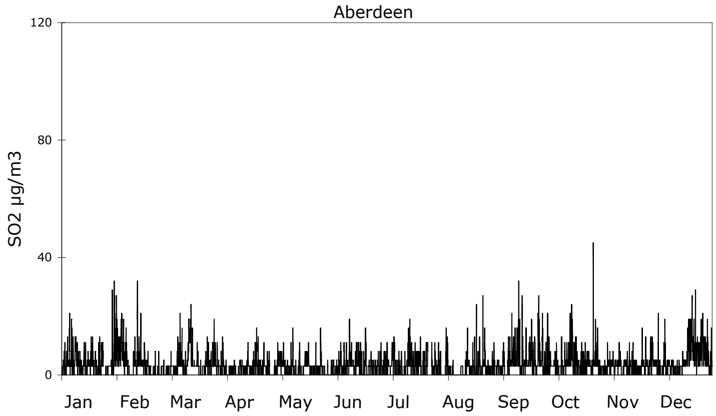
These figures show time series graphs of hourly average sulphur dioxide concentrations at four *typical* site types for 2006.



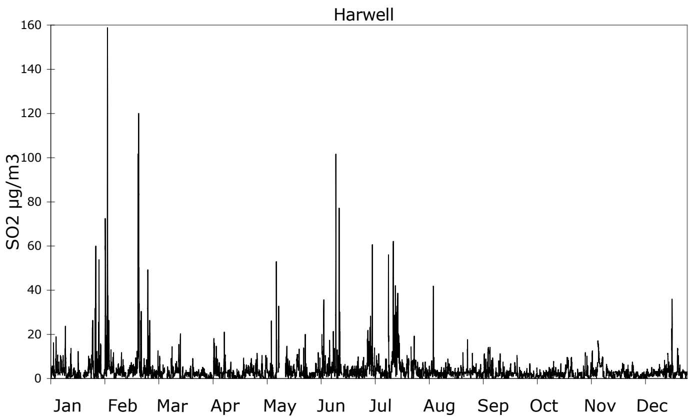
Kerbside Site
(London Marylebone Road)



Roadside Site
(*Bury*)



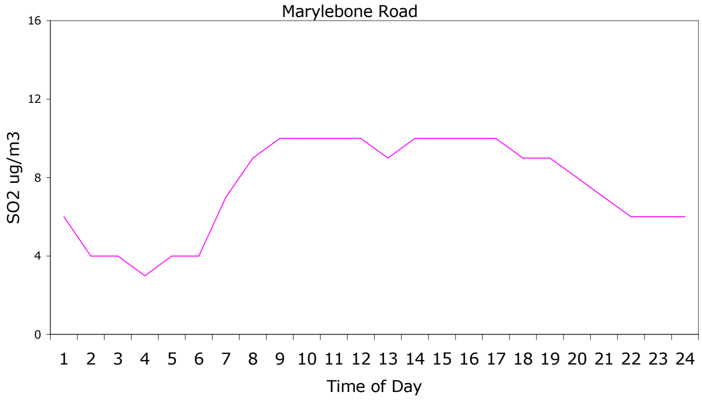
Urban Background Site
(*Aberdeen)*



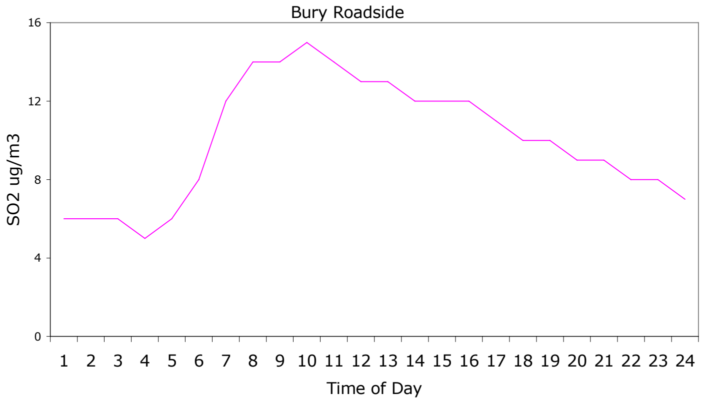
Rural Site
(*Harwell)*

16.6 Diurnal Variations

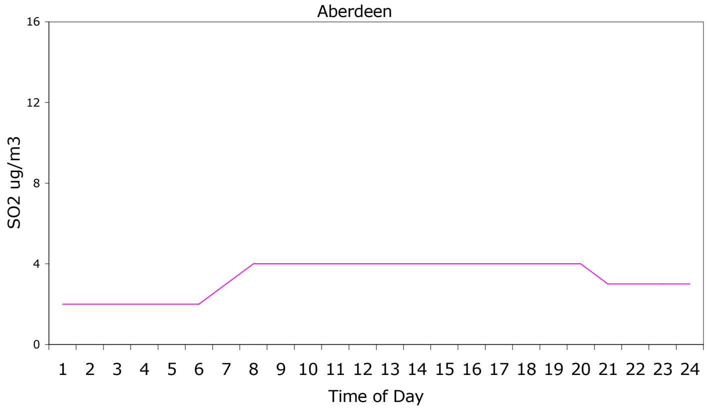
These figures show how sulphur dioxide concentrations vary on average for each hour of day during 2006, at a number of selected *typical* monitoring site types. Local time is used, rather than GMT, since this will more closely reflect the daily cycle of man-made emissions.



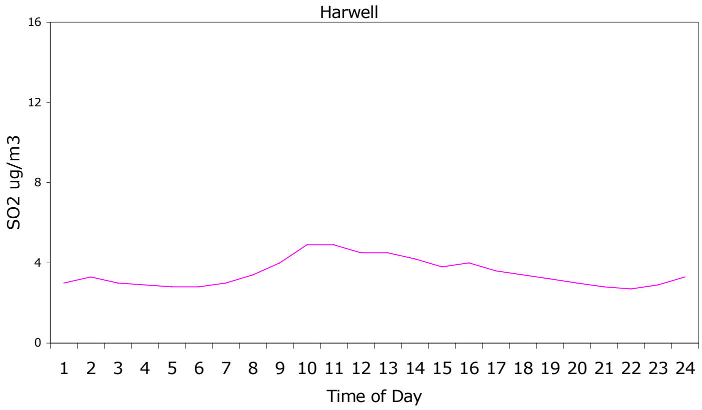
Kerbside Site
(Marylebone Road)



Roadside Site
(Bury)



Urban Background Site
(Aberdeen)

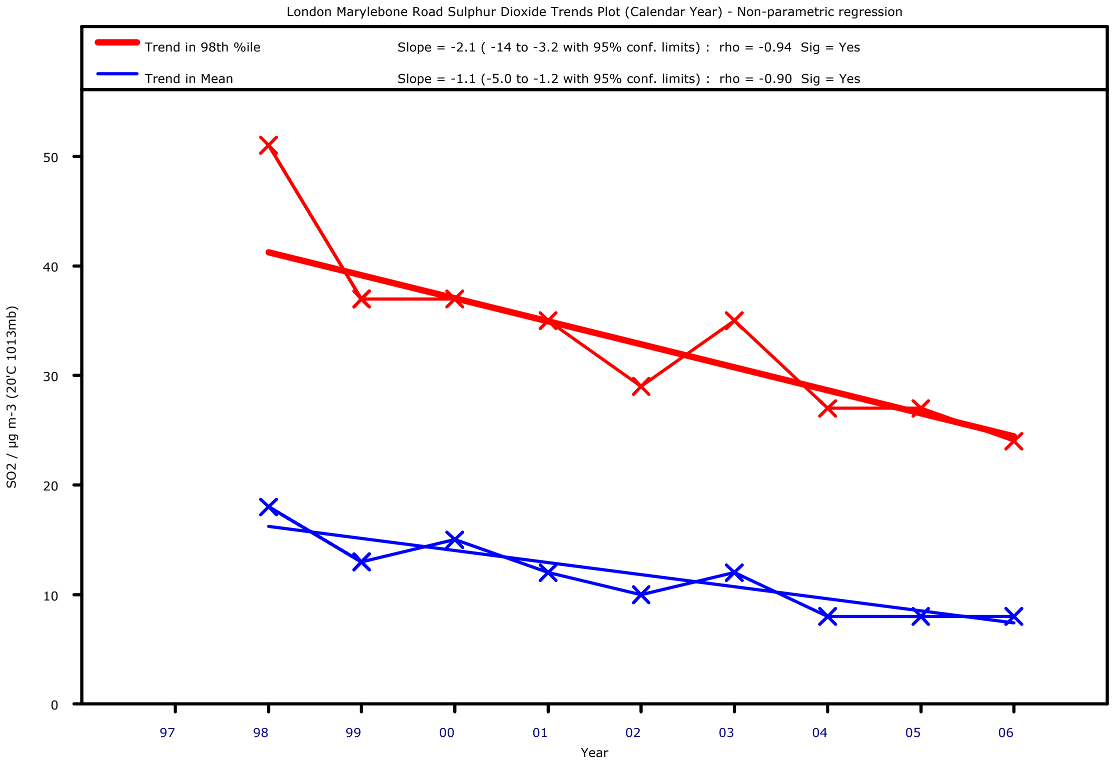


Rural Site
(Harwell)

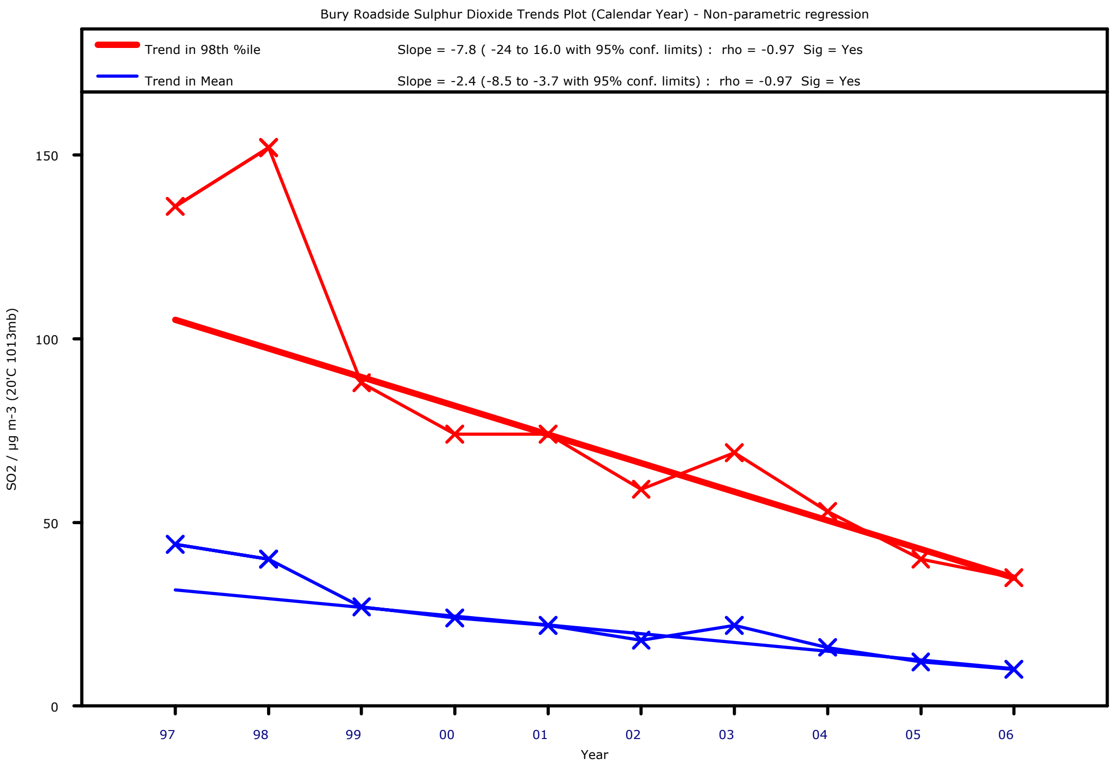
16.7 Trends in annual concentrations

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

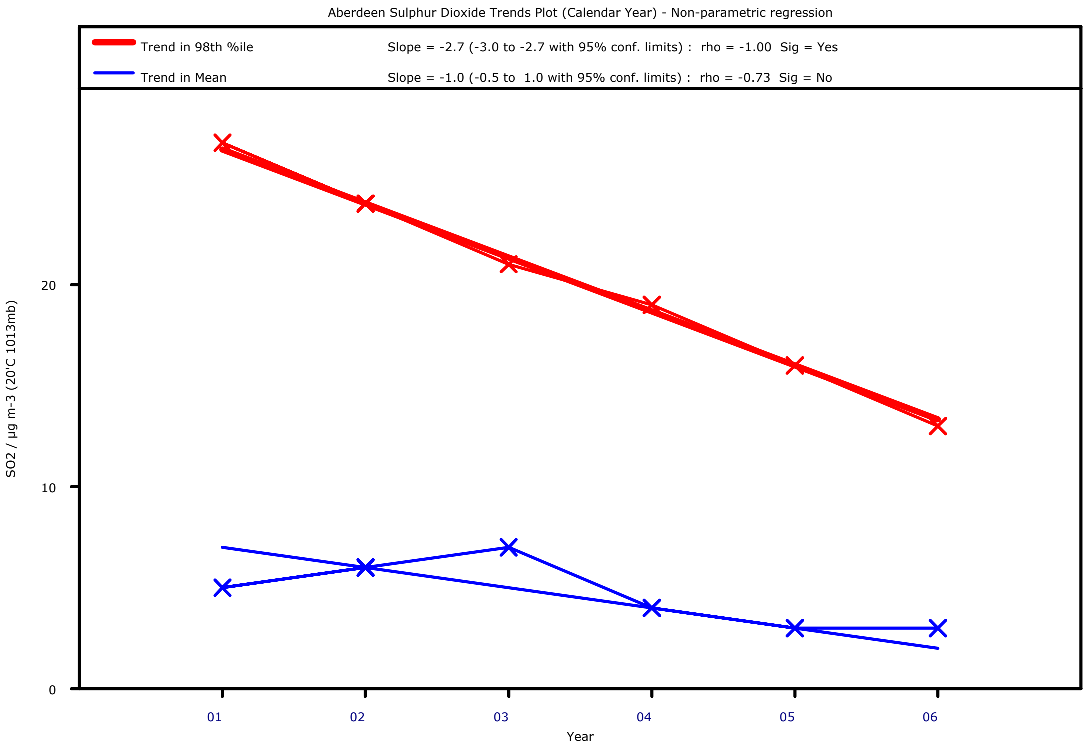
London Marylebone Road Sulphur Dioxide Trends plot – non-parametric regression



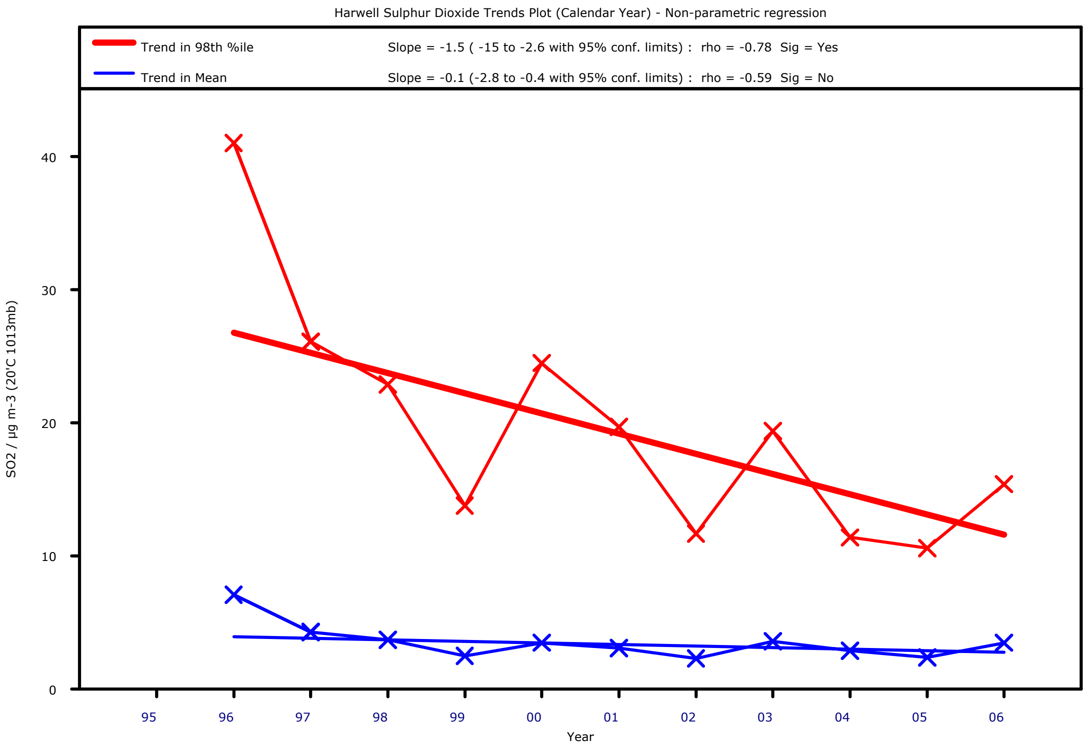
Bury Roadside Sulphur Dioxide Trends Plot – Non-parametric regression



