Air Pollution in the UK: 2005

A report prepared by Netcen for
Defra and the Devolved Administrations

Front cover image
December 2005: The Buncefield plume photographed from the air

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

This report has been compiled and written by Jon Bower, Jeff Lampert, Geoff Broughton, John Stedman, Andrew Kent, Jaume Targa, Paul Willis, Stephen Pye, Susannah Grice and many others within Netcen; 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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Our ultimate objective- clean air for all **© Jon Bower**

1. Executive Summary

For those of you who are 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. In order to maximise user-friendliness, we have written these reports- as far as possible - in simple and non-technical language.

This report includes data and analyses from the calendar year (January to December) of 2005. The pollutants summarised and analysed 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 routinely 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 133 stations during 2005. These networks serve a variety of policy, regulatory, scientific research and public health objectives.

In this report, we:

1. ***Consider current UK and European efforts to tackle air pollution.*** These both progressed significantly during 2005; we identify and discuss the major developments.
2. ***Describe current UK air monitoring networks, their objectives and methodologies.*** Major changes to these programmes – in particular the national Smoke/SO_2 and NO_2 diffusion tube networks -are considered.
3. ***Review current UK Air Quality Objectives*** and examine how and where these were exceeded during the year. We also identify exceedences of the UK Air quality Strategy daily objective for PM_{10} particles at a number of near-road locations.
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 2005. This year, we examine a summer photochemical smog event, together with air quality impacts from the Buncefield fires.
6. ***Assess long-term trends*** in order to identify how pollution levels in the atmosphere have changed over time. This year, we examine for the first time both past and projected future changes in UK’s pollution climate.
7. ***Examine social aspects of air pollution in the UK.*** Again, this is a first for these annual reports.
8. ***Identify published, web and media sources for information*** on the UK’s air quality. In particular, we provide details of new national air quality archives and websites for Scotland, Wales and Northern Ireland.
9. ***Provide detailed statistical summary tables*** for each measured pollutant

The report, together with the UK Air Quality Archive at www.airquality.co.uk, provides the most comprehensive and complete analytical picture of UK’s air pollution in 2005.

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2. Introduction

An outline of what's in this report...

The quality of the air that we breathe can have important impacts on our health and quality of life. It can also have major impacts on ecosystems and climate change. Measuring and understanding air pollution provides a sound scientific basis for its management and control. Considerable effort is therefore devoted in the UK to the systematic measurement of levels of air pollution nationwide. This effort started in earnest following the infamous coal-burning smogs of the 1950s and 60s, but has expanded massively in scope, coverage and sophistication since then. These developments to monitoring programmes continued apace during 2005.

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. The rural air monitoring station at Aston Hill, Powys, Wales

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.

The report comprises three parts. The first 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 3)*.
- 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 4)*.
- 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 4.7).*
- Examine key episodes - major periods of elevated pollution - that occurred in 2005. We give particular prominence this year to the Buncefield Incident, discussing why such a large-scale event appeared to have so little impacts on ground-level air quality *(Section 5).*
- Investigate through a series of detailed maps and analyses how pollution levels vary across the UK *(Section 6).*
- Assess long-term pollution trends in order to see whether pollution levels are declining over time. For the first time, we also try to examine how UK pollution may change over the coming years. (*Section 7).*
- Examine some of the social aspects of air pollution. Is there a relation between air pollution, inner cities and deprived areas? We examine these and other important questions for the first time in this series of annual air quality reports *(Section 8).*

The second part of the report is primarily statistical, providing a detailed pollutant-specific summary of measurements. From Sections 9 to 17, we provide for each pollutant measured in the UK's national automatic monitoring networks, together with other programmes measuring compliance with UK Air Quality Objectives:

- 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 in 2005
- 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 a series of Appendices, we'll also 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 different UK national 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: 2005

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, and also look forward to how things may change in the future.

To end this section, we discuss for the first time some of the important social aspects and impacts of air pollution in the UK.

3. UK and International Policy for Tackling Air Pollution

The policy background to why we monitor air quality…

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 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"[1], 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[2], 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.

3.1 European Background: a year of rapid change

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 progress against these 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[3] 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 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 (3rd Daughter Directive)
4) Arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons (4th 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.

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[6]. 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[7] 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.

Latest developments- 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 through large-scale initiatives such as CAFE (Clean Air For Europe)[5]. The CAFE Programme was set up 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.

The European Commission has set out its intention to develop a new air quality policy approach based upon sound scientific information about pollutant levels, impacts and trends throughout Europe. This strategy, designed to achieving further significant improvements in air quality across Europe, was proposed in September 2005. It has been produced under the framework of the Sixth Environment Action Programme (6th EAP), a wide-ranging programme of Community action on the environment with key objectives covering a period of ten years. The priorities of the 6th EAP cover climate change, nature and biodiversity, environment, health and quality of life, and natural resources and waste.

The 6th EAP calls for the development of seven thematic strategies, including a coherent and integrated strategy on air pollution. The Thematic Strategy for air pollution proposed in 2005 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.

In essence, the Strategy 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.

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.

The pollutants of most direct concern for human health are airborne particulates and ozone – indeed, no safe levels have yet been identified for either pollutant. The Strategy establishes ambitious targets for these and other pollutants that are intended to be achievable by 2020. The Strategy's ultimate aspiration is to achieve levels of air quality that do not give rise to unacceptable impacts or risks to human health and the environment.

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 takes into account links with other problems and policy areas. At the same time, it has been based on an integrated assessment of different environmental and health effects, and aims to provide the most cost-effective solution for the chosen level of objectives.

Full details of the Strategy are available at
http://europa.eu.int/comm/environment/air/cafe/index.htm

Thematic Strategy - objectives and tools

The Thematic Strategy on air pollution establishes interim objectives for air pollution throughout the European Union and proposes appropriate measures for achieving them. It recommends that current legislation be modernised, be better focused on the most serious pollutants and that more is 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.

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. 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. For the first time, it 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 4.4).

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 third countries may eventually need to adopt.

Current air quality legislation will be streamlined to help Member States implement it more efficiently. In fact, the Commission proposes to integrate air quality legislation by merging the existing key legal instruments - the Framework Directive, four Daughter Directives and Decision on exchange of information - into a single Ambient Air Quality Directive. This Directive will not only revise the Framework and Daughter Directives 1-3, but will also include $PM_{2.5}$ targets for the first time. At the time of this report's finalisation (August 2006), these proposals are still under negotiation.

The proposed new integrated Directive would substantially cut existing legal texts, clarify and simplify their provisions and modernise reporting requirements. At the same time as simplifying existing legal instruments, more flexibility will be given to the Member States. Where they can demonstrate that they have taken all reasonable measures to implement the legislation but are, nevertheless, unable to comply with air quality standards in certain places, it is proposed to allow them to request an extension to the compliance deadline in the affected zones; this would be granted provided that strict criteria are met and coherent plans are put in place to move towards compliance.

The Commission intends to propose a revision of the National Emissions Ceilings Directive to bring its emissions ceilings into line with the objectives of the Strategy. In addition, a range of other possible measures will be examined, such as the introduction of a new "Euro V" set of car emission standards and other initiatives in the energy, transport and agriculture sectors, the Structural Funds and international cooperation.