Aberdeen sulphur dioxide Trends Plot – Non-parametric regression



Harwell Sulphur Dioxide Trends Plot – Non-parametric regression



16.8 Sulphur Dioxide Statistical Summary 2006

i) SO_2 annual statistics I

Site	Site Type	Annual average of hourly means µg m^{-3}	Annual data capture of hourly means %	Maximum hourly mean µg m^{-3}	Maximum 15-minute mean µg m^{-3}	Date of maximum 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	6	89.5	125	133	02/02/2006	77	45	23
Barnsley Gawber	UB	10	93.0	90	120	22/03/2006	72	59	35
Birmingham Centre	UC	4	96.8	61	67	03/02/2006	43	32	16
Birmingham Tyburn	UC	2	98.6	67	77	02/02/2006	35	21	12
Blackpool Marton	UB	4	87.1	56	80	13/10/2006	37	27	14
Bolton	UB	2	86.1	80	93	01/02/2006	40	29	8
Bournemouth	UB	3	98.6	37	45	06/06/2006	29	24	11
Bradford Centre	UC	12	90.7	64	101	24/12/2006	48	32	21
Bristol Centre	UB	3	53.8	40	64	22/08/2006	40	27	11
Bury Roadside	RD	10	81.6	165	178	01/02/2006	82	61	35
Coventry Memorial Park	UB	2	95.3	88	114	05/02/2006	40	24	10
Exeter Roadside	RD	2	91.0	19	21	25/07/2006	16	11	7
Harwell	RU	3.5	96.3	158.8	198.4	02/02/2006	100.0	53.7	16.5
Hove Roadside	RD	3	99.3	77	122	12/05/2006	27	19	9
Hull Freetown	UC	5	97.6	85	136	20/02/2006	59	37	12
Ladybower	RU	4.0	93.4	64.6	128.2	03/11/2006	49.5	29.8	12.9
Leamington Spa	UB	4	87.0	74	88	03/02/2006	27	21	10
Leeds Centre	UC	3	99.2	106	152	30/01/2006	64	43	17
Leicester Centre	UC	2	98.6	114	141	02/02/2006	40	24	11
Liverpool Speke	UB	6	92.6	178	221	18/02/2006	88	56	18
London Bexley	SU	5	96.9	162	410	17/07/2006	130	90	30
London Bloomsbury	UC	5	94.6	96	130	05/01/2006	77	51	23
London Brent	UB	3	94.6	122	200	28/06/2006	61	40	16
London Cromwell Road 2	RD	6	88.7	85	136	17/07/2006	48	29	20
London Eltham	SU	4	97.4	146	186	17/07/2006	98	64	26
London Hillingdon	SU	2	98.0	77	154	01/07/2006	35	24	11
London Lewisham	UC	4	97.8	120	149	17/07/2006	82	59	22
London Marylebone Road	KB	8	91.3	101	170	17/07/2006	67	43	22
London N. Kensington	UB	4	98.8	144	261	17/07/2006	67	45	18
London Southwark	UC	4	75.6	104	125	17/07/2006	72	48	19
London Teddington	UB	3.5	98.5	180.9	330.1	01/07/2006	60.9	42.8	19.7
London Westminster	UB	5	88.6	93	136	01/07/2006	61	43	22
Lullington Heath	RU	2.8	82.1	35.1	63.6	03/11/2006	29.0	21.8	9.3
Manchester Piccadilly	UC	5	95.8	56	80	09/12/2006	43	29	10
Manchester South	SU	3	96.9	56	67	01/02/2006	29	21	8
Middlesbrough	I	5	98.2	152	200	05/07/2006	98	72	23
Newcastle Centre	UC	4	98.2	77	144	04/06/2006	45	24	11
Northampton	UB	3	98.7	53	72	18/07/2006	32	24	11
Norwich Centre	UC	2	99.3	21	29	06/03/2006	16	13	7

ii) SO_2 exceedence statistics I

Site	Mod. band	Days	High band	Days	Very High band	Days	Air Quality Standard (15-Minute Mean)	Days	Daughter Directive Hourly Mean and Air Quality Standard (Hourly Mean)	Days	Daughter Directive Daily Mean and Air Quality Standard (Daily Mean)	Days
England												
Barnsley 12	0	0	0	0	0	0	0	0	0	0	0	0
Barnsley Gawber	0	0	0	0	0	0	0	0	0	0	0	0
Birmingham Centre	0	0	0	0	0	0	0	0	0	0	0	0
Birmingham Tyburn	0	0	0	0	0	0	0	0	0	0	0	0
Blackpool Marton	0	0	0	0	0	0	0	0	0	0	0	0
Bolton	0	0	0	0	0	0	0	0	0	0	0	0
Bournemouth	0	0	0	0	0	0	0	0	0	0	0	0
Bradford Centre	0	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	0
Bury Roadside	0	0	0	0	0	0	0	0	0	0	0	0
Coventry Memorial Park	0	0	0	0	0	0	0	0	0	0	0	0
Exeter Roadside	0	0	0	0	0	0	0	0	0	0	0	0
Harwell	0	0	0	0	0	0	0	0	0	0	0	0
Hove Roadside	0	0	0	0	0	0	0	0	0	0	0	0
Hull Freetown	0	0	0	0	0	0	0	0	0	0	0	0
Ladybower	0	0	0	0	0	0	0	0	0	0	0	0
Leamington Spa	0	0	0	0	0	0	0	0	0	0	0	0
Leeds Centre	0	0	0	0	0	0	0	0	0	0	0	0
Leicester Centre	0	0	0	0	0	0	0	0	0	0	0	0
Liverpool Speke	0	0	0	0	0	0	0	0	0	0	0	0
London Bexley	1	1	0	0	0	0	**1**	**1**	0	0	0	0
London Bloomsbury	0	0	0	0	0	0	0	0	0	0	0	0
London Brent	0	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	0
London Eltham	0	0	0	0	0	0	0	0	0	0	0	0
London Hillingdon	0	0	0	0	0	0	0	0	0	0	0	0
London Lewisham	0	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	0
London N. Kensington	0	0	0	0	0	0	0	0	0	0	0	0
London Southwark	0	0	0	0	0	0	0	0	0	0	0	0
London Teddington	1	1	0	0	0	0	**1**	**1**	0	0	0	0
London Westminster	0	0	0	0	0	0	0	0	0	0	0	0
Lullington Heath	0	0	0	0	0	0	0	0	0	0	0	0
Manchester Piccadilly	0	0	0	0	0	0	0	0	0	0	0	0
Manchester South	0	0	0	0	0	0	0	0	0	0	0	0
Middlesbrough	0	0	0	0	0	0	0	0	0	0	0	0
Newcastle Centre	0	0	0	0	0	0	0	0	0	0	0	0
Northampton	0	0	0	0	0	0	0	0	0	0	0	0
Norwich Centre	0	0	0	0	0	0	0	0	0	0	0	0

iii) SO_2 annual statistics II

Site	Site Type	Annual average of hourly means µg m^{-3}	Annual data capture of hourly means %	Maximum hourly mean µg m^{-3}	Maximum 15-minute mean µg m^{-3}	Date of maximum 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 - *continued*									
Nottingham Centre	UC	3	95.2	146	154	02/02/2006	48	24	12
Oxford Centre Roadside	RD	3	96.5	53	64	10/08/2006	21	16	9
Plymouth Centre	UC	2	52.9	19	29	12/05/2006	13	11	6
Portsmouth	UB	4	98.2	51	82	07/05/2006	37	27	11
Preston	UB	3	97.1	45	61	09/05/2006	35	24	10
Reading New Town	UB	5	94.3	128	133	01/02/2006	82	24	12
Redcar	SU	8	83.8	152	239	05/09/2006	106	72	23
Rochester	RU	6.6	96.6	160.9	184.6	30/12/2006	110.7	74.7	17.7
Rotherham Centre	UC	---	40.6	35	37	20/12/2006	---	---	---
Salford Eccles	I	9	88.0	250	391	12/06/2006	133	85	29
Sandwell West Bromwich	UB	4	96.5	45	69	22/08/2006	35	29	15
Scunthorpe Town	I	7	94.1	226	263	24/03/2006	138	101	45
Sheffield	UC	7	92.9	61	67	02/02/2006	35	21	14
Southampton Centre	UC	3	74.0	45	51	30/09/2006	37	24	9
Southend-on-Sea	UB	4	98.9	109	274	17/05/2006	61	40	14
Southwark Roadside	RD	---	10.4	40	43	01/02/2006	---	---	---
Stockport Shaw Heath	UB	3	99.0	74	77	01/02/2006	35	24	9
Stoke-on-Trent Centre	UC	5	94.7	64	88	11/09/2006	48	29	14
Sunderland	UB	2	97.2	29	29	10/04/2006	24	13	7
Thurrock	UB	5	98.2	207	237	23/01/2006	96	59	16
Wicken Fen	RU	3.5	92.1	28.2	45.5	27/02/2006	23.4	18.9	10.3
Wigan Centre	UB	4	94.0	136	162	17/06/2006	64	37	18
Wirral	UB	6	76.5	56	72	25/02/2006	51	37	16
Wolverhampton Centre	UC	2	97.8	112	130	03/02/2006	48	21	8
N Ireland									
Belfast Centre	UB	7	94.1	98	112	08/01/2006	74	59	28
Belfast East	UC	4	96.3	114	130	20/12/2006	90	67	33
Derry	UB	3	92.7	45	56	29/01/2006	35	24	10
Scotland									
Aberdeen	UB	3	98.8	45	80	21/08/2006	35	21	12
Edinburgh St Leonards	UB	3	98.7	144	181	04/07/2006	109	59	16
Glasgow	UC	2	90.1	27	35	25/01/2006	16	13	6
Grangemouth	I	7	98.1	346	790	14/03/2006	184	114	55
Wales									
Cardiff Centre	UC	3	95.8	93	114	18/08/2006	56	35	10
Cwmbran	UB	3	71.3	45	59	16/05/2006	32	19	9
Narberth	RU	2.9	81.5	91.2	101.6	08/06/2006	60.1	24.5	10.8
Port Talbot	I	8	96.8	122	229	08/03/2006	138	88	28
Swansea	UC	5	51.7	117	218	07/01/2006	72	40	17
Swansea	RD	---	27.9	106	128	03/11/2006	---	---	---
Wrexham	UC	4	92.4	69	80	09/05/2006	45	35	14

iv) SO_2 exceedence statistics II

Site	Mod. band	Days	High band	Days	Very High band	Days	Air Quality Standard (15-Minute Mean)	Days	Daughter Directive Hourly Mean and Air Quality Standard (Hourly Mean)	Days	Daughter Directive Daily Mean and Air Quality Standard (Daily Mean)	Days
England - *continued*												
Nottingham Centre	0	0	0	0	0	0	0	0	0	0	0	0
Oxford Centre Roadside	0	0	0	0	0	0	0	0	0	0	0	0
Plymouth Centre	0	0	0	0	0	0	0	0	0	0	0	0
Portsmouth	0	0	0	0	0	0	0	0	0	0	0	0
Preston	0	0	0	0	0	0	0	0	0	0	0	0
Reading New Town	0	0	0	0	0	0	0	0	0	0	0	0
Redcar	0	0	0	0	0	0	0	0	0	0	0	0
Rochester	0	0	0	0	0	0	0	0	0	0	0	0
Rotherham Centre	0	0	0	0	0	0	0	0	0	0	0	0
Salford Eccles	5	3	0	0	0	0	**5**	**3**	0	0	0	0
Sandwell West Bromwich	0	0	0	0	0	0	0	0	0	0	0	0
Scunthorpe Town	0	0	0	0	0	0	0	0	0	0	0	0
Sheffield	0	0	0	0	0	0	0	0	0	0	0	0
Southampton Centre	0	0	0	0	0	0	0	0	0	0	0	0
Southend-on-Sea	1	1	0	0	0	0	**1**	**1**	0	0	0	0
Southwark Roadside	0	0	0	0	0	0	0	0	0	0	0	0
Stockport Shaw Heath	0	0	0	0	0	0	0	0	0	0	0	0
Stoke-on-Trent Centre	0	0	0	0	0	0	0	0	0	0	0	0
Sunderland	0	0	0	0	0	0	0	0	0	0	0	0
Thurrock	0	0	0	0	0	0	0	0	0	0	0	0
Wicken Fen	0	0	0	0	0	0	0	0	0	0	0	0
Wigan Centre	0	0	0	0	0	0	0	0	0	0	0	0
Wirral	0	0	0	0	0	0	0	0	0	0	0	0
Wolverhampton Centre	0	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	0
Belfast East	0	0	0	0	0	0	0	0	0	0	0	0
Derry	0	0	0	0	0	0	0	0	0	0	0	0
Scotland												
Aberdeen	0	0	0	0	0	0	0	0	0	0	0	0
Edinburgh St Leonards	0	0	0	0	0	0	0	0	0	0	0	0
Glasgow	0	0	0	0	0	0	0	0	0	0	0	0
Grangemouth	13	9	**1**	**1**	0	0	**13**	**8**	0	0	0	0
Wales												
Cardiff Centre	0	0	0	0	0	0	0	0	0	0	0	0
Cwmbran	0	0	0	0	0	0	0	0	0	0	0	0
Narberth	0	0	0	0	0	0	0	0	0	0	0	0
Port Talbot	0	0	0	0	0	0	0	0	0	0	0	0
Swansea	0	0	0	0	0	0	0	0	0	0	0	0
Swansea	0	0	0	0	0	0	0	0	0	0	0	0
Wrexham	0	0	0	0	0	0	0	0	0	0	0	0

17. Ozone - Measurement Sites, Instrumentation and Statistics

17.1 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.

17.2 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.*

17.3 Data Quality Requirements of EC Directive 2002/3/EC

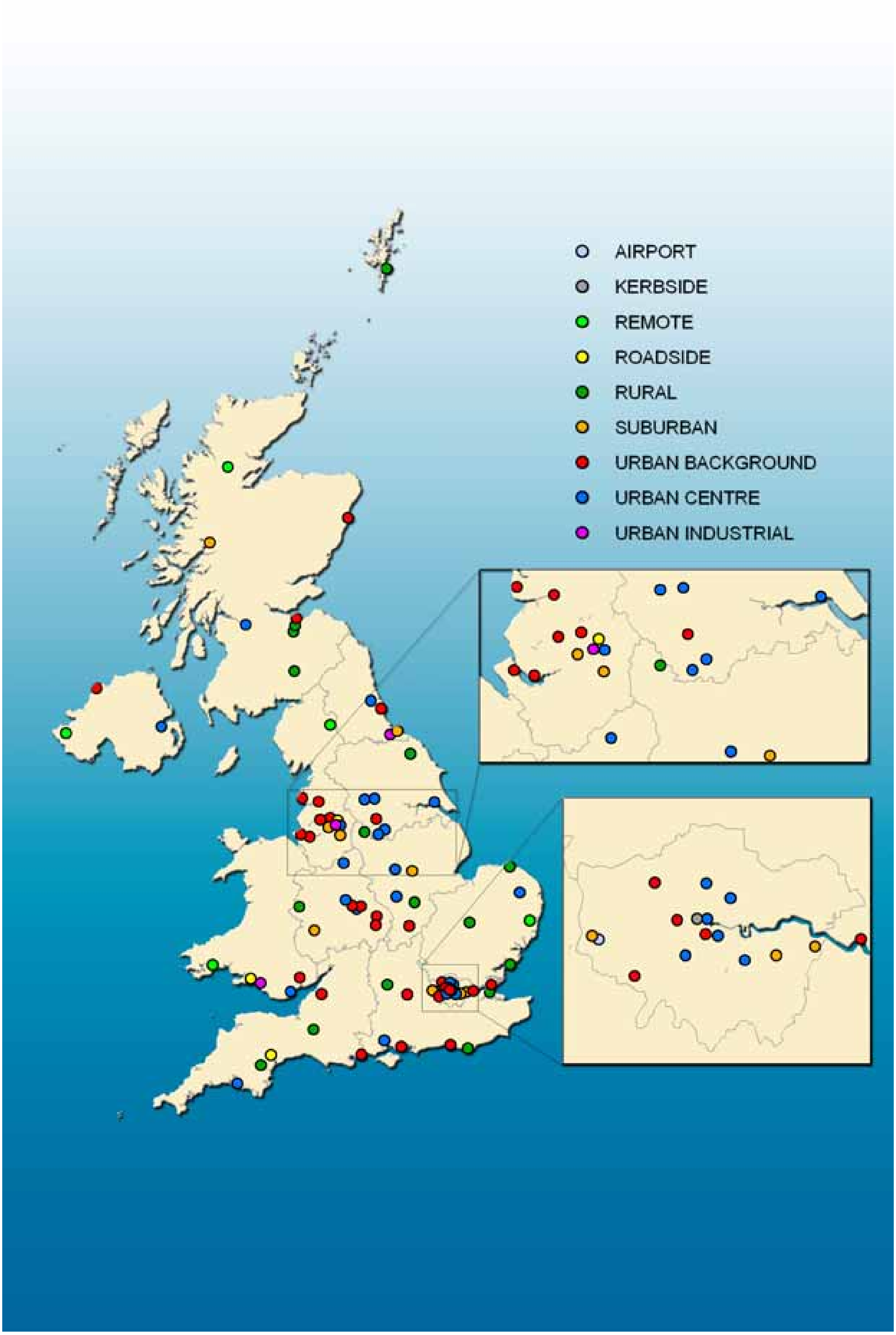
Uncertainty 15%
Minimum data capture 90%

17.4 Objectives and Bandings

Summary of objectives of the Air Quality Strategy			
	Objective*	**Measured as**	**To be achieved by**
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

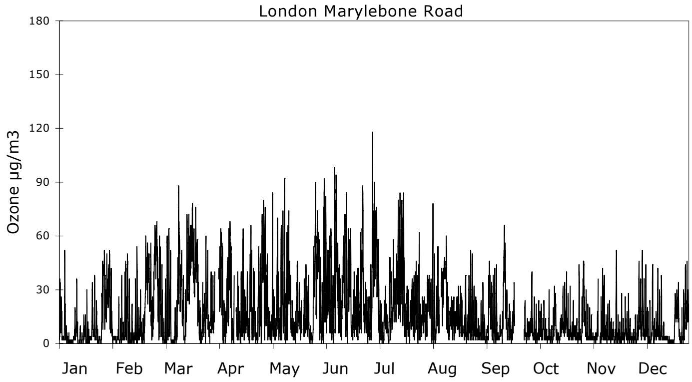
Air Quality Bands and Index Values		
Band	**Index**	**Ozone µgm^{-3}**
Low	1	0-33
	2	34-65
	3	66-99
Moderate	4	100-125
	5	126-153
	6	154-179
High	7	180-239
	8	240-299
	9	300-359
Very High	10	360 or more



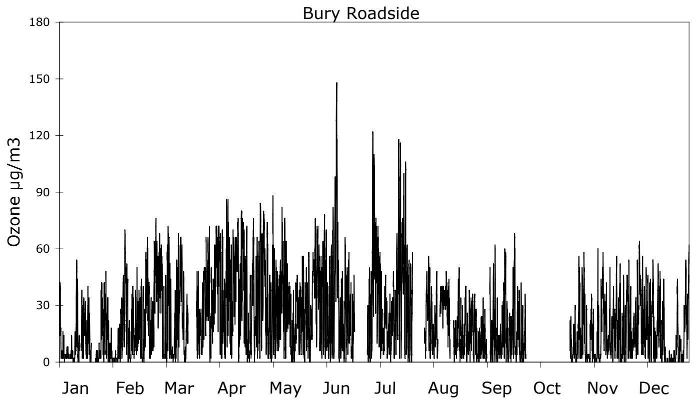
UK Automatic Ozone Monitoring Sites 2006

17.5 Hourly Average Concentrations

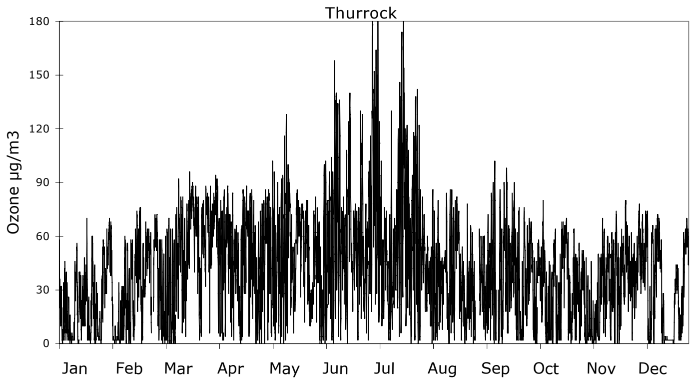
These figures show time series graphs of hourly average ozone concentrations at four *typical* site types for 2006.



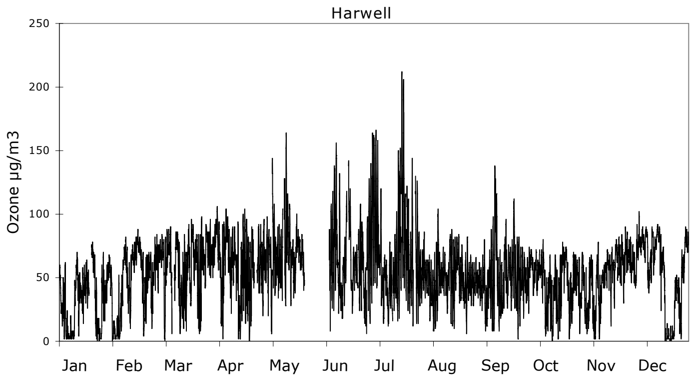
Kerbside Site
(*Marylebone Road)*



Roadside Site
(*Bury)*



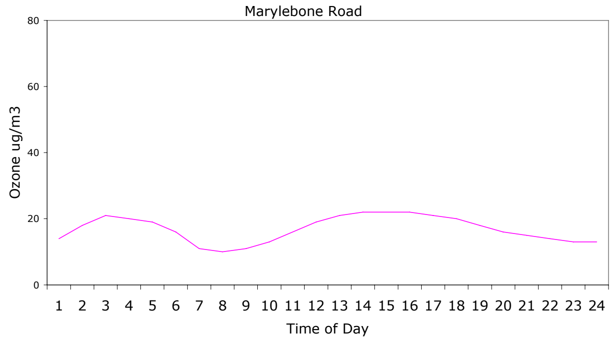
Urban Background Site
(*Thurrock)*



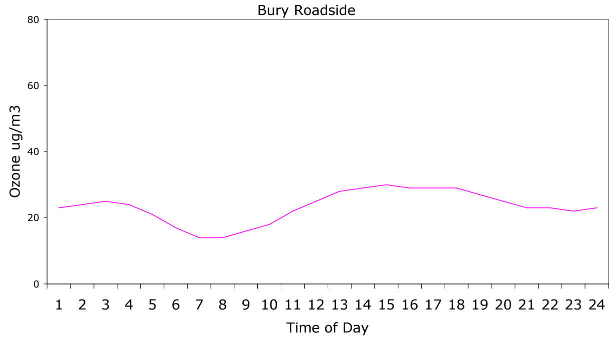
Rural Site
(Harwell)

17.6 Diurnal Variations

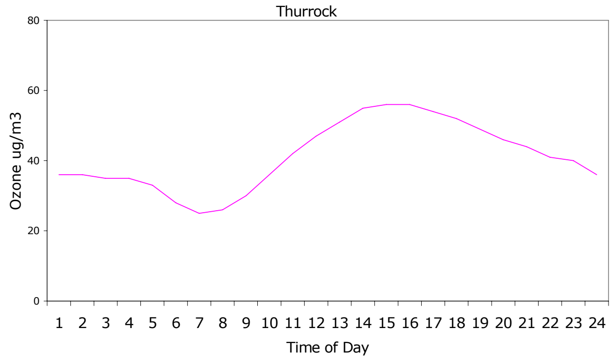
These figures show how ozone concentrations vary on average for each hour of day during the year, at a number of selected *typical* monitoring site types. Local time is used, rather than GMT, since this will more closely reflect the daily cycle of man-made emissions.



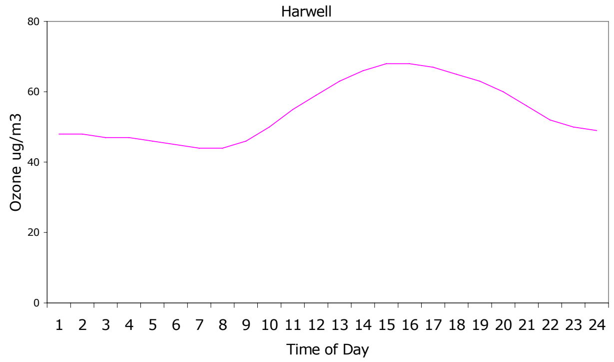
Kerbside Site
(*Marylebone Road)*



Roadside Site
(*Bury)*



Urban Background Site
(*Thurrock)*

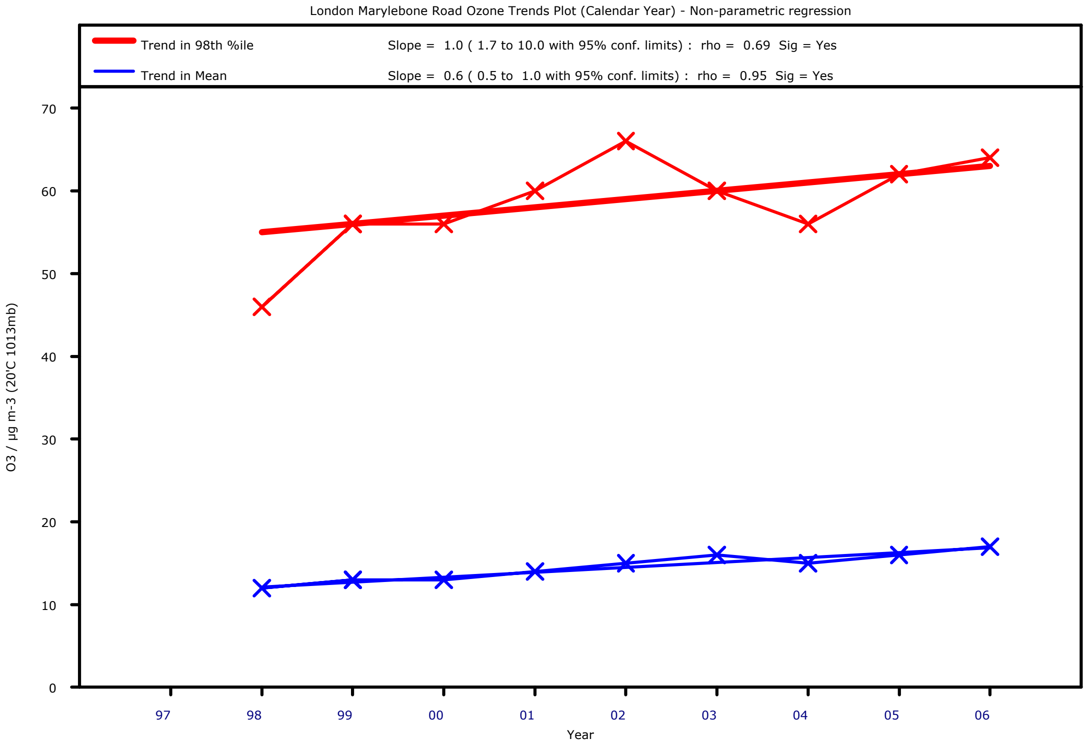


Rural Site
(Harwell)

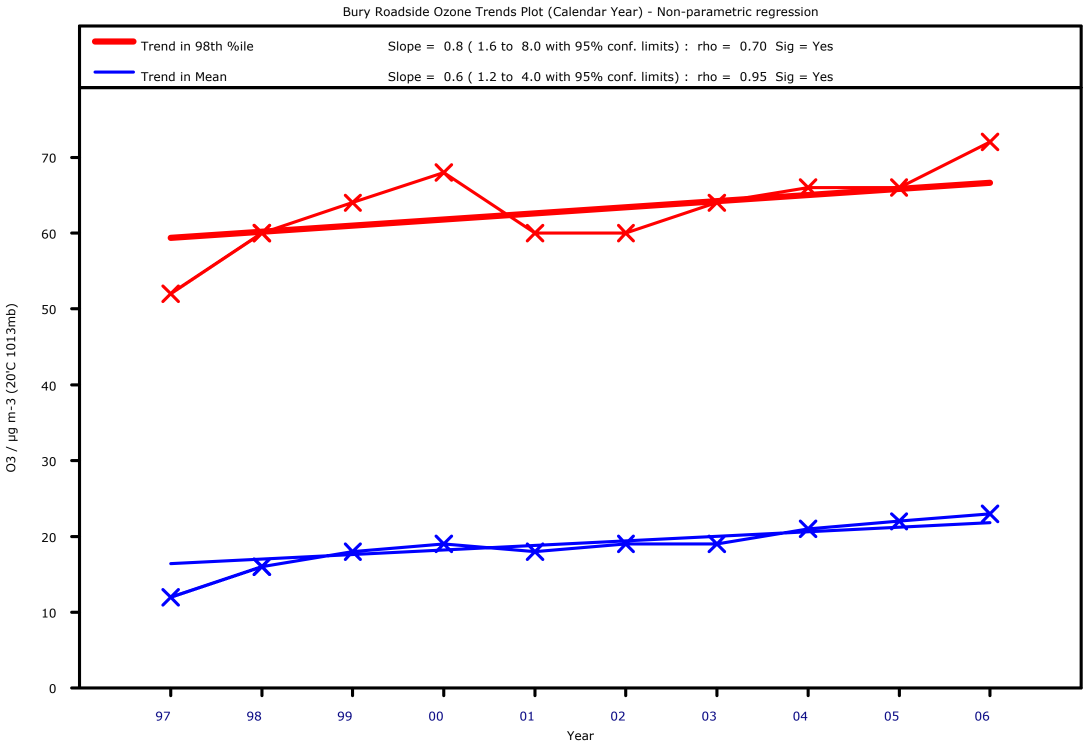
17.7 Trends in annual concentrations

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

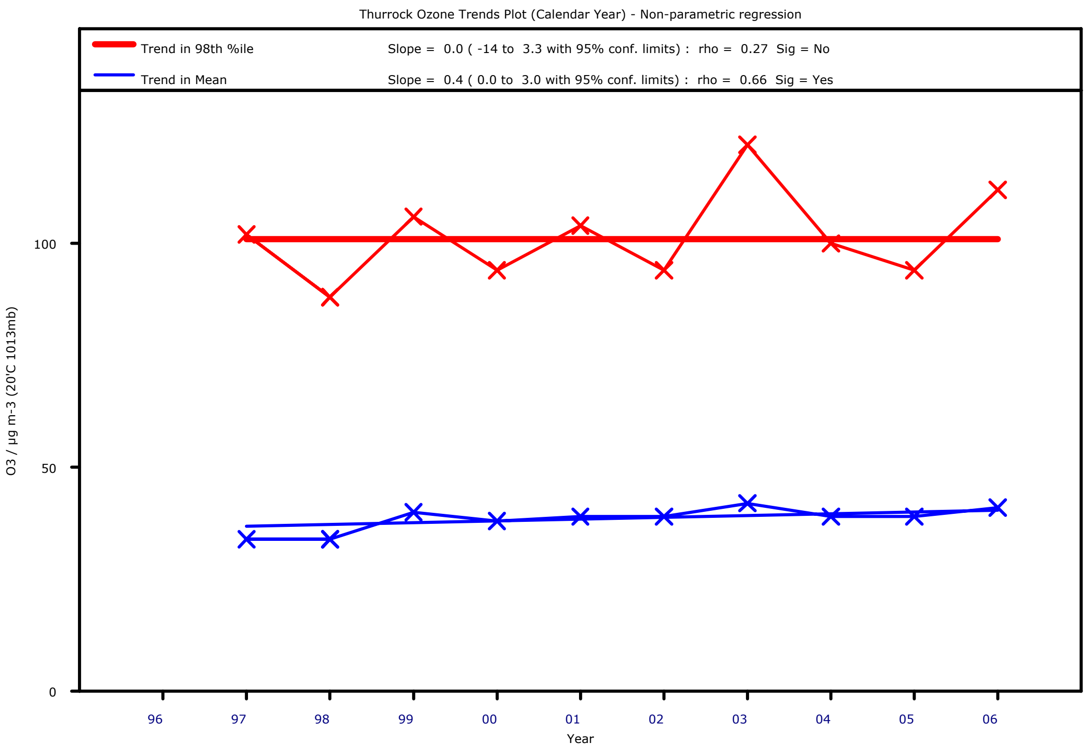
London Marylebone Road Trends Plot – Non-parametric regression



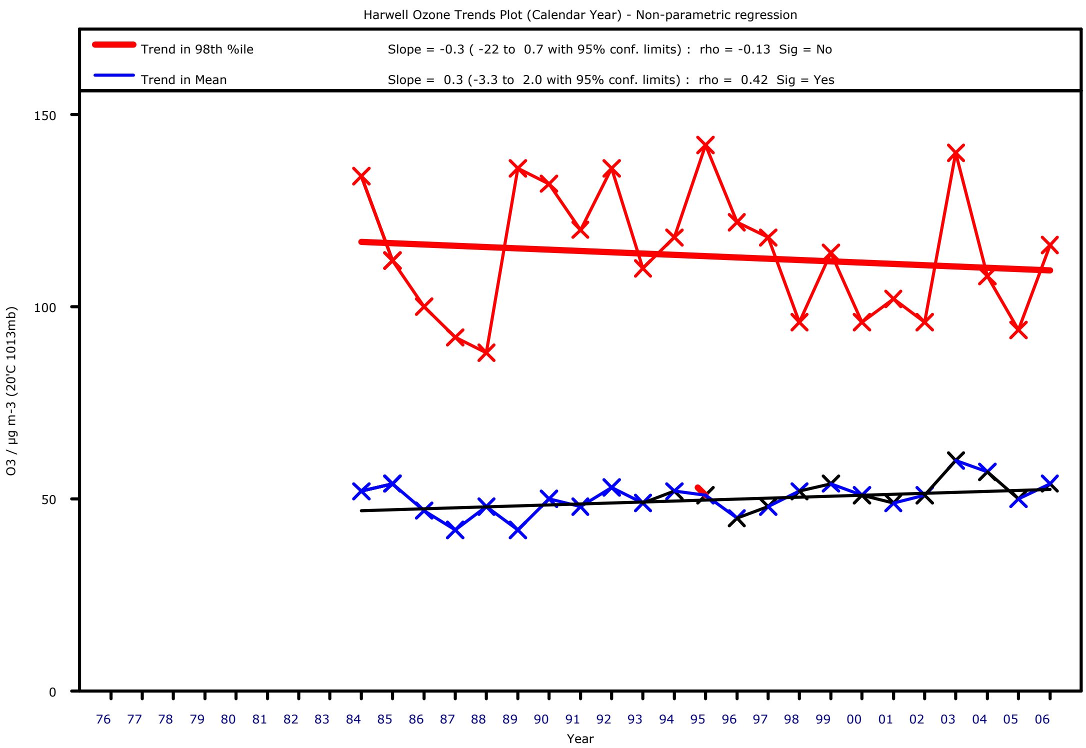
Bury Roadside ozone Trends Plot – Non-parametric regression



Thurrock Ozone Trends Plot – Non-parametric regression



Harwell Ozone Trends Plots – Non-parametric regression



17.8 Ozone Statistical Summary 2006

i) O_3 annual statistics I

	Site Type	Annual average of hourly means µg m^{-3}	Annual data capture of hourly means %	Maximum hourly mean µg m^{-3}	Maximum running 8-hour mean µg m^{-3}	Date of maximum running 8-hour mean	97%ile of daily max run 8hr µg m^{-3}
England							
Barnsley Gawber	UB	47	93.3	182	167	17/07/2006	125
Birmingham Centre	UC	43	95.6	168	159	02/07/2006	118
Birmingham Tyburn	UB	41	98.7	186	176	19/07/2006	129
Blackpool Marton	UB	58	95.2	240	207	18/07/2006	142
Bolton	UB	46	97.3	180	162	10/06/2006	126
Bottesford	SU	52	98.8	196	179	19/07/2006	140
Bournemouth	UB	52	98.7	232	217	18/07/2006	133
Bradford Centre	UC	37	92.7	164	144	01/07/2006	99
Brighton Preston Park	RD	55	96.3	206	188	18/07/2006	138
Bristol St Paul's	UB	43	53.9	202	176	03/07/2006	144
Bury Roadside	RD	23	85.1	148	136	10/06/2006	77
Coventry Memorial Park	UB	51	98.9	198	187	19/07/2006	140
Exeter Roadside	RD	42	97.0	210	192	18/07/2006	106
Glazebury	SU	48	73.9	188	173	19/07/2006	143
Great Dun Fell	RU	63	99.0	176	156	20/07/2006	126
Harwell	RU	54	93.6	212	184	19/07/2006	132
High Muffles	RU	58	89.5	174	160	05/07/2006	139
Hull Freetown	UC	45	97.7	158	136	02/07/2006	116
Ladybower	RU	50	94.9	168	156	10/06/2006	119
Leamington Spa	UB	46	98.4	228	205	19/07/2006	138
Leeds Centre	UC	40	99.2	154	148	10/06/2006	109
Leicester Centre	UC	43	98.6	184	174	10/06/2006	133
Leominster		55	96.4	192	178	04/07/2006	124
Liverpool Speke	UB	48	97.2	188	183	19/07/2006	125
London Bexley	SU	43	94.5	212	161	19/07/2006	126
London Bloomsbury	UC	29	96.1	178	149	26/07/2006	107
London Brent	UB	44	98.8	222	202	19/07/2006	143
London Eltham	SU	43	97.3	194	182	26/07/2006	133
London Hackney	UC	---	24.5	80	73	05/12/2006	---
London Haringey	UC	43	71.8	246	201	19/07/2006	155
London Harlington	A	37	91.5	206	185	19/07/2006	145
London Hillingdon	SU	28	98.0	182	137	17/07/2006	99
London Lewisham	UC	34	99.6	152	128	19/07/2006	106
London Marylebone Road	KD	17	95.7	118	84	01/07/2006	73
London N. Kensington	UB	40	94.8	204	178	26/07/2006	140
London Southwark	UC	---	39.9	106	91	10/09/2006	---
London Teddington	UB	51	98.9	206	193	19/07/2006	152
London Wandsworth	UC	34	99.3	182	155	26/07/2006	123
London Westminster	UB	38	97.2	192	161	26/07/2006	130
Lullington Heath	RU	61	89.1	238	212	18/07/2006	147
Manchester Piccadilly	UC	29	90.7	144	132	02/07/2006	105
Manchester South	SU	33	98.1	164	132	17/07/2006	104

ii) O_3 exceedence statistics I

Site	Moderate band	Days	High band	Days	Very High band	Days	Air Quality Standard (Running 8-hour Mean)	Days
England								
Barnsley Gawber	251	32	**2**	**1**	0	0	**140**	**24**
Birmingham Centre	244	29	0	0	0	0	**145**	**22**
Birmingham Tyburn	293	35	**7**	**2**	0	0	**181**	**24**
Blackpool Marton	626	73	**23**	**5**	0	0	**365**	**50**
Bolton	364	46	**1**	**1**	0	0	**196**	**28**
Bottesford	434	54	**12**	**4**	0	0	**267**	**31**
Bournemouth	352	46	**36**	**6**	0	0	**240**	**28**
Bradford Centre	116	18	0	0	0	0	**60**	**10**
Brighton Preston Park	488	50	**22**	**3**	0	0	**344**	**36**
Bristol St Paul's	190	22	**15**	**5**	0	0	**132**	**16**
Bury Roadside	40	8	0	0	0	0	**15**	**4**
Coventry Memorial Park	451	53	**12**	**2**	0	0	**275**	**35**
Exeter Roadside	172	20	**15**	**4**	0	0	**112**	**13**
Glazebury	283	35	**6**	**3**	0	0	**175**	**22**
Great Dun Fell	427	28	0	0	0	0	**371**	**24**
Harwell	401	46	**12**	**2**	0	0	**250**	**34**
High Muffles	582	54	0	0	0	0	**430**	**33**
Hull Freetown	313	51	0	0	0	0	**159**	**23**
Ladybower	269	30	0	0	0	0	**162**	**22**
Leamington Spa	402	47	**23**	**6**	0	0	**277**	**33**
Leeds Centre	195	28	0	0	0	0	**104**	**19**
Leicester Centre	370	41	**6**	**3**	0	0	**241**	**26**
Leominster	332	45	**8**	**2**	0	0	**187**	**26**
Liverpool Speke	251	29	**8**	**1**	0	0	**173**	**21**
London Bexley	314	42	**3**	**1**	0	0	**170**	**26**
London Bloomsbury	173	25	0	0	0	0	**87**	**15**
London Brent	435	50	**46**	**6**	0	0	**305**	**38**
London Eltham	410	45	**6**	**1**	0	0	**268**	**33**
London Hackney	0	0	0	0	0	0	0	0
London Haringey	360	40	**45**	**6**	0	0	**262**	**31**
London Harlington	337	39	**14**	**4**	0	0	**211**	**28**
London Hillingdon	133	22	**1**	**1**	0	0	**59**	**10**
London Lewisham	186	32	0	0	0	0	**75**	**16**
London Marylebone Road	1	1	0	0	0	0	0	0
London N. Kensington	442	43	**12**	**5**	0	0	**283**	**35**
London Southwark	4	2	0	0	0	0	0	0
London Teddington	555	58	**25**	**5**	0	0	**373**	**42**
London Wandsworth	303	36	**1**	**1**	0	0	**171**	**26**
London Westminster	345	39	**2**	**2**	0	0	**215**	**28**
Lullington Heath	650	66	**38**	**6**	0	0	**490**	**46**
Manchester Piccadilly	155	18	0	0	0	0	**88**	**13**
Manchester South	173	21	0	0	0	0	**101**	**14**