3.2 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. 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. In addition, more than half of all natural and semi-natural habitats in Britain still have too high levels of harmful acidity.

Medical evidence shows that many thousands of people die prematurely every year because of the effects of air pollution, and this can accelerate during extreme weather conditions. Many more become unwell or may require hospital treatment. The young and infirm are often particularly affected, as well as people living in deprived areas. Some of the social aspects and impacts of air pollution are addressed more fully in Section 8 of this report.

The new air quality indicator

Air quality is one of the UK Government's 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.

Although an air quality headline indicator was first introduced in support of the UK Sustainable Development Strategy in 1999, this was substantially extended in scope when the strategy was revised in 2005. In particular, new components were added, better reflecting the effects on health of long term exposure to lower levels of pollution.

The extended indicator now includes trends for annual levels of particulate and ozone pollution, the two pollutants thought to have the greatest health impacts (part a), as well as the number of days on which levels of any one of a basket of five major pollutants were 'moderate or higher' (part b).

Part b) is the air quality headline indicator of the former (1999) sustainable development strategy, and the banding system it uses is that of the Air Pollution Information Service (www.airquality.co.uk/archive/standards.php#band). More detailed data and information on the indicator are available from the Air Quality Archive at www.airquality.co.uk.

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

The UK Air Quality Strategy

The Air Quality Strategy for England, Scotland, Wales and Northern Ireland, first published in March 1997 and revised in January 2000, has established a strong framework for tackling air pollution over the coming years. The Strategy is available in full from http://www.defra.gov.uk/environment/airquality/strategy/.

The overall objectives of the Strategy are to:

- Map out future ambient air quality policy in the United Kingdom in the medium term
- Provide best practicable protection to human health by setting health-based objectives for air pollutants
- Contribute to the protection of the natural environment through objectives for the protection of vegetation and ecosystems
- Describe current and future levels of air pollution
- 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. As our knowledge of these effects has deepened, the objectives have been progressively refined and strengthened. Objectives for a ninth pollutant, Polycyclic Aromatic Hydrocarbons (PAHs)[9] were introduced in 2003.

A summary of the current UK Air Quality Objectives in Regulation is provided in Table 1 overleaf. These are based on the Air Quality Regulations 2000 and (Amendment) Regulations 2002 for the purpose of Local Air Quality Management.

Some explanation of terminology may assist in understanding Table 1.

Standards for air pollution are concentrations over a given time period that are considered to be acceptable in the light of what is known about the effects of each pollutant on health and on the environment. They can also be used as a benchmark to see if air pollution is getting better or worse over time.

An ***exceedence*** of a standard is a period of time (which is defined in each standard) where the concentration is higher than that set down by the standard. In order to make useful comparisons between pollutants, for which the standards may be expressed in terms of different averaging times, the number of days on which an exceedence has been recorded is often reported.

An ***objective*** is the target date on which exceedences of a standard must not exceed a specified number.

Note that important deadlines for meeting objectives for Benzene, 1,3-Butadiene, PM_{10} particles, Sulphur Dioxide and Carbon Monoxide were passed in 2003 and 2004. Others – for nitrogen and sulphur oxides- must be met by the end of 2005. Corresponding objectives not to be included in Regulation for the purposes of Local Air Quality Management (LAQM) are summarised in Tables 2a and 2b. Details of corresponding EC Limit Values and WHO Guidelines are provided in the Appendices of this report

Exceedences of the current PM_{10} particles 24-hour mean objective at a number of roadside monitoring sites are reviewed in Section 5.4.

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 for media-based reporting of air quality and potential health effects to the public. This is summarised in Box 1 overleaf.

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.

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.

Table 1. UK Air Quality Objectives set in Regulation, 2005

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
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

Table 2a UK air quality objectives not set in regulation, 2005

Pollutant	Air Quality Objective		Date to be achieved by
	Concentration	Measured as	
Ozone *(for protection of human health)*	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
Nitrogen dioxide *(for protection of vegetation & ecosystems)*	30 $\mu g\ m^{-3}$	Annual mean	31.12.2000
Sulphur dioxide *(for protection of vegetation & ecosystems)*	20 $\mu g\ m^{-3}$ 20 $\mu g\ m^{-3}$	Annual mean Winter average (Oct-Mar)	31.12.2000 31.12.2000
PAHs	0.25ng m^{-3}	Annual mean	31.12.2010

Table 2b UK air quality objectives for particles (PM_{10} gravimetric) not set in regulation, 2005

Region	Objective	Measured as	Date to be achieved by
Greater London	50 µg m^{-3} not to be exceeded more than 10 times per year	24-hour mean	31.12.2010
Greater London	23 µg m^{-3}	Annual mean	31.12.2010
Greater London	20 µg m^{-3}	Annual mean	31.12.2015
Rest of England, Wales and Northern Ireland	50 µg m^{-3} not to be exceeded more than 7 times per year	24-hour mean	31.12.2010
Rest of England, Wales and Northern Ireland	20 µg m^{-3}	Annual mean	31.12.2010

Consultation on the Air Quality Strategy

Despite overall improvements in UK's air quality, it is 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.

During 2006, the process of further developing the UK Air Quality Strategy continues. A consultation document issued on 5 April by Defra and the Devolved Administrations seeks 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. Please see http://www.defra.gov.uk/corporate/consult/airqualstrat-review/index.htm for fuller details. The consultation ended on 11 July 2006.

The consultation concludes that health impacts of particles currently cost up to £21 billion per year and result in an average reduction of life expectancy of eight months. Existing controls are expected to reduce this to 5.5 months by 2020. However, Defra believes that new proposals could further reduce this to five months and cut particulate levels by 15%.

Air pollution also caused over half the UK's natural and semi-natural habitats to exceed harmful levels of acidity in 2003, and the review proposes improved protection for protected habitats.

Among the proposed package of measures are:

- Adoption of new tighter European vehicle emissions standards (so called Euro-standards);
- National road charging;
- Incentives for cleaner vehicles;
- Further reductions in emissions from small combustion plants; and
- Further reductions in emissions from ships.

In addition, a new programme is aimed at controlling fine particles; this marks a shift away from a focus on pollution hotspots towards a more beneficial approach of reducing exposure levels for the general population. The consultation poses the question of whether the UK should proceed alone with this new approach, or wait for the EU to formulate its own exposure-reduction objectives.

As well as direct benefits to public health, these new policies have the potential to provide important benefits to quality of life, reducing health inequalities and helping to protect the environment.

The consultation document also seeks views on the Strategy's current objectives for air pollutants and in particular:

- A new, more cost effective, policy framework and objectives for controlling pollutants for which there is no safe level such as fine particles (known as $PM_{2.5}$);
- Improved protection for Sites of Special Scientific Interest and other protected habitats; and
- A new objective on ozone for the protection of our environment.

The consultation process also sets an agenda for longer-term action to improve our understanding of air pollutants and attempts to qualitatively assess the potential for further air quality improvements in the very long term.

3.3 A Local Focus

UK Government and the Devolved Administrations in Scotland, Wales and Northern Ireland are responsible for overall policy and legislation affecting our 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 - which may include such measures as congestion charging, traffic management, planning and financial incentives - to tackle problems in the affected areas.