iii) O_3 annual statistics II

	Site Type	Annual average of hourly means µg m^{-3}	Annual data capture of hourly means %	Maximum hourly mean µg m^{-3}	Maximum running 8-hour mean µg m^{-3}	Date of maximum running 8-hour mean	97%ile of daily max run 8hr µg m^{-3}
England - *continued*							
Market Harborough	RU	57	95.3	188	174	19/07/2006	144
Middlesbrough	I	49	97.6	216	178	10/06/2006	107
Newcastle Centre	UC	44	98.2	172	158	02/07/2006	105
Northampton	UB	50	97.1	214	203	19/07/2006	142
Norwich Centre	UC	47	99.2	186	170	10/06/2006	124
Nottingham Centre	UC	39	98.2	180	160	17/07/2006	116
Plymouth Centre	UC	---	13.7	84	76	15/02/2006	---
Portsmouth	UB	54	99.0	230	212	18/07/2006	139
Preston	UB	50	95.4	218	195	18/07/2006	143
Reading New Town	UB	49	94.4	180	158	02/07/2006	131
Redcar	SU	50	89.4	164	140	18/07/2006	110
Rochester Stoke	RU	49	98.6	200	150	02/07/2006	121
Rotherham Centre	UC	30	90.9	158	131	17/07/2006	98
Salford Eccles	I	38	94.4	182	168	10/06/2006	133
Sandwell West Bromwich	UB	42	98.0	198	175	17/07/2006	128
Sheffield Centre	UC	33	96.9	130	105	12/05/2006	86
Sibton	RU	57	92.0	184	172	04/07/2006	135
Somerton	RU	57	92.2	192	174	04/07/2006	123
Southampton Centre	UC	36	94.7	150	139	18/07/2006	97
Southend-on-Sea	UB	55	98.9	232	188	04/07/2006	154
St Osyth	RU	54	98.0	206	175	19/07/2006	134
Stoke-on-Trent Centre	UC	51	93.2	244	230	19/07/2006	159
Sunderland Silksworth	UB	55	93.7	202	166	18/07/2006	118
Thurrock	UB	41	98.2	214	170	19/07/2006	128
Weybourne	RU	70	88.9	188	172	10/06/2006	132
Wicken Fen	RU	66	86.4	278	260	19/07/2006	171
Wigan Centre	UB	48	96.3	190	171	02/07/2006	137
Wirral Tranmere	UB	50	91.6	208	187	18/07/2006	116
Wolverhampton Centre	UC	45	97.8	182	170	19/07/2006	112
Yarner Wood	RU	63	96.4	234	213	18/07/2006	121
N Ireland							
Belfast Centre	UC	42	92.3	188	137	19/07/2006	90
Derry	UB	49	79.6	196	178	19/07/2006	92
Lough Navar	RU	47	98.8	170	158	19/07/2006	89
Scotland							
Aberdeen	UB	48	99.0	158	148	08/05/2006	103
Auchencorth Moss	RU	---	16.4	86	83	20/11/2006	---
Bush Estate	RU	58	97.9	158	143	10/06/2006	98
Edinburgh St Leonards	UB	52	98.5	152	147	08/05/2006	106
Eskdalemuir	RU	58	98.8	176	163	05/07/2006	117
Fort William	SU	---	44.0	162	147	19/07/2006	---
Glasgow Centre	UC	35	98.4	132	111	08/05/2006	90
Lerwick	RU	66	95.9	144	136	06/05/2006	104
Strath Vaich	RU	72	83.6	182	161	08/05/2006	126
Wales							
Aston Hill	RE	72	92.4	220	212	19/07/2006	149

iv) O_3 exceedence statistics II

Site	Moderate band	Days	High band	Days	Very High band	Days	Air Quality Standard (Running 8-hour Mean)	Days
England - continued								
Market Harborough	516	53	**4**	**2**	0	0	**332**	**36**
Middlesbrough	264	40	**4**	**2**	0	0	**138**	**22**
Newcastle Centre	197	26	0	0	0	0	**96**	**16**
Northampton	395	45	**20**	**6**	0	0	**275**	**31**
Norwich Centre	414	42	**3**	**1**	0	0	**264**	**32**
Nottingham Centre	260	28	**1**	**1**	0	0	**156**	**20**
Plymouth Centre	0	0	0	0	0	0	0	0
Portsmouth	528	59	**38**	**6**	0	0	**346**	**39**
Preston	395	48	**26**	**7**	0	0	**276**	**30**
Reading New Town	371	45	**1**	**1**	0	0	**223**	**30**
Redcar	304	37	0	0	0	0	**190**	**21**
Rochester Stoke	379	53	**3**	**2**	0	0	**209**	**30**
Rotherham Centre	103	15	0	0	0	0	**45**	**10**
Salford Eccles	232	22	**3**	**2**	0	0	**165**	**17**
Sandwell West Bromwich	278	32	**7**	**2**	0	0	**183**	**23**
Sheffield Centre	31	9	0	0	0	0	**7**	**3**
Sibton	531	57	**5**	**2**	0	0	**326**	**38**
Somerton	363	43	**3**	**1**	0	0	**215**	**27**
Southampton Centre	88	13	0	0	0	0	**37**	**6**
Southend-on-Sea	874	97	**33**	**8**	0	0	**551**	**60**
St Osyth	484	57	**6**	**4**	0	0	**294**	**37**
Stoke-on-Trent Centre	457	61	**63**	**9**	0	0	**348**	**33**
Sunderland Silksworth	325	36	**2**	**2**	0	0	**211**	**20**
Thurrock	315	39	**8**	**3**	0	0	**197**	**25**
Weybourne	1154	106	**3**	**1**	0	0	**801**	**78**
Wicken Fen	1323	139	**81**	**14**	0	0	**875**	**102**
Wigan Centre	534	64	**7**	**4**	0	0	**291**	**43**
Wirral Tranmere	264	37	**11**	**4**	0	0	**160**	**20**
Wolverhampton Centre	212	26	**1**	**1**	0	0	**121**	**17**
Yarner Wood	709	73	**31**	**4**	0	0	**480**	**50**
N Ireland								
Belfast Centre	55	8	**1**	**1**	0	0	**41**	**4**
Derry	69	9	**4**	**1**	0	0	**52**	**4**
Lough Navar	88	8	0	0	0	0	**62**	**6**
Scotland								
Aberdeen	182	23	0	0	0	0	**109**	**13**
Auchencorth Moss	0	0	0	0	0	0	0	0
Bush Estate	121	22	0	0	0	0	**70**	**9**
Edinburgh St Leonards	218	36	0	0	0	0	**121**	**17**
Eskdalemuir	287	35	0	0	0	0	**170**	**23**
Fort William	54	7	0	0	0	0	**25**	**5**
Glasgow Centre	69	10	0	0	0	0	**32**	**5**
Lerwick	224	25	0	0	0	0	**159**	**15**
Strath Vaich	746	71	**1**	**1**	0	0	**465**	**48**
Wales								
Aston Hill	652	74	**43**	**6**	0	0	**457**	**42**

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Air Pollution in the UK: 2006

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 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- primarily measured as PM_{10} at the present time
- 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 SO2 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, and 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. Although coarse (large) particle size ranges may cause significant local nuisance or soiling impacts, it is the finer (small) fractions that are capable of deep lung/airway penetration. This is why these fractions such as PM_{10} and $PM_{2.5}$ are measured in UK national monitoring networks.

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

Particles are produced from a variety of natural and man-made sources. Natural sources include sea salt, soil blowoff, Saharan dust, 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 2005 event 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 aerosol is a good example of the latter; this 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.

The principal source of PM_{10} (the mass fraction of particles collected by a sampler with a 50% inlet cut-off at aerodynamic diameter 10µm) in many cities is road traffic emissions, particularly from diesel vehicles. As well as creating dirt, odour and visibility problems, PM_{10} particles are associated with health effects including increased risk of heart and lung disease. In addition, they may carry surface- absorbed carcinogenic compounds into the lungs. 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 $PM_{2.5}$.

Existing PM_{10} data 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.

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

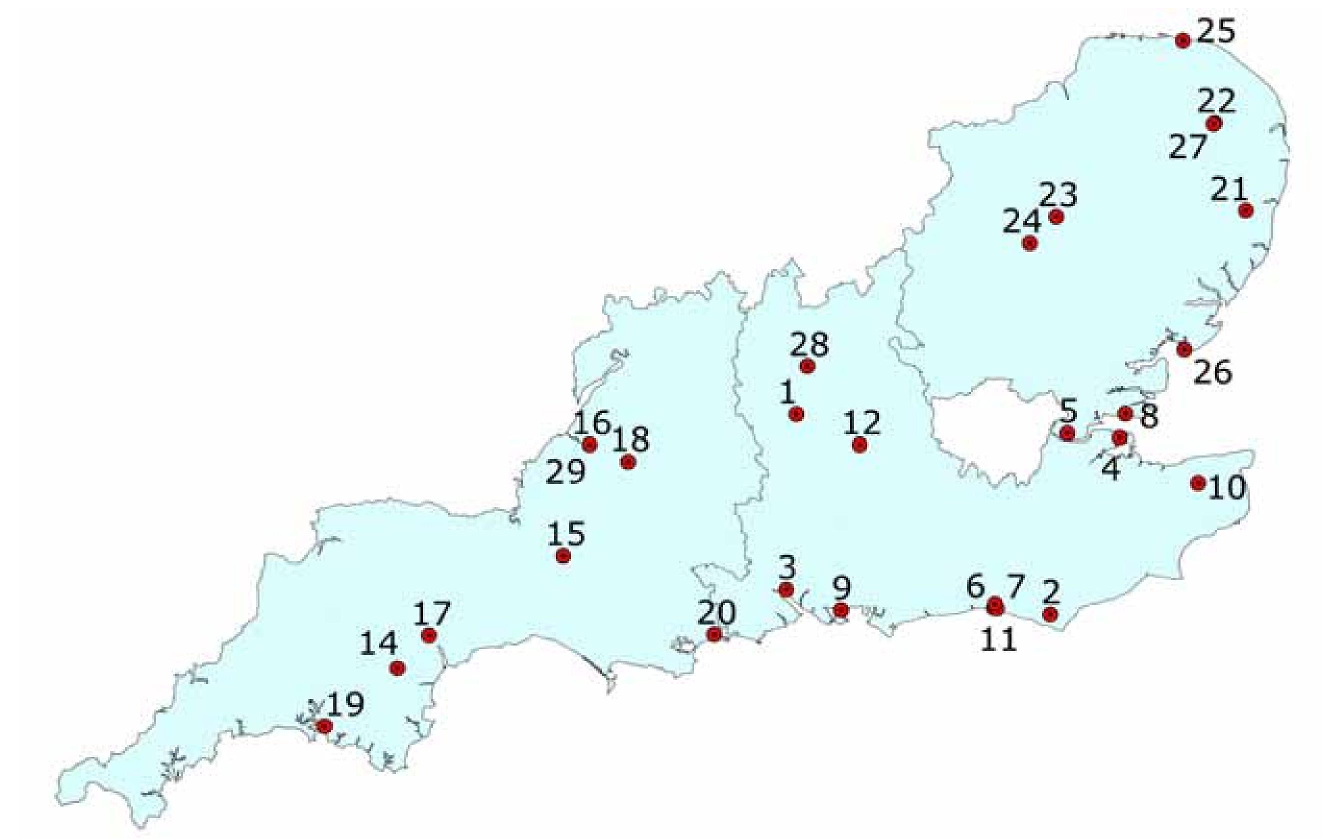
The majority of Lead (Pb) emissions arise from older vehicles fuelled with leaded petrol. Industry, in particular secondary non-ferrous metal smelters, may also contribute to emissions of lead in localised industrial areas. This source is becoming increasingly significant due to the progressive reduction 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

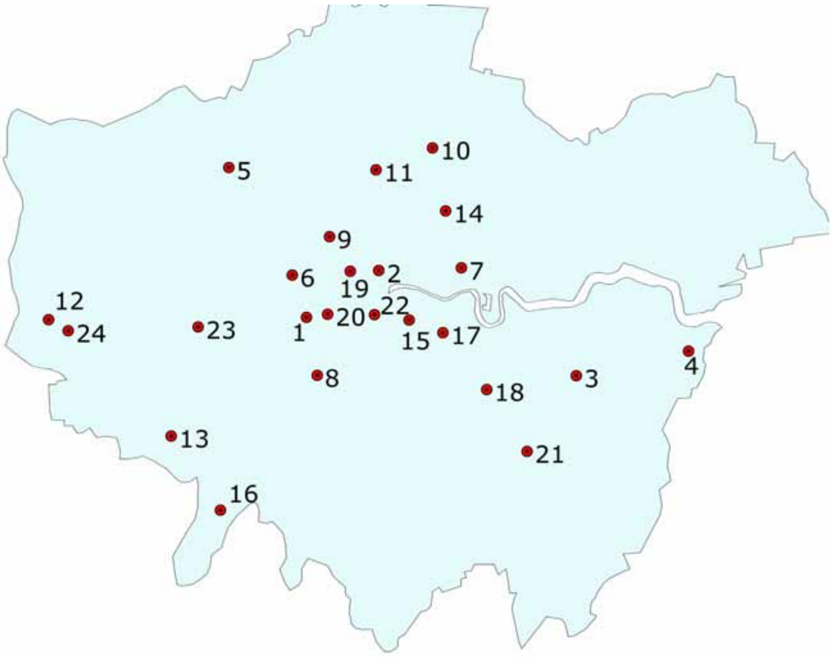
These maps show Automatic Urban and Rural Network (AURN) and Hydrocarbon air monitoring sites in different parts of the UK.

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**



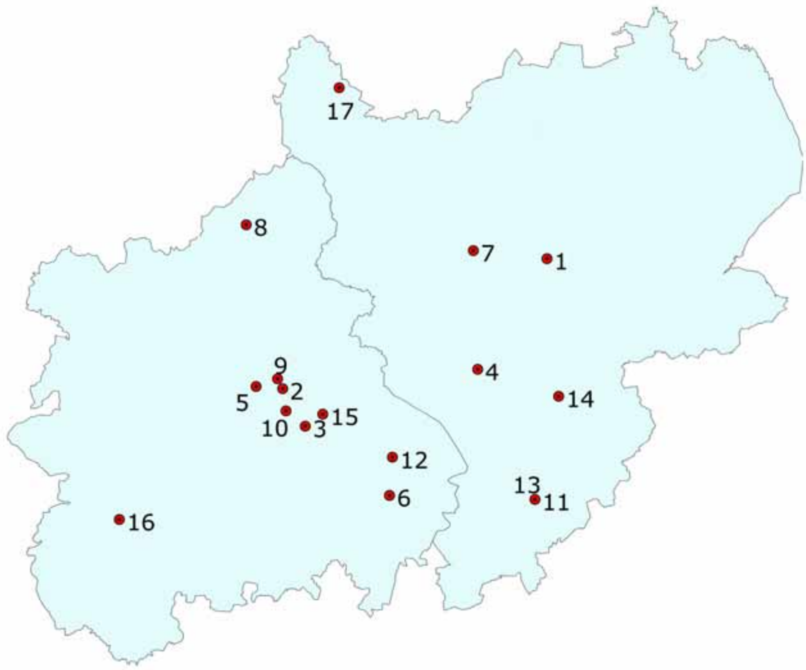
No	Site Name
1	Harwell
2	Lullington Heath
3	Southampton Centre
4	Rochester
5	Thurrock
6	Hove Roadside
7	Brighton Roadside
8	Southend-on-Sea
9	Portsmouth
10	Canterbury
11	Brighton Roadside PM10
12	Reading New Town
13	Brighton Preston Park
14	Yarner Wood
15	Somerton
16	Bristol Old Market
17	Exeter Roadside
18	Bath Roadside
19	Plymouth Centre
20	Bournemouth
21	Sibton
22	Norwich Centre
23	Wicken Fen
24	Cambridge Roadside
25	Weybourne
26	St Osyth
27	Norwich Forum Roadside
28	Oxford Centre Roadside
29	Bristol St Paul's

Figure A2.1 Automatic Sites, Southern England



No	Site Name
1	West London
2	London Bloomsbury
3	London Eltham
4	London Bexley
5	London Brent
6	London N. Kensington
7	Tower Hamlets Roadside
8	London Wandsworth
9	Camden Kerbside
10	Haringey Roadside
11	London Haringey
12	London Hillingdon
13	London Teddington
14	London Hackney
15	London Southwark
16	London A3 Roadside
17	Southwark Roadside
18	London Lewisham
19	London Marylebone Road
20	London Cromwell Road 2
21	London Bromley
22	London Westminster
23	Brentford Roadside
24	London Harlington

Figure A2.2 Automatic Sites, London



No	Site Name
1	Bottesford
2	Walsall Alumwell
3	Birmingham Centre
4	Leicester Centre
5	Wolverhampton Centre
6	Leamington Spa
7	Nottingham Centre
8	Stoke-on-Trent Centre
9	Walsall Willenhall
10	Sandwell West Bromwich
11	Northampton
12	Coventry Memorial Park
13	Northampton PM10
14	Market Harborough
15	Birmingham Tyburn
16	Leominster
17	Ladybower