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[10, 11, 12, 13, 41]; they are now commencing the third round of assessment.

As of August 2006, over 197 Local Authorities – roughly 45% of those in the UK - have established one or more AQMAs. Most of these are in urban areas and result from traffic emissions of nitrogen dioxide (NO_2) or PM_{10} particles. Road traffic emissions are the main source of declaration 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 3 below.

Table 3. Current UK-wide status of Air Quality Management Areas (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 (August 2006)	No of AQMAs due to C_6H_6	No of AQMAs due to NO_2	No of AQMAs due to PM_{10}	No of AQMAs due to SO_2	Draft (Full) Action plans submitted (June 2006)
England (excl London)	320	82	143	1	133	34	11	84 (52)
London	33	30	31	-	30	26	-	31 (24)
Scotland	32	3	8	-	5	3	1	0 (3)
Wales	22	4	5	-	4	1	-	4 (2)
N. Ireland	26	n/a	11	-	4	8	1	2 (2)
TOTAL	**433**	**119**	**198**	**1**	**176**	**72**	**13**	**121 (83)**

** data courtesy of University of West of England and Bureau Veritas*

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. These authorities have been advised to prepare their action plans within 12-18 months of designation. Over 121 authorities have now produced such action plans, setting out the measures the authority 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 (or Transport Scotland in Scotland) 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, 61 authorities in England, 5 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. The increase in the number of AQMAs required in this round is due in large part to the improved methodologies being employed to identify areas of poor air quality for the second and subsequent rounds; to the increasing scale of monitoring being undertaken by local authorities; and to 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. Alongside 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.

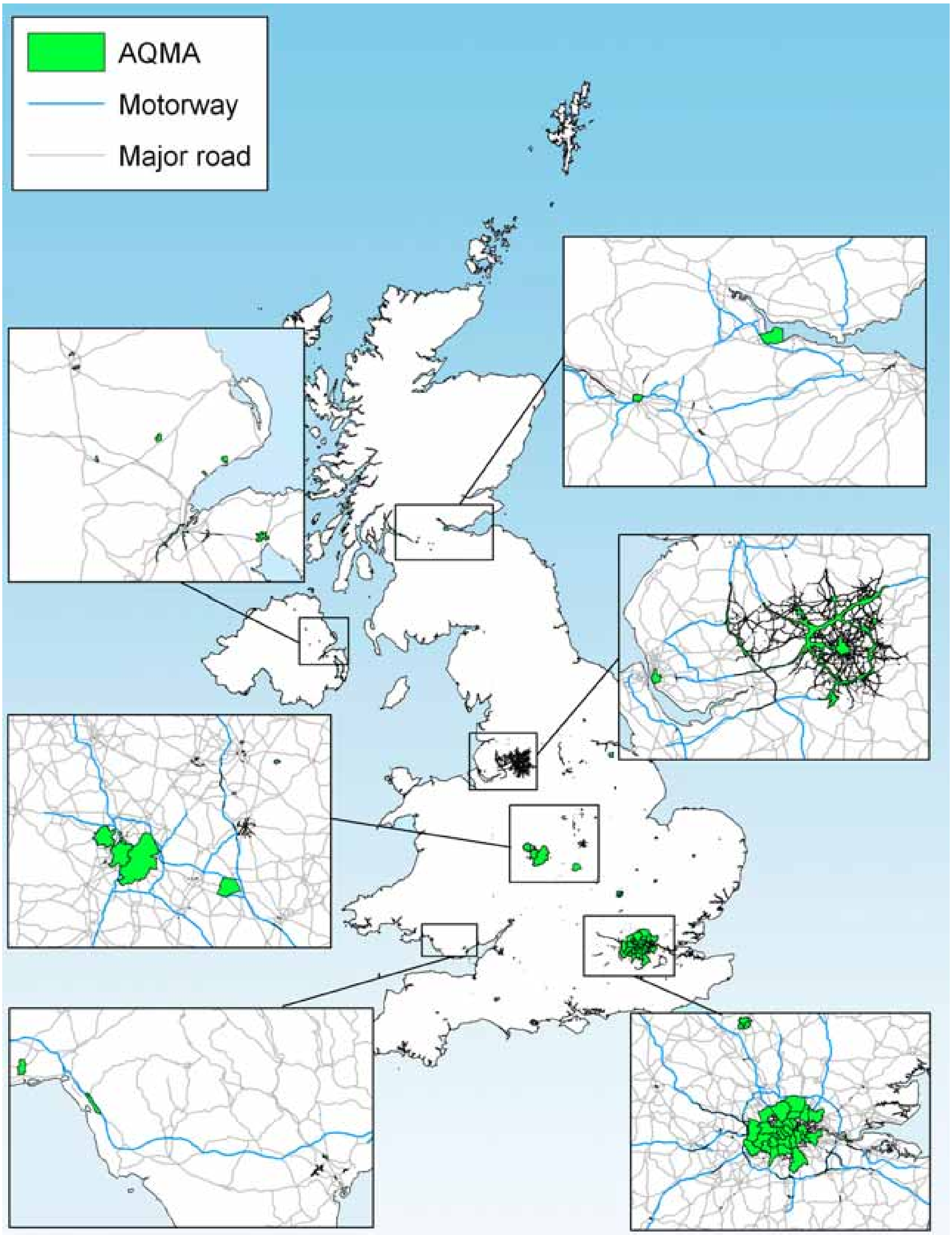


Figure 2. Map of current UK Air Quality Management Areas (AQMAs)

4. Where and how air pollution is measured in the UK

To manage something effectively, you first have to be able to measure it.

4.1 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[14] of the United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro in 1992 and during the Johannesburg Summit[15] 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
- Assessment 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
- Rising 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 4.7.

4.2 A Brief History of Monitoring in the UK

The history of air pollution monitoring in the UK goes back a long way. Primarily in response to the serious urban smogs of the 1950s and 60s, black smoke and sulphur dioxide have been monitored on a national scale in the UK since 1961. Initially called the National Survey, this major network has monitored the massive improvement of air quality since a succession of Clean Air Acts[16] 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 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. Major changes to the long running ‘National Survey’ of smoke and sulphur dioxide and national NO_2 diffusion tube networks are reviewed in Section 4.3.

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 and 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 DoE-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). This presently (2006) consists of 127 sites and remains the most important single monitoring programme in the UK today.

Data from the AURN, together with corresponding measurements from the 6 automatic hydrocarbon monitoring stations, are presented in this report. The AURN presently includes 89 urban or suburban, 24 rural or remote and 14 London Network sites: 64 sites are directly funded by Defra and the Devolved Administrations, whilst 63 are affiliated sites owned and operated by Local Authorities and other organisations.

The expansion in automatic monitoring is clearly illustrated in Figures 3 and 4, where we show the increase in site numbers and total measurements made since the commencement of automatic air quality monitoring in the UK. The UK’s automatic networks continue to evolve year-on-year; changes in these programmes during the past year are summarised in Table 4.

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.