Figure A2.3 Automatic Sites, Midlands

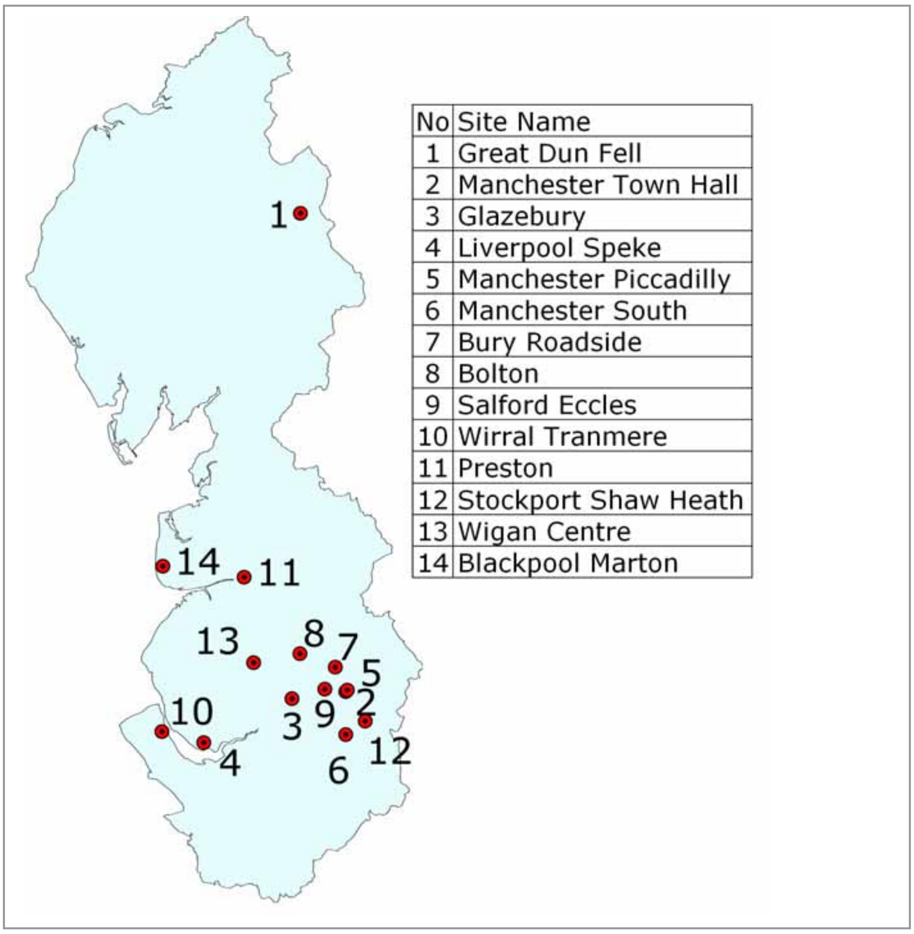


Figure A2.4 Automatic Sites, NW England

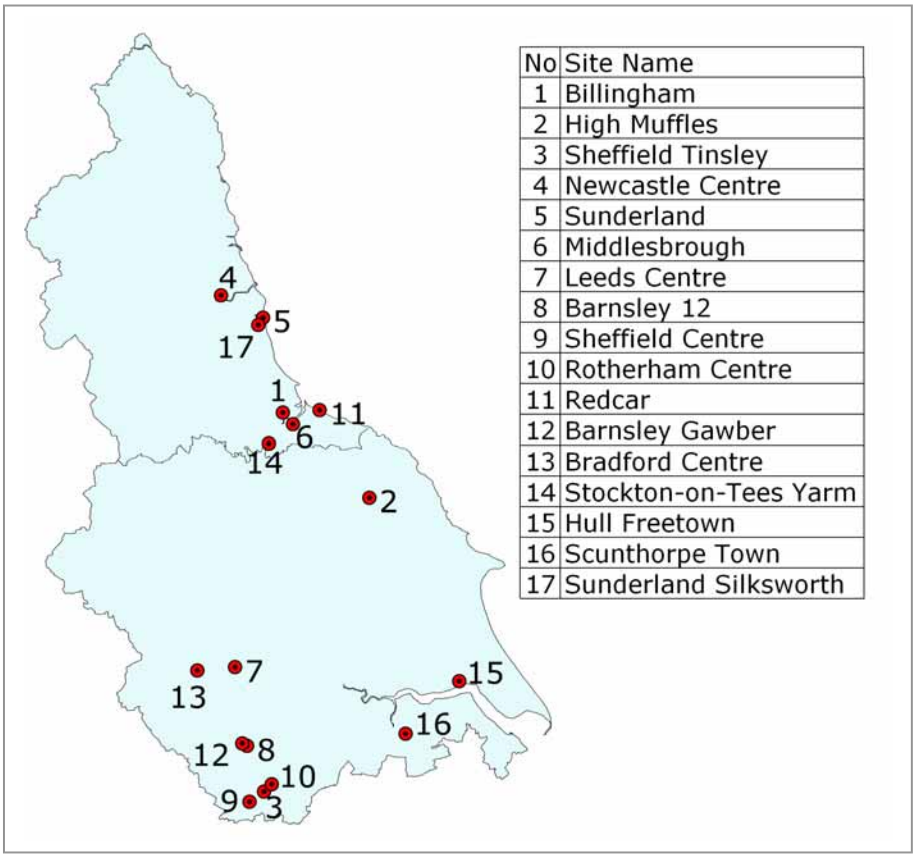


Figure A2.5 Automatic Sites, NE England

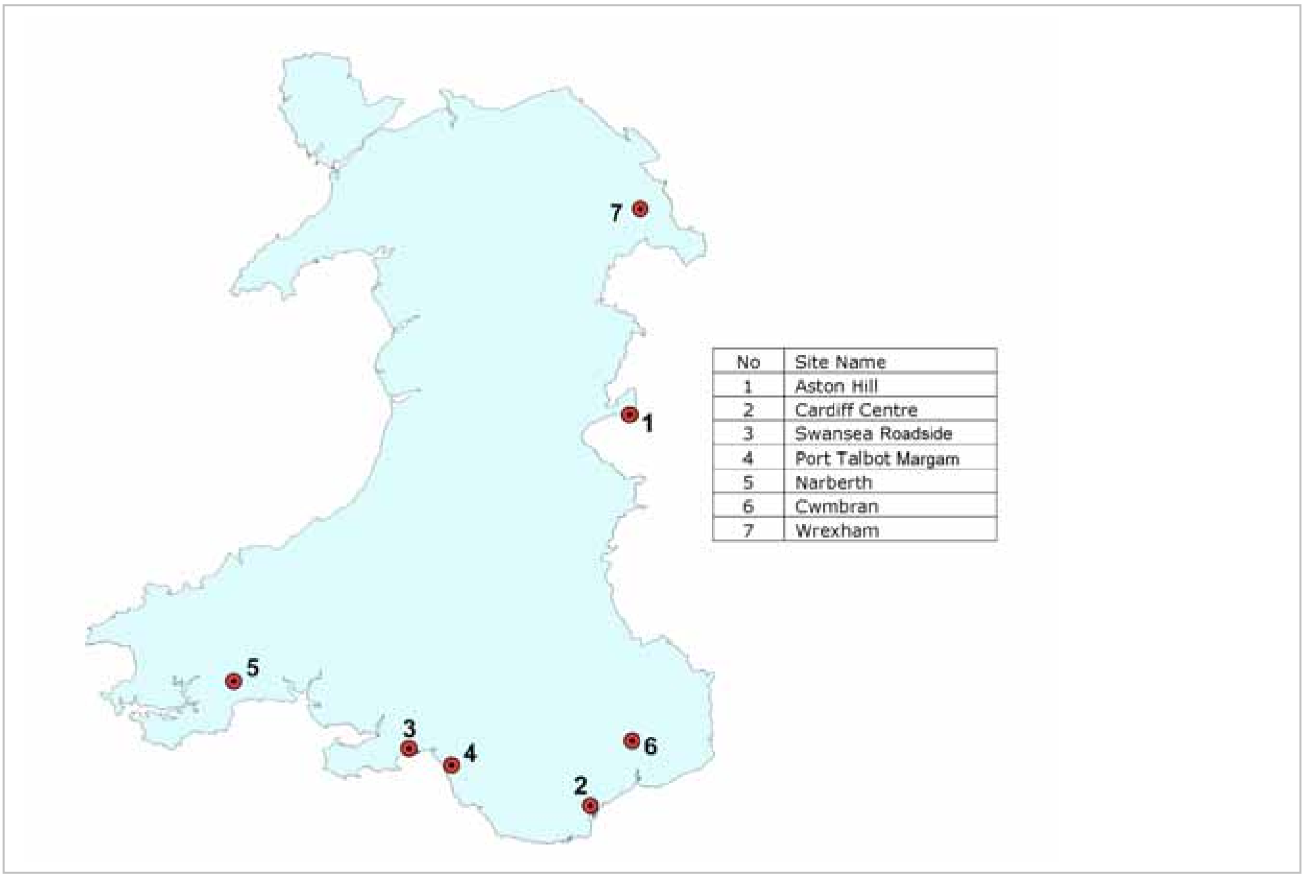


Figure A2.6 Automatic Sites, Wales

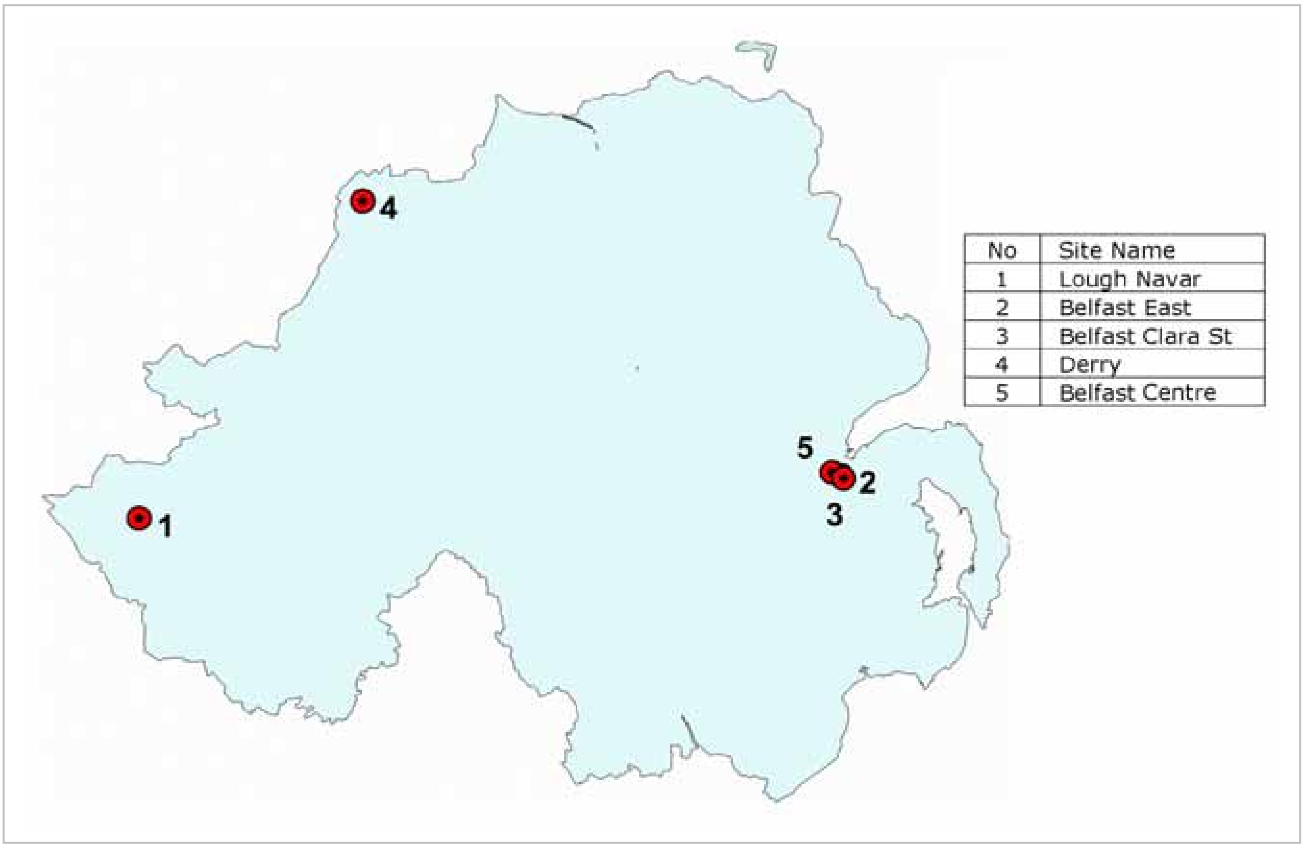
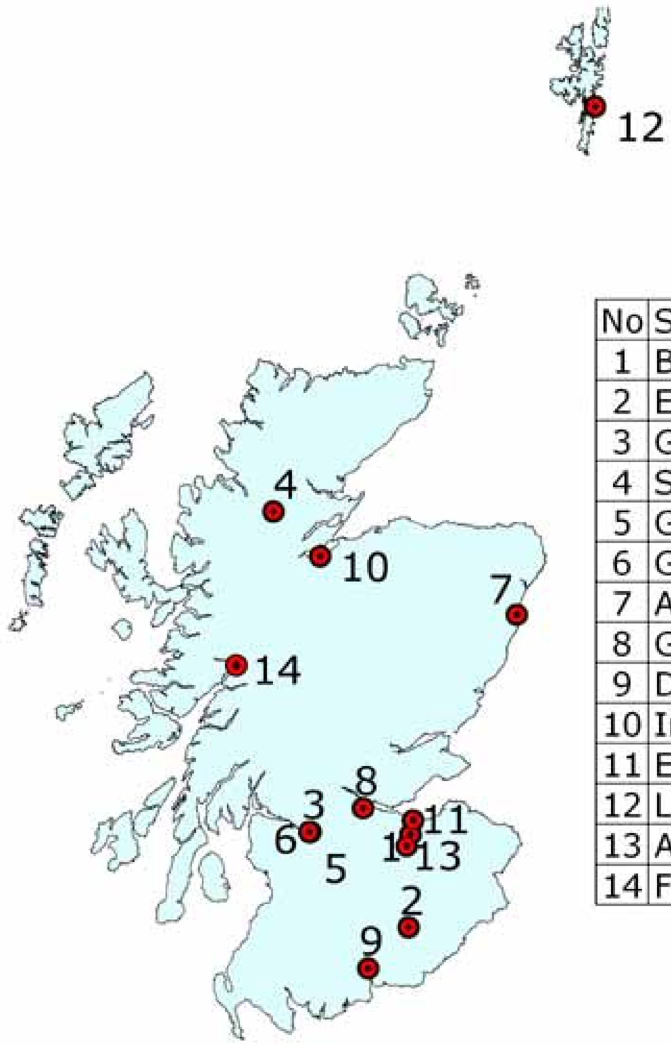


Figure A2.7 Automatic Sites, Northern Ireland



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	Edinburgh St Leonards
12	Lerwick
13	Auchencorth Moss
14	Fort William

Figure A2.8 Automatic Sites, Scotland

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.

A 3.1	**The Automatic Urban and Rural Network**
A 3.2	**The Acid Deposition and Rural SO_2 networks**
A 3.3	**The Hydrocarbon Monitoring Networks**
A 3.4	**The PAH and TOMPS Networks**
A 3.5	**The Heavy Metals Networks**
A 3.6	**The National Ammonia and Nitric Acid Network**
A 3.7	**The Black Smoke Network**

A 3.1 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 largest UK automatic monitoring programme. It consists of 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}). These are monitored on an hourly basis at measurement sites throughout the UK.

As of August 2007, the AURN consists of 130 monitoring sites. Of these, 66 are directly funded by Defra and the devolved administrations, and a further 64 affiliated sites are owned and operated by local authorities; 14 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 Figure 1)

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 AURN. The responsibility for operating individual monitoring sites is assigned to 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 techniques 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. See Section 4.4 for information on recent evaluations of PM_{10} measurement techniques.

Two additional monitoring sites were commissioned in Scotland in 2006. Fort William measuring NO_x and O_3 for Ozone Directive compliance, and Auchencorth Moss as an EMEP rural 'supersite' measuring the full range of pollutants. TEOM FDMS units were also introduced to the network for the first time in 2006, to provide reference method equivalent measurements of PM_{10} particulate matter.

AURN Measurement Techniques (considered in greater detail in Part 2)

O_3	UV absorption
NO/NO_x	Chemiluminescence
SO_2	UV fluorescence
CO	IR Absorption
PM_{10}	Tapered Element Oscillating Microbalance Beta Attenuation monitor Gravimetric monitor

There have been considerable changes in European air quality legislation in the last few years and the AURN has successfully expanded and evolved to conform to these new requirements.

A3.2 The Acid Deposition and Rural SO_2 Monitoring Networks

(Managed and operated for Defra and the DAs by CEH and AEA)

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 9 primary and 59 secondary sampling sites. Subsequent changes made to the programme, including new measurement techniques for trace rural gases, altered sampling frequencies and reductions in the number of monitoring sites, have made this distinction less clearcut.

In 1999, 7 new sites were established to monitor rainwater composition in ecologically sensitive areas. Further changes in 2006 saw the exposure of triplicate diffusion tubes at three sites, and commencement of a wet-only daily precipitation collector at one site.

The SO_2 measurements in the ADMN and Rural SO_2 monitoring programme were terminated at the end of 2005. These have been replaced by measurements made as part of the expanded nitric acid measurement programme (see Section 3.6).

In 2006, the network covers the following measurements and sites:

The Acid Deposition and Rural SO_2 Monitoring Network- site numbers and 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 site
Sulphur Dioxide	– Sampled on a monthly basis at 8 sites
Particulate Sulphate	– Sampled on a ***daily*** basis at 5 sites
Nitrogen Dioxide	– Diffusion tube measurements on a ***monthly*** basis at 32 sites
Nitric acid, other acid gases and aerosols	– Denuder measurements on a ***monthly*** basis at 12 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), started 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 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' was 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.

The UK Automatic Hydrocarbon Network currently consists of five sites, located at Cardiff, Glasgow, Harwell, London Eltham and London Marylebone Road. Three of these sites – Cardiff, Glasgow and Harwell- utilise an Environnment VOC71M analyser configured to measure and report the concentrations of 1,3-butadiene, benzene, toluene, ethylbenzene, (m+p)-xylene and o-xylene. Benzene data are used for comparison with the UK Air Quality Objectives and are also reported to the European Commission to fulfil requirements of the Benzene Daughter Directive; 1,3-butadiene data are used for comparison with UK Objectives.

The two London sites are fitted with automatic Perkin Elmer gas chromatographs measuring a wider range of VOCs, equivalent to that studied under the original measurement programme. Both instruments are capable of measuring and reporting at least 27 hydrocarbons. Measurements from all five sites will be 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.

Auchencorth Moss, a new EMEP monitoring site measuring speciated VOCs, together with ozone, PM_{10} and $PM_{2.5}$ (both via Partisol) for the AURN, commenced operation in June 2006.

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 35 sites around the United Kingdom, as well as 1,3-butadiene at 9 of these locations. 1,3-Butadiene is measured at sites expected to have high concentrations of this carcinogenic pollutant, in order to assess compliance with the UK Air Quality Strategy Objective (2.25 $\mu g/m^3$ expressed as a running annual mean).

Benzene is also monitored to assess compliance with UK Objectives (between 3.25 and 16.25 $\mu g/m^3$ 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 µg/m^3 annual average). Note that both species have Objectives and Limit Values expressed in the form of an annual average concentration, so that high time resolution is not required from the measurements.

Sampling is therefore undertaken for periods of a fortnight onto sorbent tubes containing Carbopack X. For benzene, the air is pumped through the sampling tubes using purpose-built pump units that switch between two tubes to produce two nominally identical samples covering each fortnight. For 1,3-butadiene, pairs of sorbent tubes sample the air passively (by diffusive processes) over the fortnight of sample exposure.

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.

Currently, all samplers are located at monitoring stations operated within the Automatic Urban and Rural Network (AURN)- discussed separately in Section A 3.3. Measurements began over the period December 2001 to August 2002, following the decommissioning of the first generation Automatic Hydrocarbon Network, which provided on-line measurements of hourly data for 26 hydrocarbon species at 13 sites. The data obtained now provide a useful addition to automatic measurements undertaken in the current 5-site programme.

The fortnightly pumped measurement method for benzene was developed specifically for this network, following the requirement of the EU 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, 5 parts) include the pumped method used in this network.

A 3.4 The PAH and TOMPs Networks

(Networks managed and operated for Defra and the DAs by AEA Energy & Environment and Lancaster University respectively since April 2004)

These two programmes are highly integrated, being based on a 24-site sampler network covering a broad range of representative urban, industrial, semi-rural and rural location types; 18 of these are operated wholly within the PAHs programme, whilst a further 6 sites are operated as the TOMPS monitoring network but with samples also analysed for PAHs.

i) PAHs

Polycyclic aromatic hydrocarbons (PAHs) 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 PAHs, based in turn on the recommendations of the Expert Panel on Air Quality Standards (EPAQS) for an annual air quality standard of 0.25 ng benzo[a]pyrene /m^3 to be achieved by 2010.

- The European Community's fourth Air Quality Daughter Directive (2005/107/EC), which includes a target value for benzo[a]pyrene as a representative PAH as an annual average of 1 ng /m^3 to be achieved by 2012.
- The UK's decision to sign, and ratify, the UNECE protocol on Persistent Organic Pollutants (POPs), which includes PAHs. Under the protocol, there is a requirement for signatories to control emissions of PAHs to measure and assess the long-range transport of four specified PAHs.

All these policy imperatives require sound data on ambient concentrations and trends of PAHs in the environment.

2007 has been a year of transition for the PAH network. The modified Anderson GPS-1 pesticide samplers, capturing both gas and particle-phase PAHs on glass fibre and polyurethane filter, which have been deployed at all 18 UK network locations since they started, some in 1991 are being phased out during 2007 to implement standard EN15549 from the beginning of 2008. The number of UK network locations will increase from 18 to 32 sites during 2007 in response to the 4th Air Quality daughter Directive and the network will use Digitel DH-80 high volume aerosol samplers. Thirty two of the UK Network locations will capture particle-phase only PAHs on glass fibre filters while two sites will include both an additional modified DH-80 high volume sampler capturing both gas and particle-phase PAHs on glass fibre and polyurethane filers and a deposition sampler.

Careful extraction of the filter and 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 PAHs retained by the filter. Hence for some of the more volatile compounds only a small fraction is retained.

ii) TOMPs

Toxic Organic Micropollutants (TOMPs)- include Polychlorinated Dibenzo-*p*-Dioxins, Polychlorinated Dibenzofurans (PCDD/Fs), PAHs as above, and Polychlorinated Biphenyls (PCBs). PCDD/Fs and PAHs are formed as unwanted by-products during various industrial, chemical and combustion processes. The 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, in order to assess both human exposure and the relationship between source emissions and levels in the ambient atmosphere.
- The UK's decision to sign, and ratify when possible, the UNECE protocol on Persistent Organic Pollutants (POPs), which includes PCDD/Fs, PCBs and PAHs. 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.

The TOMPS network measures concentrations of these trace organic species at six sites. Samples from these sites are then analysed for PAHs as part of the PAH network. The sampling method is again 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 including gas chromatography coupled with high-resolution mass spectrometry.

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)

The UK Government has in the past funded separate long-term monitoring programmes responding to specific needs of EC Directives in relation to toxic and industrial metals. These 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 lead-in-petrol (2 rural, 3 urban and 3 kerbside) and
- Eight sites operating in three industrial areas monitoring lead - Walsall (IMI and Brookside works) and Newcastle (Elswick works).