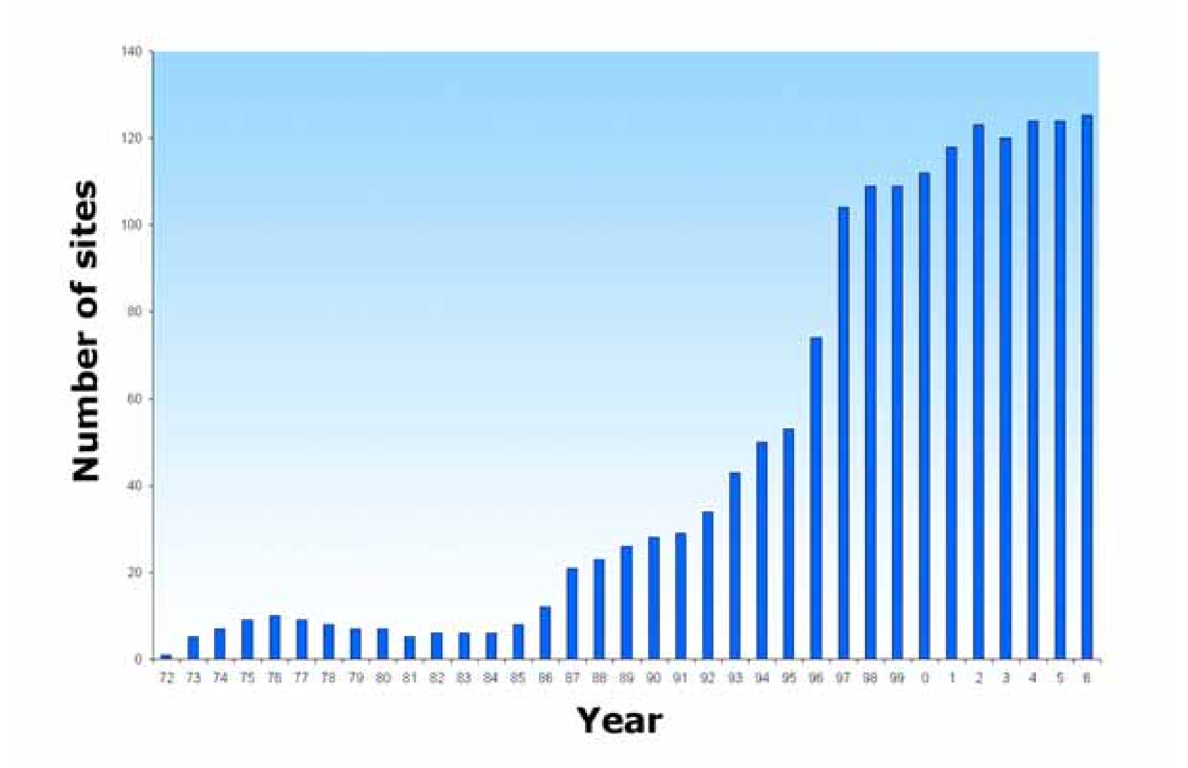


Figure 3. The number of automatic measurement stations in the UK has grown substantially since 1972

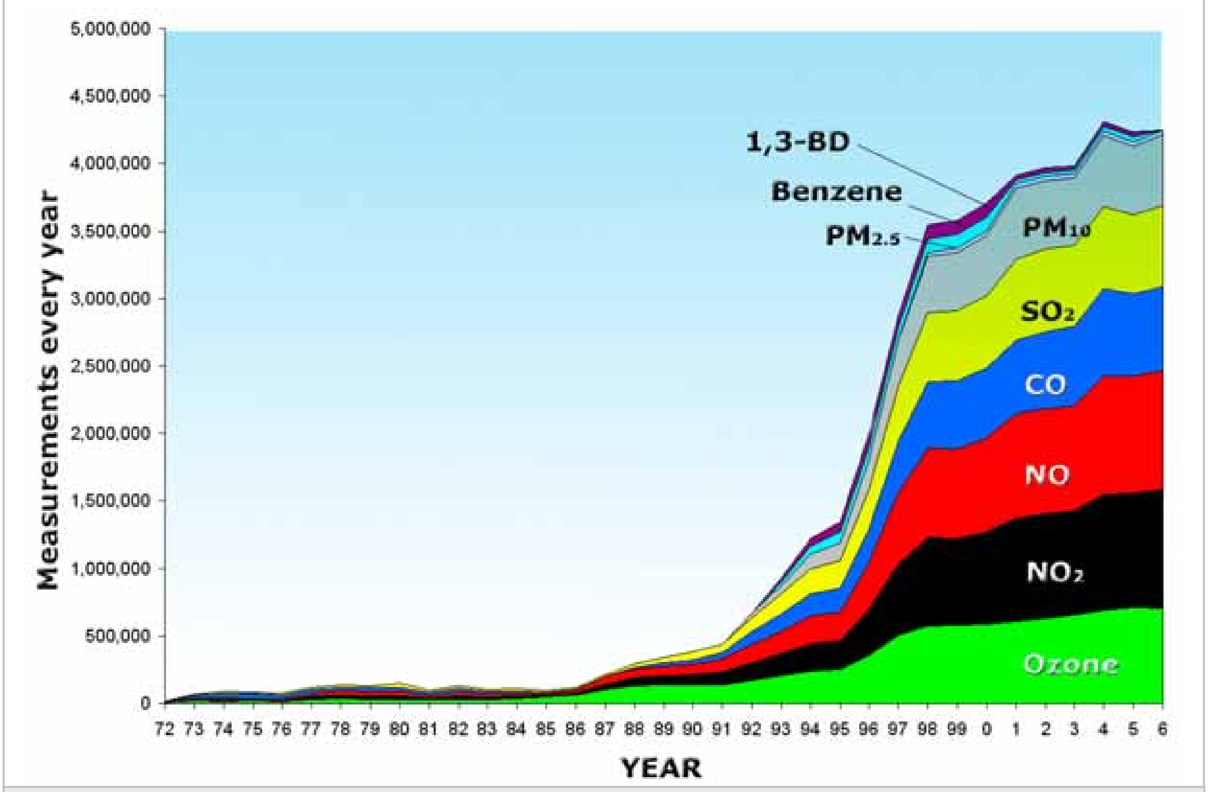


Figure 4. The number of hourly measurements made every year has also increased dramatically for all pollutants in the automatic monitoring networks (O_3, NO_2, CO, SO_2 and PM_{10}) and for other UK Strategy pollutants

Table 4. Changes to the automatic networks in 2005 and 2006

Sites	Date Commenced	Pollutants
Newly established sites		
Lerwick	25 May 05	Ozone
Leominster	18 Jul 05	NO_2 and O_3
Auchencorth Moss (HC network)	9 June 2006	VOCs, O_3, PM_{10}, $PM_{2.5}$
Fort William	22 June 2006	NO_2, O_3
Site Relocations		
Blackpool relocated to Blackpool Marton	Blackpool closed 10 November 2004. Blackpool Marton started 13 June 2005.	NO_x O_3 CO SO_2 and PM_{10}
Norwich Roadside relocated to Norwich Forum Roadside	Norwich Roadside closed on 14 February 2005. Norwich Forum Roadside started on 31 May 2005.	NO_x
Bath Roadside	Site moved short distance on 27 April 2005, name not changed.	NO_x CO
Oxford Centre renamed	Change of name only in Feb 2005 to Oxford Centre Roadside.	NO_x CO SO_2
Cardiff Centre	Site closed from 9 May 2005 till 30 September 2005 for refurbishment of cabin.	NO_x O_3 CO SO_2 and PM_{10} BTEX
Middlesbrough	Site moved 17m. Closed on 18 May 2005, reopened 23 May 2005, name not changed.	NO_x O_3 CO SO_2 and PM_{10}
Leamington Spa	Site relocated to new cabin. Closed on 25 July 2005 and re-opened 21 October 2005.	NO_x O_3 CO SO_2 and PM_{10}
Bradford Centre	Site moved 15m on 3 August 2005.	NO_x O_3 CO SO_2 and PM_{10}
Bristol Centre relocated to Bristol St. Pauls	Bristol Centre closed 15 September 2005. Bristol St. Pauls started on 15 June 2006	NO_x O_3 CO SO_2 and PM_{10}
Belfast Clara St.	BAM replaced with TEOM at the end of 2005	PM_{10}

There has also been continuing growth during 2005 in the amount of monitoring undertaken by Local Authorities. Many of these sites now contribute data to nationally organised measurement programmes 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 measurement consistency and accuracy - see Section 4.6.