The EU Framework Directive (96/62/EC) establishes a framework under which, by means of Daughter Directives, the EU can establish limit and target values for concentrations in ambient air of certain pollutants. The First Daughter Directive (99/30/EC) sets a Limit Value for lead in air concentrations at 0.5 $\mu g/m^3$, expressed as an annual mean to be achieved by 1st January 2005.

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 1 January 2000. This has, in turn, led to a dramatic decline in ambient lead levels in many UK environments. As a consequence, some monitoring sites, which only measured lead concentrations, have since been closed.

In 2000, a year-long monitoring network was established 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 with the aim of setting limit values for arsenic, cadmium, nickel and mercury. Results of this programme showed that further monitoring at a number of sites was required in order to establish compliance with the proposed Target Values. Monitoring continues currently at five of these sites – Avonmouth, Hallen Village, Swansea, Sheffield and Runcorn.

The 4th Daughter Directive (2004/107/EC) was published in the Official Journal of the European Commission on 26th January 2005. The 4th Daughter Directive sets 'target values' for arsenic, cadmium, nickel (and polycyclic aromatic hydrocarbons) in the PM_{10} particulate fraction of ambient air.

Member States must transpose the 4th Daughter Directive into national law by 15th February 2007. The European Commission will report on its implementation by 31st December 2010. Governments must report to the Commission on zones and agglomerations where the target values are exceeded with the first such reports being required by 30th September 2008. The 4th Daughter Directive also requires monitoring of mercury although no limit or target values have been set.

The disparate nature of the historic monitoring networks for heavy metals in the UK, which have individually responded to specific Directive needs, resulted in differences in practice between networks and did not permit UK-wide reporting in a consistent manner.

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. Sampling is now undertaken for weekly periods at sites on 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.

Since September 2004, the number of elements measured at the old Industrial Metals sites has been increased to ensure there is consistency across the Network. All 17 sites now monitor for As, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Pt, V and Zn. Additionally, measurements are made for ambient vapour phase mercury concentrations at 13 sites.

(ii) The Rural Heavy Metals and Mercury Network
(Network managed and operated for Defra and the DAs by Centre for Ecology and Hydrology)

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 Thermo FH95 single or FH95SEQ sequential samplers, together with weekly or 4-weekly collections of precipitation. In addition a further three secondary sites collect precipitation samples only and two more 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^P and Hg^0.

As concentrations of these species are so low (of the order of pg m^{-3} for RGM and Hg^p), 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 KCl-coated denuder and particulate trap, respectively. During the following hour, the collected RGM and HgP 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 a Analytical detection limit = 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

The National Ammonia Monitoring Network (NAMN) was established with approximately 70 sites in 1996. Its objective is to quantify long-term temporal and spatial changes in air concentrations and deposition in gaseous NH_3. The monitoring provides a baseline in NH_3, which is necessary for examining responses to changes in the agricultural sector and to assess 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.

The main sources of NH_3 in the atmosphere are from the decomposition and volatilisation of animal wastes. 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. It is recognised that deposition of atmospheric NH_3 contributes to acidification and eutrophication processes, which can cause damage to sensitive ecosystems.

A 2-tiered approach was originally used in the network; this consisted of a baseline network of around 50 sites sampling ammonia using the active DELTA (DEnuder for Long-Term Atmospheric sampling) system - where power is available. A secondary network of passive diffusion tubes explored air concentration variability in high concentration areas, with the method calibrated at 10 sites against the DELTA approach. In both cases, sampling was performed on a monthly basis.

Further methodological improvements were introduced over time. In 1999, the DELTA method was extended to allow sampling of ammonium aerosol at all active sites. This was followed by the establishment of the Nitric Acid Monitoring Network at 12 of the active sites, using an extension of the DELTA method to additionally sample gaseous HNO_3/SO_2/HCl, aerosol NO_3^-/SO_4^{2-}/Cl^- and the base cations Ca^{2+}/Mg^{2+}/Na^+, also on a monthly basis. In 2000, a new improved passive sampling method was developed and introduced; the Adapted Low-cost, Passive High Absorption (ALPHA) sampler (LOD, Limit of Detection = 0.02 µg NH_3 m^{-3}) replaced the less sensitive diffusion tube (LOD = 1 µg NH_3 m^{-3}) in the network.

Accompanying these changes has been an increase in the number of monitoring sites to 94, to improve the interpolated concentration field for NH_3; at the same time, there was a reduction in the number of sites monitoring NH_4^+, as this is a secondary pollutant with less spatial variability than NH_3.

There are currently 94 sites in the NAMN. At 57 of these sites, an active diffusion denuder methodology using the CEH DELTA (DEnuder for Long Term Atmospheric sampling) system is used to provide the main spatial and temporal patterns of NH_3 (and also NH_4^+ aerosol) across the UK. The high sensitivity ALPHA (Adapted Low-cost Passive High-Absorption) sampler is implemented at a further 49 sites to assess regional and local scale variability in air NH_3 concentrations in source regions.

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 ALPHA sampler has also been tested in several international intercomparisons, for example the EC ECOMONT project, and was included in the CEN TC264/WG11 pilot study into diffusive samplers for NH_3. The number of DELTA sites where an extension of the method is used to additionally sample acid gases and aerosols as part of the Nitric Acid Monitoring network has also increased from 12 to 30 sites in January 2006.

Overall, the NAMN structure currently consists of:

Site type	Number
DELTA sites sampling gaseous NH_3	57
DELTA sites also sampling aerosol NH_4^+	43
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	49
Intercomparison sites with both DELTA & ALPHA samplers	12
Total number of sites	94

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 contract. In January 2006, the network was expanded from 12 sites to 30 sites, many of which are integrated with the UK National Ammonia Monitoring Network (NAMN). An extension of the DELTA system at the NAMN sites is used to additionally sample HNO_3 and related species (SO_2, HCl, NO_3^-, SO_4^{2-}, Cl^-, Na^+, Ca^{2+}, Mg^{2+}), in parallel with monthly sampling of NH_3 and NH_4^+at the 57 NAMN sites.

The aim of these measurements is to:

- Explore spatial patterns
- Compare results with dispersion models, seasonality and
- Contribute to national N deposition estimates.

In January 2006, the network was expanded from 12 to 30 sites. The drivers for this expansion of the programme are:

- Increasing use of the measurement data in, for example, Pollution Climate mapping and assessing Acid Deposition Processes
- 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), thereby contributing to mass closure, which was one of the recommendations in the Defra's Air Quality Expert Group's report on Particulate Matter
- To provide measurements of rural SO_2 levels, replacing measurements made previously in the ADMN and rural SO_2 programmes (A3.2).
- To reduce uncertainties in the calculation of national and regional deposition budgets, especially in upland areas which are sensitive to acid deposition
- To co-locate the samplers with equipment from other monitoring networks, improving overall cost-effectiveness of the measurement programme and allowing intercomparison between samplers.

Sulphur dioxide measurements, as previously made by the Rural SO_2 and Acid Deposition monitoring networks, are now obtained from the expanded nitric acid monitoring network.

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 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 units of μgm^{-3}.

In 2005, monitoring of Black Smoke ceased to be a regulatory requirement in the United Kingdom, with particulate matter being regulated as PM_{10} and $PM_{2.5}$. In that year, Defra commissioned an independent review of the UK urban network for measurement of Black Smoke, SO_2 and NO_2. Its recommendations for Black Smoke monitoring included continuing a network of about 20 sites, some of which should be at AURN locations.

The contract to run the new UK Black Smoke Network started on 1st September 2006. Samplers at the 10 AURN sites were installed between October 2006 and March 2007.

The design of the Network was planned to incorporate 11 existing Black Smoke sites and to install 10 Black Smoke samplers in AURN stations. The sites are given in the Table below and Figure 6.8 in Part 1 of this report.

Existing Sites	AURN sites
Strabane 2	Edinburgh St Leonard's
Cardiff 12	Glasgow Centre
Halifax 17	Manchester Piccadilly
South Kirkby 1	Belfast Centre
Halesowen 8	Bradford
Sunderland 8	Stoke Centre
Norwich 7	North Kensington
Dunmurry 3	Birmingham Tyburn
Woolwich 9	Nottingham Centre
Bath 6	Folkestone, Kent Network
Marylebone Road	

Black Smoke sampling uses the 8-port sampler that has historically been used in the UK network, based on the standard method BS 1747 Part 11, ISO 9835. The principle of the 8-port sampler method involves drawing air at a constant flow rate of around 1.4 l/min through a Whatman Number 1 cellulose filter, so that about 2 m^3 of air (at ambient conditions of temperature and pressure) is sampled for each daily sample. Suspended particulate matter is collected on the filter over an area determined by a choice of clamp – in this case with a one inch diameter - forming a dark stain. The inlet - an upturned funnel - is not designed to be size selective, and has been shown in one study to collect the approximate size fraction $PM_{4.5}$.

The 8-port sampler is designed with eight pairs of filter clamps for weekly operation, providing daily sampling from a midnight-to-midnight basis. The timed eight-port valve is set to switch over at midnight to expose a fresh filter paper each day. Weekly visits are made to change filter papers and to record weekly sample volumes and flow rates.

Black smoke concentrations are then estimated by means of a reflectance measurement. The darkness of the stain is measured with an EEL M43D reflectometer, the reflectance being determined relative to a blank filter of the same type. The instrument uses a light bulb to give a broad band source that is reflected back from the smoke stain to a photo-sensitive element and produces a reading between 0% and 100% reflectance. NPL measures the reflectance of all of the filters sampled by the Network. Previously, reflectometry measurements were performed by local Councils using their own reflectometers.

The measured reflectance, sampled volume and filter area are used to calculate the concentration of dark particulate matter in the sampled air, as Black Smoke Index, with units of µg/m^3, using the relationship given in BS 1747: Part 2:

$$C = \frac{1}{V}\left(91679.22 - 3332.046R + 49.618884R^2 - 0.35329778R^3 + 0.0009863435R^4\right)$$

where:

C = concentration in µg/m^3
V = volume of sampled air in ft^3
R = reflectometer reading (%)

The above relationship is only valid for a one inch diameter filter clamp - an additional factor is required for other clamp sizes. This relationship is also only valid for values of R above 40%, which was true for all samples measured in the Network over recent years.

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	2006	-0.1	-0.14	0.01	-0.93	12
Harwell	RU	98 %ile	1995	2006	-0.38	-0.6	0	-0.92	12
London Eltham	SU	Annual mean	1994	2006	-0.32	-0.38	-0.1	-0.92	10
London Eltham	SU	98 %ile	1994	2006	-1.5	-1.57	0.23	-0.88	10

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	2006	-0.02	-0.02	0	-0.95	11
Harwell	RU	98 %ile	1996	2006	-0.05	-0.1	0.1	-0.88	11
London Eltham	SU	Annual mean	1994	2006	-0.04	-0.05	-0.01	-0.99	10
London Eltham	SU	98 %ile	1994	2006	-0.24	-0.23	0.03	-0.92	10

* 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 at:

http://en.wikipedia.org/wiki/Spearman%27s_rank_correlation_coefficient or
http://thesaurus.maths.org/mmkb/entry.html;jsessionid=4479ADC6A4A9960FB664227E1CC708E1?action=entryByConcept&id=351&langcode=en

A4.3(i) Sites with Significant Trends for Carbon Monoxide, mg m^{-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
Bath Roadside	RD	Annual mean	1997	2006	-0.1	-0.1	-0.1	-0.99	10
Bath Roadside	RD	98 %ile	1997	2006	-0.3	-0.3	-0.1	-0.98	10
Belfast Centre	UC	Annual mean	1992	2006	-0.1	-0.1	0	-0.94	15
Belfast Centre	UC	98 %ile	1992	2006	-0.3	-0.4	0.2	-0.94	15
Birmingham Centre	UC	Annual mean	1992	2006	0	0	0	-0.88	15
Birmingham Centre	UC	98 %ile	1992	2006	-0.1	-0.8	-0.1	-0.96	15
Bristol Old Market	RD	Annual mean	1997	2006	-0.1	-0.7	-0.2	-0.88	10
Bristol Old Market	RD	98 %ile	1997	2006	-0.4	-2.6	-0.7	-0.92	10
Cardiff Centre	UC	Annual mean	1992	2006	0	-0.1	0.1	-0.88	15
Cardiff Centre	UC	98 %ile	1992	2006	-0.1	-0.7	-0.1	-0.96	15
Derry	UB	98 %ile	1997	2006	-0.1	-0.2	-0.1	-0.95	10
Exeter Roadside	RD	Annual mean	1997	2006	-0.1	-0.5	-0.1	-0.95	10
Exeter Roadside	RD	98 %ile	1997	2006	-0.3	-2.7	-0.6	-0.99	10
Glasgow Centre	UC	Annual mean	1997	2006	0	-0.1	0	-0.78	10
Glasgow Centre	UC	98 %ile	1997	2006	-0.2	-0.7	-0.1	-0.88	10
Glasgow City Chambers	UB	Annual mean	1990	2006	-0.1	-0.1	0.3	-0.93	17
Glasgow City Chambers	UB	98 %ile	1990	2006	-0.3	-0.6	-0.1	-0.97	17
Glasgow Kerbside	KB	Annual mean	1997	2006	-0.1	-0.3	-0.1	-0.95	10
Glasgow Kerbside	KB	98 %ile	1997	2006	-0.3	-0.8	-0.4	-0.98	10
Leeds Centre	UC	Annual mean	1993	2006	0	-0.2	0	-0.78	14
Leeds Centre	UC	98 %ile	1993	2006	-0.1	-0.3	-0.1	-0.86	14
Leicester Centre	UC	Annual mean	1994	2006	0	-0.1	0	-0.72	13
Leicester Centre	UC	98 %ile	1994	2006	-0.1	-0.2	0	-0.96	13
London A3 Roadside	RD	Annual mean	1997	2006	-0.1	-0.2	-0.1	-0.97	10
London A3 Roadside	RD	98 %ile	1997	2006	-0.3	-1.2	-0.4	-0.97	10
London Bexley	SU	Annual mean	1994	2006	0	0	0	-0.8	13
London Bexley	SU	98 %ile	1994	2006	-0.1	-0.5	0	-0.9	13
London Bloomsbury	UC	Annual mean	1992	2006	0	-0.2	0	-0.75	15
London Bloomsbury	UC	98 %ile	1992	2006	-0.1	-0.7	0.1	-0.81	15
London Brent	UB	Annual mean	1996	2006	0	-0.1	0.1	-0.66	11
London Brent	UB	98 %ile	1996	2006	-0.2	-0.3	1.2	-0.95	11
London Hackney	UC	Annual mean	1997	2006	0	0	0.2	-0.68	10
London Hackney	UC	98 %ile	1997	2006	-0.2	-0.1	0.6	-0.94	10
London Hillingdon	SU	Annual mean	1997	2006	0	-0.1	-0.1	-0.9	10
London Hillingdon	SU	98 %ile	1997	2006	-0.1	-1.8	-0.3	-0.96	10

A4.3 (ii) Sites with Significant Trends for Carbon Monoxide, mg m^{-3} / yr (cont)

Carbon Monoxide mg m^{-3} / yr - *continued*									
Site	**Environment**	**Annual Parameter**	**Start Year**	**End Year**	**Slope**	**Low Range**	**High Range**	**Rho**	**No. of years**
London N. Kensington	UB	98 %ile	1996	2006	-0.1	-0.5	1	-0.93	11
London Southwark	UC	Annual mean	1997	2006	0	-0.1	0	-0.78	10
London Southwark	UC	98 %ile	1997	2006	-0.2	-1.3	-0.3	-0.92	10
Manchester Piccadilly	UC	98 %ile	1996	2006	-0.1	-0.2	0.3	-0.82	11
Middlesbrough	I	98 %ile	1995	2006	0	-0.1	0	-0.78	12
Newcastle Centre	UC	Annual mean	1992	2006	-0.1	-0.1	0	-0.95	15
Newcastle Centre	UC	98 %ile	1992	2006	-0.2	-0.4	-0.1	-0.98	15
Nottingham Centre	UC	Annual mean	1997	2006	-0.1	-0.1	0	-0.75	10
Nottingham Centre	UC	98 %ile	1997	2006	-0.2	-0.6	-0.2	-0.93	10
Sheffield Centre	UC	Annual mean	1996	2006	0	-0.1	0	-0.8	11
Sheffield Centre	UC	98 %ile	1996	2006	-0.2	-0.3	0.3	-0.95	11
Sheffield Tinsley	I	Annual mean	1992	2006	0	-0.4	0	-0.63	15
Sheffield Tinsley	I	98 %ile	1992	2006	-0.1	-2.7	-0.3	-0.9	15
Southampton Centre	UC	Annual mean	1994	2006	-0.1	-0.1	0	-0.92	13
Southampton Centre	UC	98 %ile	1994	2006	-0.2	-0.5	-0.1	-0.97	13
Stoke-on-Trent Centre	UC	Annual mean	1997	2006	0	-0.1	0	-0.91	10
Stoke-on-Trent Centre	UC	98 %ile	1997	2006	-0.2	-0.8	-0.2	-0.97	10
Swansea	UC	Annual mean	1995	2006	0	-0.1	0	-0.9	12
Swansea	UC	98 %ile	1995	2006	-0.2	-0.2	-0.1	-0.98	12
Thurrock	UB	Annual mean	1997	2006	0	-0.2	0	-0.76	10
Thurrock	UB	98 %ile	1997	2006	-0.1	-1.3	-0.2	-0.86	10
Tower Hamlets Roadside	RD	Annual mean	1996	2006	-0.2	-0.2	0.1	-0.93	11
Tower Hamlets Roadside	RD	98 %ile	1996	2006	-0.5	-0.6	0.5	-0.98	11
West London	UB	Annual mean	1990	2006	-0.1	-0.3	0.3	-0.77	17
West London	UB	98 %ile	1990	2006	-0.3	-0.6	1.2	-0.96	17
Wolverhampton Centre	UC	Annual mean	1996	2006	0	-0.1	0	-0.76	11
Wolverhampton Centre	UC	98 %ile	1996	2006	-0.1	-0.3	0.2	-0.92	11

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**
Belfast Centre	UC	Annual mean	1992	2006	-1.1	-2	-0.6	-0.81	15
Belfast Centre	UC	98 %ile	1992	2006	-1.9	-10.5	-1.5	-0.59	15
Billingham	I	Annual mean	1987	2006	-0.6	-2.2	-0.5	-0.79	20
Billingham	I	98 %ile	1987	2006	-0.9	-9	-0.7	-0.58	20
Birmingham Centre	UC	Annual mean	1993	2006	-1.6	-3	-0.5	-0.84	14
Birmingham Centre	UC	98 %ile	1993	2006	-3	-3.1	6	-0.76	14
Bolton	UB	98 %ile	1997	2006	-1.4	-15	-1.8	-0.64	10
Cardiff Centre	UC	Annual mean	1992	2006	-1.1	-4	-0.9	-0.83	15
Cardiff Centre	UC	98 %ile	1992	2006	-1.5	-8	-1	-0.74	15
Glasgow City Chambers	UB	Annual mean	1987	2006	-0.3	-4	-0.6	-0.6	20
Haringey Roadside	RD	Annual mean	1996	2006	-1.2	-2	2	-0.87	11
Haringey Roadside	RD	98 %ile	1996	2006	-2.2	-14.5	0	-0.73	11
Harwell	RU	Annual mean	1996	2006	-1	-2.6	0.6	-0.78	11
Harwell	RU	98 %ile	1996	2006	-2.1	-4.7	8.6	-0.85	11
Leamington Spa	UB	98 %ile	1997	2006	-1.4	-3	1.7	-0.66	10
Leeds Centre	UC	Annual mean	1993	2006	-1.9	-1.9	4	-0.83	14
Leeds Centre	UC	98 %ile	1993	2006	-3	-2	11	-0.69	14
Leicester Centre	UC	Annual mean	1994	2006	-1.1	-1.5	2	-0.88	13
Leicester Centre	UC	98 %ile	1994	2006	-2	-2.3	2	-0.72	13
London Bexley	SU	Annual mean	1994	2006	-0.9	-1.5	0	-0.7	13
London Bloomsbury	UC	Annual mean	1992	2006	-1.4	-1.7	0.8	-0.67	14
London Bloomsbury	UC	98 %ile	1992	2006	-3.1	-18	1	-0.71	14
London Brent	UB	Annual mean	1996	2006	-1	-3.5	-0.9	-0.8	11
London Eltham	SU	Annual mean	1996	2006	-0.5	-2	2	-0.69	11
London Hackney	UC	Annual mean	1997	2006	-1.6	-4	-1	-0.67	10
London N. Kensington	UB	Annual mean	1996	2006	-0.8	-1	6	-0.74	11
London Southwark	UC	Annual mean	1997	2006	-1	-3	1	-0.72	10
London Teddington	UB	Annual mean	1997	2006	-1.1	-3.5	-1.2	-0.88	10
London Teddington	UB	98 %ile	1997	2006	-1.2	-17.4	-2.9	-0.78	10
Lullington Heath	RU	Annual mean	1991	2006	-0.4	-1.5	0.9	-0.86	16
Lullington Heath	RU	98 %ile	1991	2006	-1.5	-4.2	-0.4	-0.87	16
Manchester Town Hall	UB	Annual mean	1987	2006	-0.8	-3.5	0.8	-0.78	20
Manchester Town Hall	UB	98 %ile	1987	2006	-2.5	-5.3	5.7	-0.77	20