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.

4.3 Changes to the smoke/sulphur dioxide and national nitrogen dioxide diffusion tube networks

Figure 5. The long-running national smoke/sulphur dioxide and nitrogen dioxide diffusion tube networks are disappearing or changing dramatically

The smoke and SO_2 network

The UK Smoke and Sulphur Dioxide (SO_2) Network has been operating since the early 1960s, and has tracked the massive decline in pollution from coal over the last 45 years (see Section 7). It measured two pollutant parameters: 1) particulate matter as black smoke, and 2) net gaseous acidity, expressed as SO_2 equivalents. The primary objectives of the network in recent years were:

- To monitor compliance with the original European Council Directive on Sulphur Dioxide and Suspended Particles (80/779/EEC).
- To provide a long-term database of suspended particulate matter (as black smoke) and SO_2 (as net acidity) measurements used to assess trends in concentration and spatial distribution.
- To highlight areas where elevated concentrations of black smoke or SO_2 occur, and where more detailed investigation, including the use of automated techniques, might be justified.

However, the repeal of the EC Directive 80/779/EEC on 1 January 2005 ended the network's compliance monitoring role. In response to this, and in recognition that the chemistry of the urban and rural environment has changed dramatically over the lifetime of the network, and that monitoring requirements have changed greatly as a result of the Air Quality Strategy, Defra and the Devolved Administrations commissioned an independent review of the network in 2005; this was designed to establish how the programme could best serve the needs of central and local government in the future. The review report has been published at http://www.airquality.co.uk/archive/reports/cat16/0604041119_UK_urban_network_review_summary.pdf .

The review's conclusions regarding the Smoke and SO_2 Network were as follows. Firstly, in view of the end of its compliance monitoring role, the changes in the UK's pollution climate, and the fact that automatic monitoring techniques are now widely used, the Smoke and SO_2 Network (in its present format) had come to the end of its useful life, and should therefore cease operation. However, the scientific community remains interested in black smoke as a useful particulate metric correlated with health effects, and there is a case for retaining around 20 sites monitoring smoke only.

Accordingly, Defra has taken the decision to cease operation of the Smoke and SO_2 Network as of 31st December 2005. In line with the recommendations of the review, it is likely to be replaced in the near future by a new, smaller network of sites monitoring black smoke only: however details of this new network have not yet been finalised.

The NO_2 diffusion tube network

The NO_2 Network was established in 1993, with the objective of assessing the spatial and temporal distribution of nitrogen dioxide (NO_2) concentrations in a variety of urban areas of the UK, ranging from the major cities to smaller towns.

This was done using NO_2 diffusion tubes: low-cost passive samplers ideal for indicative monitoring. The network was originally planned to operate for ten years, but was extended for a further three. However, since 1993, there have been many developments in policy and legislation on air quality. This has led to corresponding changes in monitoring requirements. Moreover, automatic monitoring techniques are now much more readily available than in the early 1990s, and are now widely deployed across the UK. As was the case for the smoke and SO_2 network, therefore, it could be argued that the basic rationale for the programme has disappeared.

Earlier in 2005, therefore, Defra commissioned an independent review of the NO_2 Network. The review concluded that the network was no longer required to assess spatial distribution of NO_2, this role being now more effectively fulfilled by a combination of computer modelling, and data from automatic monitoring sites. It also came to the view that the network was of limited use in monitoring compliance with today's limit values and objectives for NO_2. Consequently, the network was deemed to have served its purpose, and ceased operation at the end of 2005.

However, Defra appreciates that NO_2 diffusion tubes are widely used by Local Authorities for LAQM purposes, and that the old Network's QA/QC programme was beneficial not only to the Network but in the wider context of LAQM, as it helped to improve and maintain the quality of all NO_2 diffusion tube measurements carried out by Local Authorities.

Accordingly, Defra and the Devolved Administrations have decided to continue a central NO_2 diffusion tube data collation and QA/QC programme as part of a new contract, entitled "Support to Local Authorities for Air Quality Management"; this brings together the Air Quality Monitoring and Modelling Helpdesks, and QA/QC support for NO_2 diffusion tube monitoring. This contract also includes a data verification service for diffusion tube data, together with a working group aimed at harmonisation of diffusive sampling methods.

Further details of this project can be found at http://www.laqmsupport.org.uk.

4.4 Review of particle measurement methodologies

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.

Figure 6. The TEOM instrument for PM_{10}, is widely used in the AURN

The Equivalence Programme for monitoring particulate matter is an EU 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 recently completed a comprehensive evaluation of particle measurement systems currently deployed in UK 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 PM10 and PM2.5; 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 currently being planned, and these instruments are also widely used by local authorities in their LAQM regimes. In both cases, 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 4).

The report on the 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

4.5 Current national 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 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.

133 of these sites in the AURN (127) and hydrocarbon networks (6) operate automatically; these split nationally as follows:

Country	Site numbers
England	104
N. Ireland	5
Wales	8
Scotland	16

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 7. In the accompanying Figures 8 and 9, 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.

The pollutants measured, site numbers and areas covered in the UK's nationally co-ordinated monitoring networks are summarised in Table 5, whilst the main features of individual programmes are summarised in Table 6. Further information on the different UK air monitoring networks is provided in Appendix 3.

Table 5. 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	90 (A)	All of UK- urban and rural areas
Particles (PM_{10} and $PM_{2.5}$)	Road transport, industry, construction, soil and natural sources	72 (A) - PM_{10} 5 (A) – $PM_{2.5}$	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 10 (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 6. The major UK Air Quality Monitoring Networks

Network	Auto or Sampler?	No of Sites
The Automatic Urban and Rural Network (AURN)	A	127 (89 urban, 24 rural, 14 London)
Rural acid deposition, gases and particles	S	38 (acid deposition)
Automatic Hydrocarbon	A	6
Toxic Organic Micropollutants (TOMPS)	S	6 (also measure PAHs)
Polycyclic Aromatic Hydrocarbons (PAHs)	S	18
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) 10 (1, 3-butadiene)
Ammonia and Nitric Acid Network	S	94

Figure 7. Current UK Automatic Air Quality Monitoring Stations

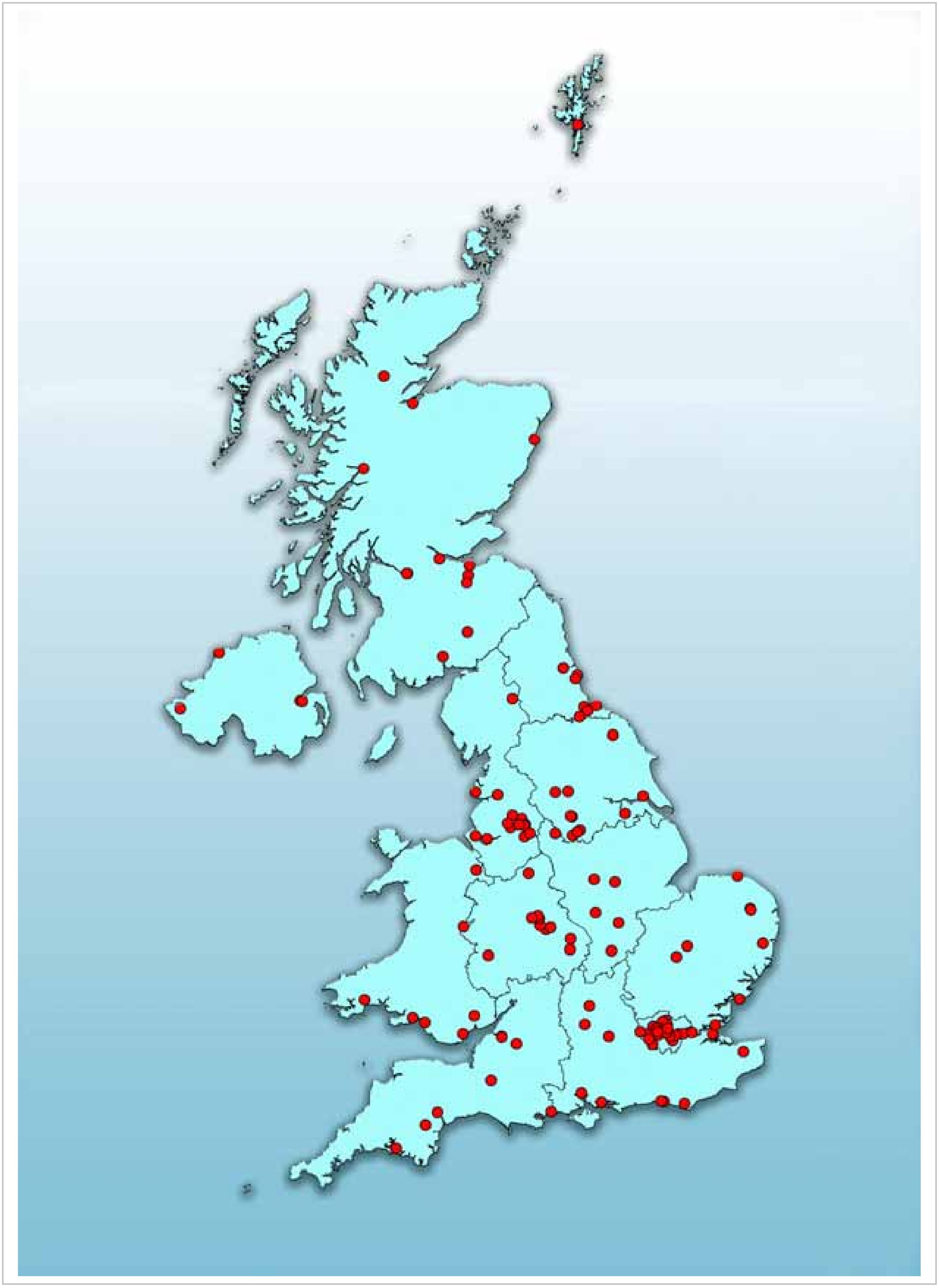


Fig 8 Current UK sampler-based measurement programmes for Persistent Organic Pollutants (POPs) and metals