A4.4 (ii) Sites with Significant Trends for Nitrogen Dioxide, µg m^{-3} / yr (cont)

Nitrogen Dioxide µg m^{-3} / yr - *continued*									
Site	**Environment**	**Annual Parameter**	**Start Year**	**End Year**	**Slope**	**Low Range**	**High Range**	**Rho**	**No. of years**
Middlesbrough	I	Annual mean	1995	2006	-0.8	-2	-0.8	-0.78	12
Middlesbrough	I	98 %ile	1995	2006	-1	-3.7	-0.5	-0.63	12
Newcastle Centre	UC	Annual mean	1992	2006	-1.5	-4	3	-0.91	15
Newcastle Centre	UC	98 %ile	1992	2006	-1.9	-10.7	10	-0.77	15
Nottingham Centre	UC	Annual mean	1997	2006	-1.8	-3.5	-1.7	-0.9	10
Port Talbot	I	Annual mean	1997	2006	-0.6	-2	-0.7	-0.88	10
Port Talbot	I	98 %ile	1997	2006	-1.6	-2.8	1	-0.79	10
Rochester Stoke	RU	Annual mean	1996	2006	-0.6	-1.5	-0.6	-0.93	11
Rochester Stoke	RU	98 %ile	1996	2006	-1.1	-1.1	7.7	-0.94	11
Salford Eccles	I	Annual mean	1997	2006	-1	-2	0	-0.75	10
Sheffield Centre	UC	Annual mean	1996	2006	-1.2	-4	0	-0.66	11
Sheffield Centre	UC	98 %ile	1996	2006	-3.2	-5.3	8	-0.79	11
Sheffield Tinsley	I	Annual mean	1991	2006	-1.3	-1.4	7	-0.92	16
Sheffield Tinsley	I	98 %ile	1991	2006	-2.8	-5.4	15	-0.86	16
Southampton Centre	UC	Annual mean	1994	2006	-1.4	-1.8	1	-0.93	13
Southampton Centre	UC	98 %ile	1994	2006	-2.9	-3.8	2	-0.91	13
Swansea	UC	Annual mean	1995	2006	-0.6	-1.8	2	-0.68	12
Walsall Alumwell	UB	Annual mean	1987	2006	-0.8	-6	-0.5	-0.87	20
Walsall Alumwell	UB	98 %ile	1987	2006	-1.6	-15	-1.2	-0.74	20
West London	UB	Annual mean	1987	2006	-1.1	-1.5	7.5	-0.89	20
West London	UB	98 %ile	1987	2006	-2.9	-6.3	27	-0.85	20
Wolverhampton Centre	UC	Annual mean	1996	2006	-0.5	-4.5	-0.9	-0.77	11

A4.5(i) Sites with Significant Trends for Oxides of Nitrogen (NOx), 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
Bath Roadside	RD	Annual mean	1997	2006	-15.4	-22.3	-8	-0.7	10
Belfast Centre	UC	Annual mean	1992	2006	-2.9	-6.5	-1.9	-0.73	15
Billingham	I	Annual mean	1987	2006	-2	-15	-1.8	-0.89	20
Billingham	I	98 %ile	1987	2006	-7.4	-105	-6.4	-0.8	20
Birmingham Centre	UC	Annual mean	1993	2006	-3.6	-6	-2.8	-0.92	14
Birmingham Centre	UC	98 %ile	1993	2006	-16.4	-21.3	23	-0.75	14
Bolton	UB	Annual mean	1997	2006	-3.4	-15	-2.7	-0.76	10
Bolton	UB	98 %ile	1997	2006	-26.4	-61	-10	-0.82	10
Bury Roadside	RD	Annual mean	1997	2006	-14.2	-55	-18.6	-0.94	10
Bury Roadside	RD	98 %ile	1997	2006	-41.2	-102	-25	-0.9	10
Cardiff Centre	UC	Annual mean	1992	2006	-3	-19	-3.5	-0.86	15
Cardiff Centre	UC	98 %ile	1992	2006	-15	-80	-15.1	-0.87	15
Glasgow City Chambers	UB	Annual mean	1987	2006	-5.4	-5.4	1.8	-0.89	20
Glasgow City Chambers	UB	98 %ile	1987	2006	-21.5	-138	43	-0.88	20
Glasgow Kerbside	KB	98 %ile	1997	2006	-19	-70.7	-8.3	-0.72	10
Haringey Roadside	RD	Annual mean	1996	2006	-7.5	-12.5	20	-0.98	11
Haringey Roadside	RD	98 %ile	1996	2006	-29.3	-48.3	251	-0.95	11
Harwell	RU	Annual mean	1996	2006	-1.5	-3.9	2.2	-0.68	11
Harwell	RU	98 %ile	1996	2006	-5.5	-18.2	23.9	-0.66	11
Leamington Spa	UB	Annual mean	1997	2006	-1	-7	0.7	-0.66	10
Leeds Centre	UC	Annual mean	1993	2006	-5.7	-7.7	6	-0.92	14
Leeds Centre	UC	98 %ile	1993	2006	-20.7	-31.4	36	-0.79	14
Leicester Centre	UC	Annual mean	1994	2006	-2.4	-3.8	1	-0.92	13
Leicester Centre	UC	98 %ile	1994	2006	-7.4	-20.1	8.7	-0.77	13
London A3 Roadside	RD	Annual mean	1997	2006	-15.2	-34	-19	-0.94	10
London A3 Roadside	RD	98 %ile	1997	2006	-42.4	-98.7	-19	-0.9	10
London Bexley	SU	Annual mean	1994	2006	-3.3	-9	-0.3	-0.85	13
London Bexley	SU	98 %ile	1994	2006	-14.6	-82	21	-0.65	13
London Bloomsbury	UC	Annual mean	1992	2006	-4.5	-12	2.4	-0.85	15
London Bloomsbury	UC	98 %ile	1992	2006	-17.4	-88	10.2	-0.88	15
London Brent	UB	Annual mean	1996	2006	-2	-13	-3.4	-0.87	11
London Eltham	SU	Annual mean	1996	2006	-3	-8.5	6	-0.87	11
London Eltham	SU	98 %ile	1996	2006	-14.3	-46	85	-0.8	11
London Hackney	UC	Annual mean	1997	2006	-4.4	-38	-7.9	-0.97	10
London Hackney	UC	98 %ile	1997	2006	-13.4	-308	-44.1	-0.87	10
London N. Kensington	UB	Annual mean	1996	2006	-2.5	-4.5	20	-0.9	11
London N. Kensington	UB	98 %ile	1996	2006	-10.2	-58	211	-0.63	11
London Southwark	UC	Annual mean	1997	2006	-5.2	-11	-3	-0.92	10
London Southwark	UC	98 %ile	1997	2006	-18.2	-216	-32	-0.78	10

A4.5 (ii) Sites with Significant Trends for Oxides of Nitrogen (NOx), µg m^{-3} / yr (cont)

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 Teddington	UB	Annual mean	1997	2006	-2.7	-19.5	-3.5	-0.84	10
London Wandsworth	UC	Annual mean	1996	2006	-4.7	-18.5	-5	-0.93	11
London Wandsworth	UC	98 %ile	1996	2006	-15	-67.5	132	-0.82	11
Lullington Heath	RU	Annual mean	1991	2006	-0.4	-1	0.8	-0.89	16
Lullington Heath	RU	98 %ile	1991	2006	-2.3	-4.9	1.8	-0.8	16
Manchester Piccadilly	UC	Annual mean	1996	2006	-1.2	-13	-1.2	-0.73	10
Manchester Town Hall	UB	Annual mean	1987	2006	-4.4	-4.8	2.6	-0.94	20
Manchester Town Hall	UB	98 %ile	1987	2006	-16.2	-57.3	62	-0.88	20
Middlesbrough	I	Annual mean	1995	2006	-1.2	-4	0.5	-0.75	12
Newcastle Centre	UC	Annual mean	1992	2006	-5.1	-12.7	15	-0.95	15
Newcastle Centre	UC	98 %ile	1992	2006	-25	-59.3	76	-0.92	15
Nottingham Centre	UC	Annual mean	1997	2006	-4.2	-7.7	-2	-0.95	10
Port Talbot	I	Annual mean	1997	2006	-1.8	-4	-2	-0.94	10
Port Talbot	I	98 %ile	1997	2006	-8.8	-31	-8.1	-0.75	10
Rochester Stoke	RU	Annual mean	1996	2006	-0.5	-2.6	0.2	-0.85	11
Rochester Stoke	RU	98 %ile	1996	2006	-5.3	-10.8	24.9	-0.72	11
Salford Eccles	I	Annual mean	1997	2006	-4.2	-8.7	-1.8	-0.83	10
Salford Eccles	I	98 %ile	1997	2006	-22.2	-50	4.8	-0.65	10
Sheffield Centre	UC	Annual mean	1996	2006	-4.5	-13	7	-0.81	11
Sheffield Centre	UC	98 %ile	1996	2006	-23.7	-40.7	67	-0.66	11
Sheffield Tinsley	I	Annual mean	1991	2006	-6.6	-11	22	-0.97	16
Sheffield Tinsley	I	98 %ile	1991	2006	-21.1	-101	214	-0.88	16
Southampton Centre	UC	Annual mean	1994	2006	-4.1	-6.8	-1	-0.97	13
Southampton Centre	UC	98 %ile	1994	2006	-17.4	-48	3.7	-0.88	13
Swansea	UC	Annual mean	1995	2006	-2.6	-6.8	-0.1	-0.6	12
Swansea	UC	98 %ile	1995	2006	-11.3	-26.8	-1.9	-0.62	12
Thurrock	UB	Annual mean	1997	2006	-1.6	-5	1	-0.81	10
Tower Hamlets Roadside	RD	Annual mean	1996	2006	-15.2	-32.5	-13	-0.99	11
Tower Hamlets Roadside	RD	98 %ile	1996	2006	-50	-84	100	-0.95	11
Walsall Alumwell	UB	Annual mean	1987	2006	-4.5	-11.7	-2	-0.96	20
Walsall Alumwell	UB	98 %ile	1987	2006	-22.7	-97.7	-24.1	-0.9	20
West London	UB	Annual mean	1987	2006	-5.7	-8.3	26	-0.96	20
West London	UB	98 %ile	1987	2006	-21.2	-68	209	-0.9	20
Wolverhampton Centre	UC	Annual mean	1996	2006	-2	-8.5	3	-0.69	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	2006	-1	-1	4	-0.97	15
Belfast Centre	UC	98 %ile	1992	2006	-4.1	-15	-4.6	-0.9	15
Birmingham Centre	UC	Annual mean	1992	2006	-0.8	-1.5	-0.3	-0.69	15
Birmingham Centre	UC	98 %ile	1992	2006	-2.8	-8.5	-1.8	-0.75	15
Cardiff Centre	UC	Annual mean	1993	2006	-0.6	-3	3	-0.65	14
Cardiff Centre	UC	98 %ile	1993	2006	-1.9	-10.5	64	-0.77	14
Derry	UB	98 %ile	1997	2006	-2.4	-4	13	-0.82	10
Glasgow Centre	UC	Annual mean	1997	2006	-0.8	-1.5	0.3	-0.73	10
Glasgow Centre	UC	98 %ile	1997	2006	-2.4	-3.5	9	-0.79	10
Haringey Roadside	RD	Annual mean	1996	2006	-0.5	-2	0	-0.69	11
Haringey Roadside	RD	98 %ile	1996	2006	-1.8	-4.5	8	-0.71	11
Leeds Centre	UC	Annual mean	1993	2006	-0.9	-1.3	0.3	-0.75	14
Leeds Centre	UC	98 %ile	1993	2006	-2.7	-5.3	7	-0.7	14
Leicester Centre	UC	Annual mean	1994	2006	-0.5	-1.3	0.5	-0.6	13
Leicester Centre	UC	98 %ile	1994	2006	-1.9	-6	4	-0.67	13
London Bexley	SU	Annual mean	1994	2006	-0.6	-1.5	-0.4	-0.63	13
London Bexley	SU	98 %ile	1994	2006	-2.1	-4.3	4	-0.81	13
London Bloomsbury	UC	Annual mean	1992	2006	-0.9	-1.5	0	-0.8	14
London Bloomsbury	UC	98 %ile	1992	2006	-3.3	-7	0.3	-0.82	14
London Brent	UB	98 %ile	1996	2006	-0.8	-2	11	-0.67	11
London N. Kensington	UB	98 %ile	1996	2006	-1.2	-2.5	14	-0.63	11
Newcastle Centre	UC	Annual mean	1992	2006	-1.4	-2	1	-0.85	15
Newcastle Centre	UC	98 %ile	1992	2006	-4.8	-6.4	1	-0.79	15
Nottingham Centre	UC	Annual mean	1997	2006	-0.4	-2	-0.5	-0.68	10
Port Talbot	I	Annual mean	1997	2006	-0.4	-1.2	0	-0.66	10
Port Talbot	I	98 %ile	1997	2006	-2.8	-4.6	10	-0.66	10
Sheffield Centre	UC	Annual mean	1996	2006	-0.7	-3	-0.9	-0.76	11
Sheffield Centre	UC	98 %ile	1996	2006	-1	-18	-3.4	-0.62	11
Southampton Centre	UC	Annual mean	1994	2006	-0.3	-1	0.3	-0.64	13
Southampton Centre	UC	98 %ile	1994	2006	-1.3	-4	2.5	-0.78	13
Swansea	UC	98 %ile	1995	2006	-1.9	-8.8	-2.4	-0.69	11
Wolverhampton Centre	UC	98 %ile	1996	2006	-1.5	-20	-3.8	-0.66	11

A4.7 Sites with Significant Trends for $PM_{2.5}$ Particulate Matter, μgm^{-3} / yr

No sites have significant trends for $PM_{2.5}$.

A 4.8(i) Sites with Significant Trends for Sulphur Dioxide, $\mu g\ m^{-3}$ / yr

Sulphur Dioxide $\mu g\ m^{-3}$ / yr									
Site	Environment	Annual Parameter	Start Year	End Year	Slope	Low Range	High Range	Rho	No. of years
Barnsley 12	UB	Annual mean	1994	2006	-1.5	-1.7	5	-0.9	13
Barnsley 12	UB	98 %ile	1994	2006	-6.8	-9	8	-0.85	13
Belfast Centre	UC	Annual mean	1992	2006	-3.6	-3.7	6	-0.96	15
Belfast Centre	UC	98 %ile	1992	2006	-18.3	-16.7	16	-0.98	15
Belfast East	UB	Annual mean	1990	2006	-5	-5.2	6	-0.99	17
Belfast East	UB	98 %ile	1990	2006	-25.6	-32.8	88	-0.97	17
Birmingham Centre	UC	Annual mean	1992	2006	-1.5	-3.5	-1.8	-0.99	15
Birmingham Centre	UC	98 %ile	1992	2006	-7.3	-17.5	-8.4	-0.99	15
Bolton	UB	Annual mean	1997	2006	-0.8	-2.5	-1.1	-0.92	10
Bolton	UB	98 %ile	1997	2006	-4.2	-10.5	0	-0.93	10
Bury Roadside	RD	Annual mean	1997	2006	-2.4	-8.5	-3.7	-0.97	10
Bury Roadside	RD	98 %ile	1997	2006	-7.8	-24	16	-0.97	10
Cardiff Centre	UC	Annual mean	1992	2006	-1.1	-3	-1.1	-0.98	15
Cardiff Centre	UC	98 %ile	1992	2006	-4.4	-11.5	-4.4	-0.97	15
Glasgow Centre	UC	Annual mean	1997	2006	-1.6	-1.1	0.5	-0.82	10
Glasgow Centre	UC	98 %ile	1997	2006	-3.8	-13	-3	-0.89	10
Harwell	RU	98 %ile	1996	2006	-1.5	-14.9	-2.6	-0.78	11
Ladybower	RU	Annual mean	1989	2006	-1.4	-3.8	2.3	-0.93	18
Ladybower	RU	98 %ile	1989	2006	-6.9	-26.6	14.9	-0.95	18
Leamington Spa	UB	Annual mean	1997	2006	-0.4	-0.7	0	-0.84	10
Leamington Spa	UB	98 %ile	1997	2006	-2.6	-4	5	-0.9	10
Leeds Centre	UC	Annual mean	1993	2006	-1.6	-3.7	-1.8	-0.97	14
Leeds Centre	UC	98 %ile	1993	2006	-6.4	-18.7	2	-0.93	14
Leicester Centre	UC	Annual mean	1994	2006	-1	-3.5	-1.4	-0.98	13
Leicester Centre	UC	98 %ile	1994	2006	-4.9	-10.5	-2	-0.98	13
London Bexley	SU	Annual mean	1994	2006	-1.1	-2.8	1	-0.87	13
London Bexley	SU	98 %ile	1994	2006	-7.7	-14.5	13	-0.84	13
London Bloomsbury	UC	Annual mean	1992	2006	-2	-2.3	1	-0.98	15
London Bloomsbury	UC	98 %ile	1992	2006	-10.4	-10.6	0	-0.98	15
London Brent	UB	Annual mean	1996	2006	-0.8	-4	-1	-0.72	11
London Brent	UB	98 %ile	1996	2006	-3.2	-11	-4	-0.88	11
London Eltham	SU	Annual mean	1996	2006	-0.3	-3	-0.9	-0.85	11
London Eltham	SU	98 %ile	1996	2006	-2.2	-18.5	-5	-0.78	11
London Hillingdon	SU	Annual mean	1997	2006	-1.4	-1.5	-0.8	-0.97	10
London Hillingdon	SU	98 %ile	1997	2006	-3.2	-9	-3	-0.87	10
London N. Kensington	UB	Annual mean	1996	2006	-0.7	-2	0	-0.9	11
London N. Kensington	UB	98 %ile	1996	2006	-3.5	-8.7	8	-0.91	11

A4.8 (ii)Sites with Significant Trends for Sulphur Dioxide, µg m^{-3} / yr (cont)