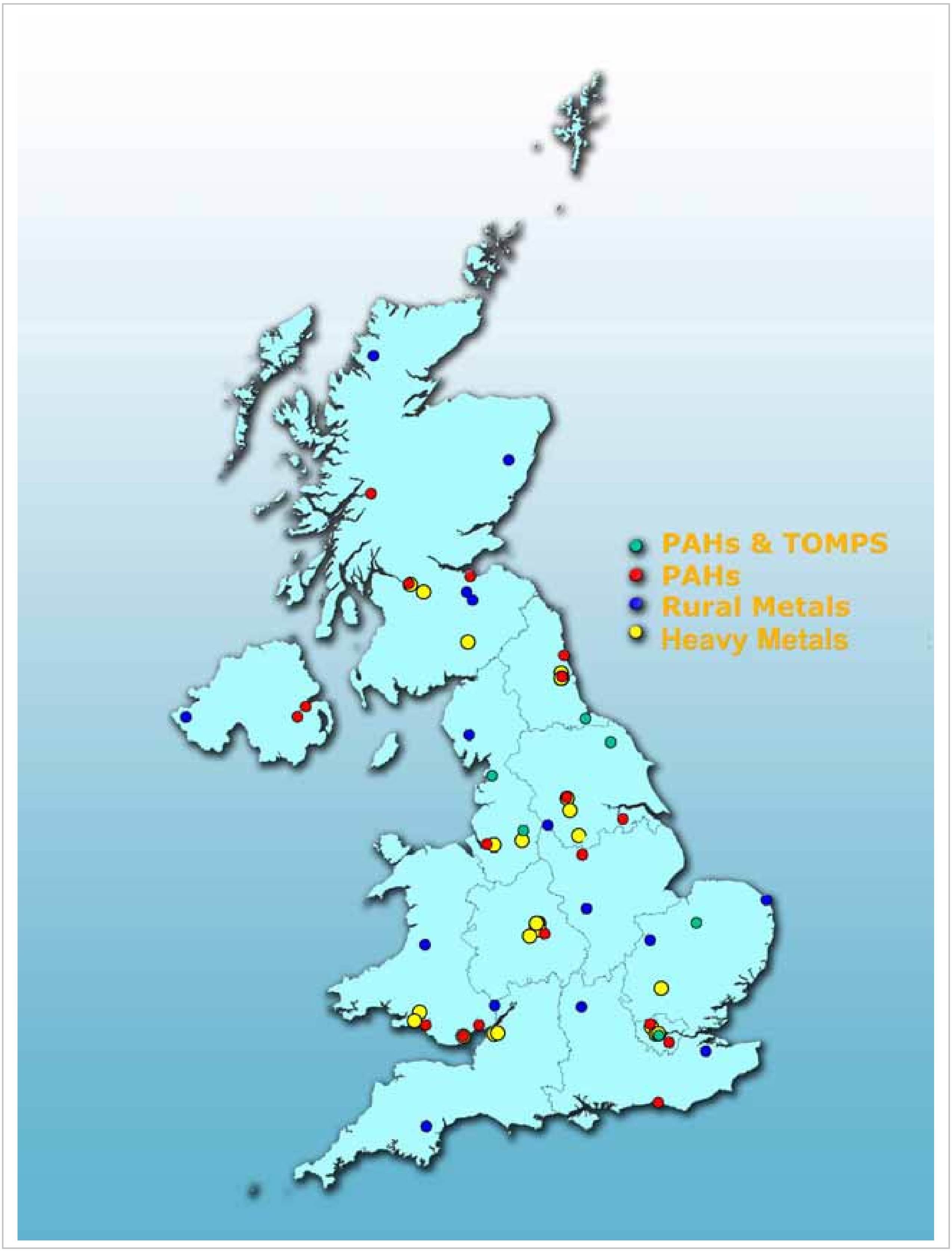
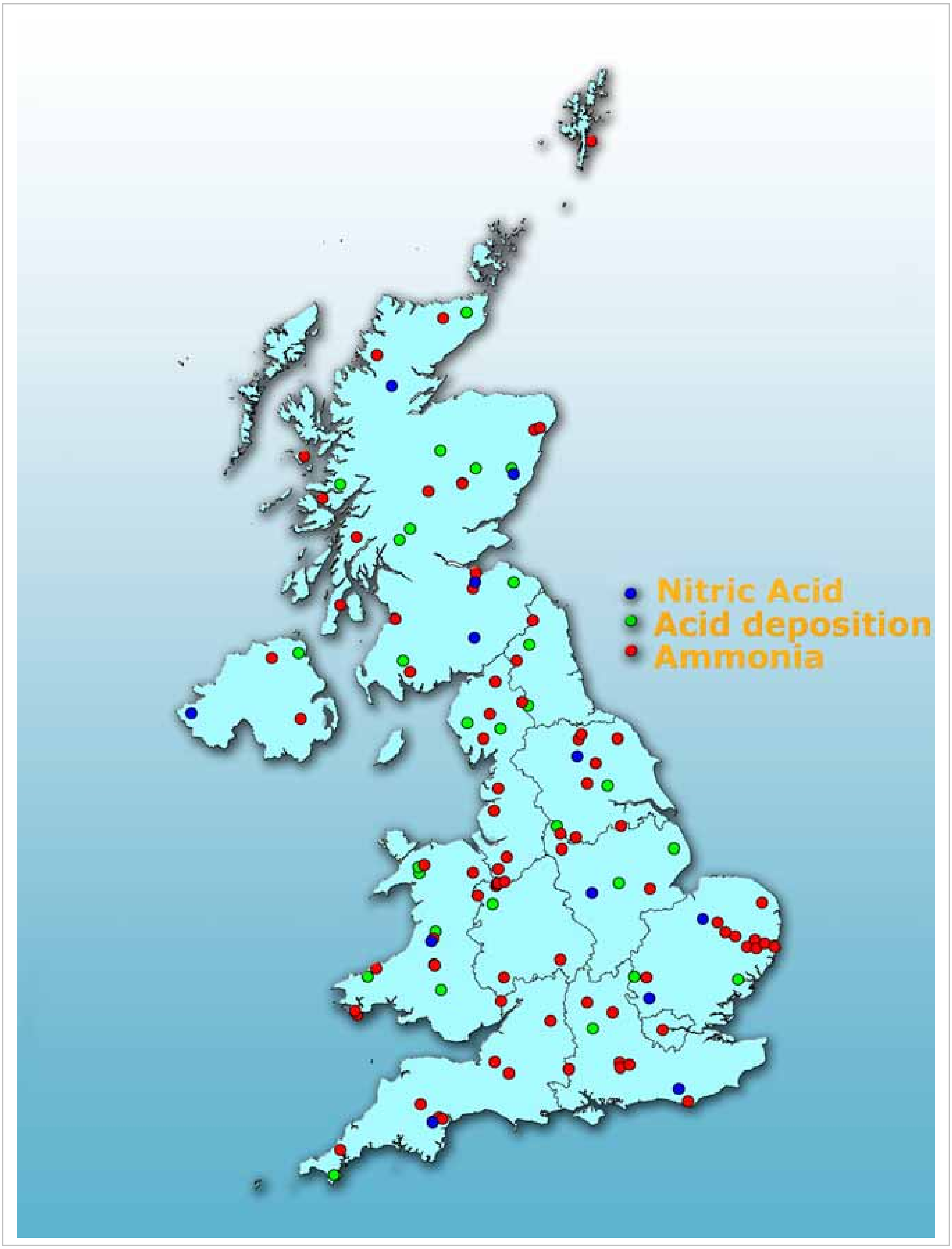


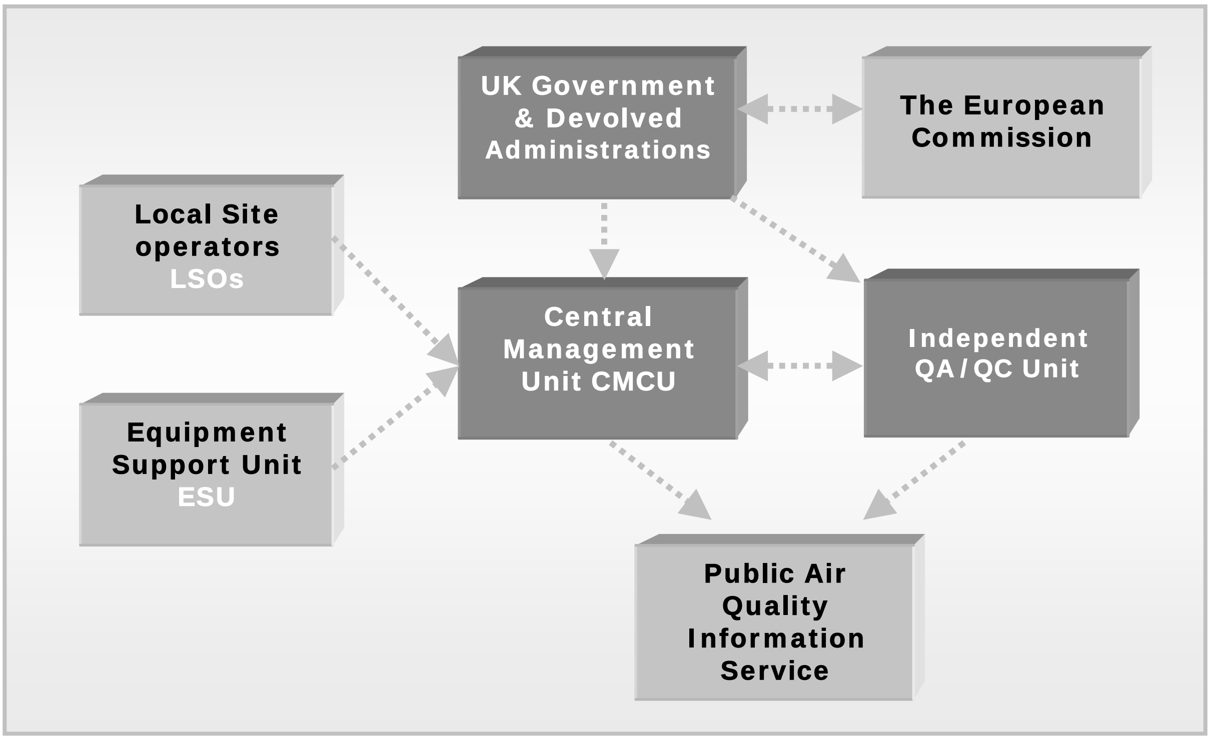
Fig 9 Current UK sampler-based measurement programmes: Acidification and Eutrophication



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 10). 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.