Sulphur Dioxide µg m^{-3} / yr - *continued*									
Site	**Environment**	**Annual Parameter**	**Start Year**	**End Year**	**Slope**	**Low Range**	**High Range**	**Rho**	**No. of years**
London Southwark	UC	Annual mean	1997	2006	-0.2	-3	-0.5	-0.72	10
London Southwark	UC	98 %ile	1997	2006	-1.6	-18	-3.5	-0.88	10
London Teddington	UB	Annual mean	1997	2006	-0.5	-2.4	-0.8	-0.94	10
London Teddington	UB	98 %ile	1997	2006	-2.1	-16	-4	-0.77	10
Lullington Heath	RU	Annual mean	1988	2006	-0.4	-1.4	-0.5	-0.87	16
Lullington Heath	RU	98 %ile	1988	2006	-1.9	-11.8	-3.8	-0.91	16
Manchester Piccadilly	UC	Annual mean	1996	2006	-1	-3	-0.5	-0.64	10
Manchester Piccadilly	UC	98 %ile	1996	2006	-5.8	-19	-7.4	-0.82	10
Middlesbrough	I	Annual mean	1995	2006	-1.1	-2	-1	-0.97	12
Middlesbrough	I	98 %ile	1995	2006	-4.8	-8.7	-2	-0.95	12
Newcastle Centre	UC	Annual mean	1992	2006	-1.5	-1.3	4	-0.95	15
Newcastle Centre	UC	98 %ile	1992	2006	-7.9	-8.3	8	-0.99	15
Nottingham Centre	UC	98 %ile	1997	2006	-6.4	-12	-4.3	-0.93	10
Port Talbot	I	Annual mean	1997	2006	-1.2	-6	-1.2	-0.69	10
Redcar	SU	Annual mean	1997	2006	-0.8	-1	3	-0.94	10
Redcar	SU	98 %ile	1997	2006	-5.4	-6	46	-0.96	10
Rochester Stoke	RU	Annual mean	1996	2006	-0.3	-2.5	-0.6	-0.89	11
Rochester Stoke	RU	98 %ile	1996	2006	-3.1	-18.6	-5.3	-0.98	11
Sheffield Centre	UC	Annual mean	1996	2006	-1.3	-5	-1.8	-0.87	11
Sheffield Centre	UC	98 %ile	1996	2006	-9.3	-24	-9.1	-0.99	11
Southampton Centre	UC	Annual mean	1994	2006	-0.6	-1.3	0	-0.9	13
Southampton Centre	UC	98 %ile	1994	2006	-1.7	-6.3	-2.4	-0.83	13
Stoke-on-Trent Centre	UC	98 %ile	1997	2006	-5.4	-12	2	-0.94	10
Sunderland	UB	Annual mean	1993	2006	-0.9	-5	-1	-0.94	13
Sunderland	UB	98 %ile	1993	2006	-5.2	-26	-5.9	-0.97	13
Swansea	UC	Annual mean	1995	2006	-1.6	-2.3	1	-0.88	12
Swansea	UC	98 %ile	1995	2006	-5.8	-11.3	0	-0.91	12
Wolverhampton Centre	UC	Annual mean	1996	2006	-1	-4	-0.4	-0.83	11
Wolverhampton Centre	UC	98 %ile	1996	2006	-6.2	-13	-1	-0.96	11

A4.9 Sites with Significant Trends for Ozone, $\mu g\ m^{-3}$ / yr

Ozone $\mu g\ m^{-3}$ / yr									
Site	**Environment**	**Annual Parameter**	**Start Year**	**End Year**	**Slope**	**Low Range**	**High Range**	**Rho**	**No. of years**
Aston Hill	RU	Annual mean	1987	2006	0.3	0.7	12	0.56	20
Belfast Centre	UC	Annual mean	1992	2006	0.6	-3	1.3	0.66	15
Belfast Centre	UC	98 %ile	1992	2006	0.5	-10	1.7	0.54	15
Birmingham Centre	UC	Annual mean	1992	2006	1	-1	1.5	0.91	15
Birmingham Centre	UC	98 %ile	1992	2006	0.5	-6	3.5	0.58	15
Bolton	UB	Annual mean	1997	2006	1.2	1	5	0.85	10
Bottesford	SU	Annual mean	1981	2006	0.6	-0.7	7	0.59	26
Bury Roadside	RD	Annual mean	1997	2006	0.6	1.2	4	0.95	10
Bury Roadside	RD	98 %ile	1997	2006	0.8	1.6	8	0.7	10
Bush Estate	RU	Annual mean	1986	2006	0.4	-7	1	0.64	21
Cardiff Centre	UC	Annual mean	1992	2006	1	0.6	2.7	0.88	15
Glasgow Centre	UC	Annual mean	1997	2006	0.6	0.8	4	0.83	10
Glazebury	SU	Annual mean	1988	2006	0.5	-5	0.4	0.53	19
Harwell	RU	Annual mean	1984	2006	0.3	-3.3	2	0.42	23
High Muffles	RU	Annual mean	1988	2006	0.2	0.3	3	0.55	19
Ladybower	RU	98 %ile	1989	2006	-1.6	-8	2	-0.49	18
Leeds Centre	UC	Annual mean	1993	2006	0.7	0.3	4	0.85	14
Leeds Centre	UC	98 %ile	1993	2006	0.9	0.8	7	0.63	14
Leicester Centre	UC	Annual mean	1994	2006	0.4	-0.5	1.8	0.77	13
London Bexley	SU	Annual mean	1995	2006	0.7	-2	1.3	0.8	12
London Bloomsbury	UC	Annual mean	1992	2006	0.6	-1	1	0.86	15
London Eltham	SU	Annual mean	1996	2006	0.5	-3	1	0.74	11
London Haringey	UC	Annual mean	1996	2006	0.7	-1	2	0.85	11
London Hillingdon	SU	Annual mean	1997	2006	0.8	0.7	3	0.82	10
London N. Kensington	UB	Annual mean	1996	2006	0.8	-4	1.7	0.86	11
London Teddington	UB	Annual mean	1997	2006	1.2	1	2	0.94	10
London Wandsworth	UC	Annual mean	1996	2006	0.7	-2	1.3	0.8	11
Lough Navar	RE	98 %ile	1987	2006	-0.4	-1	4	-0.55	20
Middlesbrough	I	Annual mean	1996	2006	0.8	-4	2	0.71	11
Newcastle Centre	UC	Annual mean	1992	2006	0.9	0.8	2	0.89	13
Newcastle Centre	UC	98 %ile	1992	2006	1	-4	2.3	0.8	13
Nottingham Centre	UC	Annual mean	1997	2006	1	0.5	3.5	0.8	10
Salford Eccles	I	Annual mean	1997	2006	0.8	0.3	3	0.76	10
Strath Vaich	RE	Annual mean	1987	2006	0.3	0.2	6	0.54	20
Swansea	UC	Annual mean	1995	2006	0.6	-6	1.1	0.61	12
Thurrock	UB	Annual mean	1997	2006	0.4	0	3	0.66	10
Wolverhampton Centre	UC	Annual mean	1996	2006	0.8	-2	2	0.88	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.

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)	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.
Set in regulations(3) for all UK:	Objective for Dec. 31st 2005, for protection of human health		Annual mean	40 (21)
Not intended to be set in regulations:	Objective for Dec. 31st 2000, for protection of vegetation.		Annual mean NO_x (NO_x as NO_2)	30 (16)
European Community 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)	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(6)	Health Guideline		1-hour mean	200
(Non-Mandatory Guidelines)	Health Guideline		Annual mean	40

(1) Conversions between $\mu g\ m^{-3}$ and ppb are as used by the EC, i.e. 1ppb NO_2 = 1.91 $\mu g\ m^{-3}$ at 20°C and 1013 mB.
(2) The Air Quality Strategy for England, Scotland, Wales and Northern Ireland. January 2000. ISBN 0-10-145482-1 & Addendum 2003.
(3) Air Quality (England) Regulations 2000 (SI 2000/928), Air Quality (Scotland) Regulations 2000 (SSI 2000/97), Air Quality (Wales) Regulations 2000 (SI 2000/1940 (W138)).
(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) 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)	Objective for Dec. 31st 2005, for protection of human health.		15-minute mean	266 (100) Not to be exceeded > 35 times per calendar year.
Set in regulations(3) for all UK.	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)	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(5)	Health Guideline		10-minute mean	500
(Non-Mandatory Guidelines)	Health Guideline		24-hour mean	125
	Health Guideline		Annual mean	50

(1) Conversions between $\mu g\ m^{-3}$ and ppb are as used by the EC, i.e. 1ppb SO_2 = 2.66 $\mu g\ m^{-3}$ at 20°C and 1013 mB.
(2) The Air Quality Strategy for England, Scotland, Wales and Northern Ireland. January 2000. ISBN 0-10-145482-1 & Addendum 2003.
(3) Air Quality (England) Regulations 2000 (SI 2000/928), Air Quality (Scotland) Regulations 2000 (SSI 2000/97), Air Quality (Wales) Regulations 2000 (SI 2000/1940 (W138)).
(4) 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.
(5)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[3]		AOT40[3] calculated from 1h values May- July.	18,000 $\mu g\ m^{-3}$ h averaged over 5 years.
European Community 3rd Daughter Directive[4]	Target Value To be achieved by 3-year period beginning 2010.		Max. daily 8-hour mean.	120 $\mu g\ m^{-3}$ 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 $\mu g\ m^{-3}$ 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 $\mu g\ m^{-3}$ and ppb are as used by the EC, i.e. 1ppb O_3 = 2.00 $\mu g\ m^{-3}$ at 20°C and 1013 mB.
(2) The Air Quality Strategy for England, Scotland, Wales and Northern Ireland. January 2000. ISBN 0-10-145482-1 & Addendum 2003.
(3) The Air Quality Strategy for England, Scotland, Wales and Northern Ireland. July 2007. The Stationery Office, PB12654.
(4) Directive (2002/3/EC)
(5) AOT40 statistic is the sum of the differences between hourly concentrations greater than 80 $\mu g\ m^{-3}$ (=40ppb) and 80 $\mu g\ m^{-3}$, 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).

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)] (Except Scotland)	Objective for Dec. 31st 2003		Max. Daily Running 8-hour mean	10 (8.6)
Scotland only[(4)]:	Objective for Dec. 31st 2003		Running 8-hour mean	10 (8.6)
European Community 2nd Daughter Directive[(5)]	Limit Value. To be achieved by Jan 1st 2005		Max. daily 8-hour mean	10 (8.6)
World Health Organisation[(6)]	Health Guideline		15-minute mean	100
	Health Guideline		30-minute mean	60
(Non-Mandatory Guidelines)	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. January 2000. ISBN 0-10-145482-1 & Addendum 2003.
(3) Air Quality (England) Regulations 2000 (SI 2000/928), Air Quality (Scotland) Regulations 2000 (SSI 2000/97), Air Quality (Wales) Regulations 2000 (SI 2000/1940 (W138)).
(4) Air Quality (Scotland) Amendment Regulations 2002 (SSI 2002/297).
(5) Council Directive 2000/69/EC. Transposed into UK Air Quality Regulations in England by SI 2002/3117, in Scotland by SSI 2002/556, in Wales by SI 2002/3183 (W299), and by Statutory Rule 2002 (357) in Northern Ireland.
(6) WHO Guidelines for Air Quality WHO/SDE/OEH/00.02 (2000).

Benzene

Guideline Set By	Description	Criteria Based On	Value[1] / μgm^{-3} (ppb)
The Air Quality Strategy[2,3] All UK	Objective for Dec. 31st 2003	Running annual mean	16.25 (5)
England[4] & Wales[5] only:	Objective for Dec. 31st 2010	Annual mean	5 (1.54)
Scotland[6] & Northern Ireland	Objective for Dec. 31st 2010	Running annual mean	3.25 (1.0)
European Community 2nd Daughter Directive[7]	Limit Value. To be achieved by Jan 1st 2010	Annual calendar year mean	5 (1.5)

(1) Conversions between $\mu g\ m^{-3}$ and ppb are those used by the EC, i.e. 1ppb benzene = 3.25 $\mu g\ m^{-3}$ at 20°C and 1013 mB.
(2) The Air Quality Strategy for England, Scotland, Wales and Northern Ireland. January 2000. ISBN 0-10-145482-1 & Addendum 2003.
(3) Air Quality (England) Regulations 2000 (SI 2000/928), Air Quality (Scotland) Regulations 2000 (SSI 2000/97), Air Quality (Wales) Regulations 2000 (SI 2000/1940 (W138)).
(4) Air Quality (Amendment) (England) Regulations 2002 (SI 2002/3043)
(5) Air Quality (Amendment) (Wales) Regulations 2002 (SI 2002/3182 (W298))
(6) Air Quality (Amendment) (Scotland) Regulations 2002 (SI 2002/297)
(7) Council Directive 2000/69/EC. Transposed into UK Air Quality Regulations in England by SI 2002/3117, in Scotland by SSI 2002/556, in Wales by SI 2002/3183 (W299), and by Statutory Rule 2002 (357) in Northern Ireland.

1,3-Butadiene

Guideline Set By	Description	Criteria Based On	Value[1] / μgm^{-3} (ppb)
The Air Quality Strategy[2,3] All UK	Objective for Dec. 31st 2003	Running annual mean	2.25 (1)

(1) Conversions between $\mu g\ m^{-3}$ and ppb are those used by the EC, i.e. 1ppb benzene = 2.25 $\mu g\ m^{-3}$ at 20°C and 1013 mB.
(2) The Air Quality Strategy for England, Scotland, Wales and Northern Ireland. January 2000. ISBN 0-10-145482-1. & Addendum 2003.
(3) Air Quality (England) Regulations 2000 (SI 2000/928), Air Quality (Scotland) Regulations 2000 (SSI 2000/97), Air Quality (Wales) Regulations 2000 (SI 2000/1940 (W138)).

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. January 2000. ISBN 0-10-145482-1 & Addendum 2003.
(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).

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.
New Air Quality Directive(2)	Limit Value for 2020, all UK except Scotland	Annual mean	25
	Exposure reduction target, urban background areas	Annual mean	20% reduction in annual mean concentration between 2010 and 2020.

(1) The Air Quality Strategy for England, Scotland, Wales and Northern Ireland. July 2007. The Stationery Office, PB12654. $PM_{2.5}$ not under regulation at this time.
(2) Under the new Air Quality Directive, still under negotiation.

Particulate Matter as PM_{10}

Guideline Set By	Description		Criteria Based On	Value / μgm^{-3}
UK Government Air Pollution Index	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
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(4)	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. January 2000. ISBN 0-10-145482-1 & Addendum 2003.
(2) Air Quality (England) Regulations 2000 (SI 2000/928), Air Quality (Scotland) Regulations 2000 (SSI 2000/97), Air Quality (Wales) Regulations 2000 (SI 2000/1940 (W138)).
(3) Air Quality (Amendment) (Scotland) Regulations 2002 (SI 2002/297)
(4) 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.

Lead (Pb)

Guideline Set By	Description	Criteria Based On	Value / μgm^{-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)	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(3) *(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. January 2000. ISBN 0-10-145482-1 & Addendum 2003.
(2) Council Directive 1999/30/EC
(3) 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.

Appendix A6- Calculation methods, statistical methods and measurement uncertainty

Here we provide boring but 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 EU 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'. 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 wide scale 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 Directives

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

A 6.2.1 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[P20].

Various air quality guidelines and statistics are defined in the documentation published by the UK Government [B2,B3,B11,B12], the European Community[B4,B5,P14-P19], the World Health Organisation[2P10-P13] and The Expert Panel on Air Quality Standards (EPAQS) [P1-P9]. 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.

A 6.2.2 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, then the statistics are 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 (see pp 16, 17- repealed at end of 2005). All other percentiles use the European Council NO_2 Directive method (see pp16, 17). 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[B2,B3,B11,B12], the European Community[B4,B5,P14-P19], the World Health Organisation[P10-P13-].

The following conversion factors from measured units to mass units defined in the EU Decision on Exchange of Information[P19].

Conversion Factors Between ppb and $\mu g\ m^{-3}$ and ppm and mgm^{-3}

Pollutant	WHO 25°C and 1013mb	EC 20 °C and 1013mb
Ozone	1 ppb = 1.9622 $\mu g\ m^{-3}$	1 ppb = 1.9957 $\mu g\ m^{-3}$
Nitrogen dioxide	1 ppb = 1.8804 $\mu g\ m^{-3}$	1 ppb = 1.9125 $\mu g\ m^{-3}$
Carbon monoxide	1 ppm = 1.1447 mg m^{-3}	1 ppm = 1.1642 mg m^{-3}
Sulphur dioxide	1 ppb = 2.6163 $\mu g\ m^{-3}$	1 ppb = 2.6609 $\mu g\ m^{-3}$
Benzene	1 ppb = 3.189 $\mu g\ m^{-3}$	1 ppb = 3.243 $\mu g\ m^{-3}$
1,3-butadiene	1 ppb = 2.2075 $\mu g\ m^{-3}$	1 ppb = 2.2452 $\mu g\ m^{-3}$

Additional conversion factors used in the UK are as follows:

- NO_x in $\mu g\ m^{-3}$ is expressed as NO_2, i.e. (NO ppb + NO_2 ppb)* 1.91 = NO_x $\mu g\ m^{-3}$
- In the UK, gravimetric equivalent PM_{10} data are calculated from TEOM monitoring data by applying a conversion factor of 1.3

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 (e.g. 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.

Exceedence

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[29] which has the following stages:

- The gradient is calculated by "Theil's incomplete" method[P22]
- The null hypothesis (i.e. the statistical significance of the trend) is tested by the Spearman's rank correlation coefficient[P23]
- The 95th confidence interval for the gradient is given by Kendall's Tau[P24]

Values for the Spearman's rank correlation coefficient used in this report are as published by Conover[P21].

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[P25].

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 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 2006 the 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 glass, tapered tube (element) changes by an amount that is directly proportional to the mass of the tube Therefore, any change in mass of the tube, due to the deposition of particles onto a small filter affixed to one end, will result in a change in the resonant frequency that is proportional to the additional mass.

In order for the TEOM to be used as a USEPA-equivalent method for PM_{10} measurement, a default adjustment factor (1.03 * TEOM reading + 3 μgm^{-3}) must be applied to the raw data. This adjustment factor was derived to account for moisture equilibration differences between the TEOM and the HI-vol sample media. The adjustment factor was determined at sites where non-volatile PM dominated and is intended to reflect the filter character more than the PM. It is understood that USEPA has no general policy on the use of this empirical adjustment factor for $PM_{2.5}$ measurements. All TEOM analysers in the UK measuring both PM_{10} and $PM_{2.5}$ are currently set up with this default adjustment factor included. In addition, TEOM analysers within the UK networks are set to report concentrations corrected to 293K and 101.3 kPa.

Due to the need to eliminate the effect of changing humidity on the mass measurement, the TEOM is required to maintain the sample filter at an elevated temperature. This has led to reported differences in concentrations of PM between the TEOM and the European reference sampler (Allen *et al*., 1997; APEG, 1999; Ayers *et al*., 1999; Soutar *et al*., 1999; Salter and Parsons, 1999; Cyrys *et al*., 2001; Williams and Bruckmann, 2001). 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 has been applied to all TEOM PM_{10} data reported here, as recommended by the EC Working Group on Particulate Matter (2001).

As a result of the UK equivalence trials for particulate instruments (reported in June 2006), it is planned that the original TEOMs will be phased out of the UK monitoring networks starting in 2007, and replaced with "Reference Equivalent" monitors. This will mean that results can then be directly compared with full confidence against the EC Directive limit values and objectives.

'Box and whisker' plots:

Box and whisker plots – such as that in Figure 7.3 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 7.4 in this report.

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How to find out more

Current and forecast air quality (national & local)

This is rapidly available in a user-friendly form from:

Teletext: page 156

The Air Pollution Information Service:
freephone 0800 556677

The UK Air Quality Archive:
www.airquality.co.uk

The Scottish Air Quality Archive:
www. scottishairquality.co.uk

The Welsh Air Quality Archive:
www. welshairquality.co.uk

The Northern Ireland Air Quality Archive:
www.airqualityni.co.uk

General information on Air Quality

The UK Air Quality Information Archive:
www.airquality.co.uk

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

The Northern Ireland Department of Environment:
www.doeni.gov.uk/epd

A companion brochure to this report entitled:
UK Air Pollution is available from Defra at:

Defra Publications
Admail 6000
London SW1A 2XX
Tel: 08459 556000, Fax: 01709 881673
e-mail: defra@cambertown.com

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.

Local Air Quality Issues

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

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