Figure 10. A devolved network organisational structure, as employed within the large-scale AURN programme.



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 4.6) and air quality information services (Section 4.7) in more detail.

4.6 Emphasis on Data Quality

The UK air monitoring networks currently produce over 15 million individual measurements every year from its automatic and sampler-based monitoring programmes. 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
(vi) Consistent with the Data Quality Objectives and methodology guidance defined in EC Daughter Directives.

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 (Figure 10), which carries out the comprehensive range of functions identified in Table 7.

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, 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 now published the relevant performance standards and these have been transposed as British Standards a 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 7. 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 11)	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 EC Daughter Directives 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 NOx, 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 11. 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 gasses
- 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.

NO2 diffusion tube monitoring

As indicated ed in section 4.3, the NO_2 diffusion tube network ceased operation at the end of 2005, following the conclusion of an independent review that it had now served its purpose. However, Defra acknowledged the value of the network's QA/QC programme in the wider context of LAQM in helping to improve and maintain the quality of all NO_2 diffusion tube measurements carried out by Local Authorities. The database of tube data from over 1100 sites since the early 1990s will continue to be of great value, not least for comparison with newer measurements.

Defra's "Support to Local Authorities for Air Quality Management" contract now incorporates a centralised quality assurance/quality control (QA/QC) framework for laboratories carrying out diffusion tube preparation and analysis. The existing activities will be reviewed and enhanced, but at present comprise –

- Promotion of the independent Workplace Analysis Scheme for Proficiency (WASP) operated by the Health and Safety Laboratory, with yearly assessment against agreed performance criteria.
- A field intercomparison exercise, in which diffusion tubes are co-located with an automatic analyser: from January 2006 this has been operated at a roadside site.
- Operation of a QC solution-testing scheme.

A data verification service for diffusion tubes has recently been launched. This offers additional data management activities for any Local Authorities who wish to make use of it. It is operated along similar lines to the national Calibration Club, and it is envisaged that it will be particularly useful to authorities operating large numbers of diffusion tubes.

4.7 Disseminating and using air quality data - and where to find out more

As discussed previously, 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 in the previous section. Once this has been done, the validated data are archived, useful information is 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 12, is vital to the success of the UK monitoring networks.

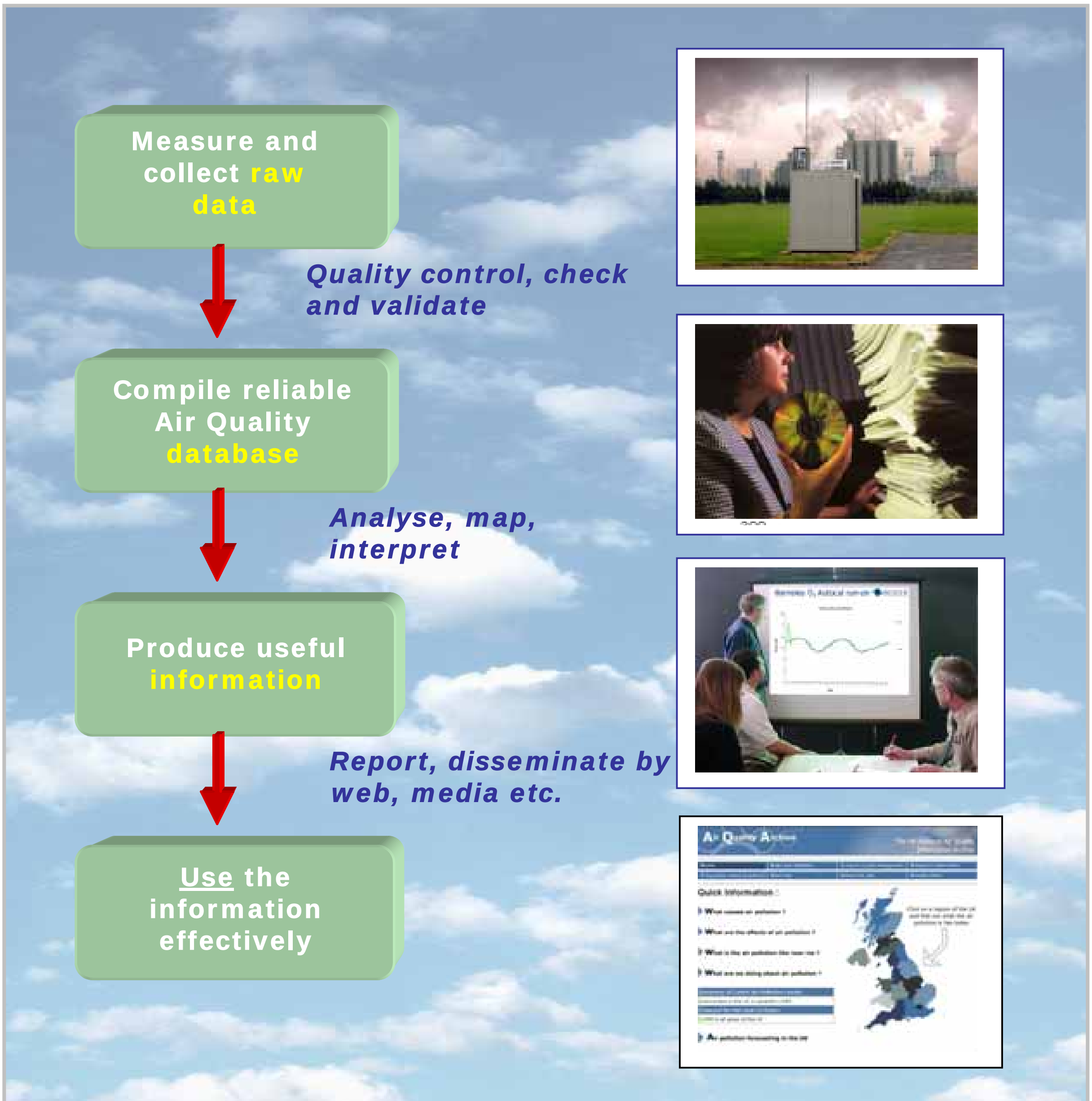


Figure 12. This report has been made possible by turning large quantities of raw air quality data into useful information

The UK's **Air Quality Archive** 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
3. To provide public warnings in the event of extreme conditions, as required by a number of EC Directives
4. To raise awareness and educate
5. To provide a comprehensive data and information resource to scientists, doctors and epidemiologists, both in UK and world-wide.

The Archive and Information Service 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 Service provides the main link between the networks and the public at large (Figure 13, Box 2). 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 170 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 ambient air quality measurement 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 for further details of information available from the website and Figure 16 for a map of the site. Box 4 provides details of a new 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 pollution events such as the Buncefield fires (discussed in Section 5). During this period, access to the website tripled. As well as its primary role in public information and awareness raising, the Archive has become a key resource for UK education and research. It has received wide praise, both within the UK and internationally.

As part of an ongoing improvement programme, the UK air quality website is currently undergoing a range of upgrades to its user interface; these are designed to further improve intelligibility, user-friendliness and ease of navigation, as well as enhancing its accessibility to all communities. See Figure 14.

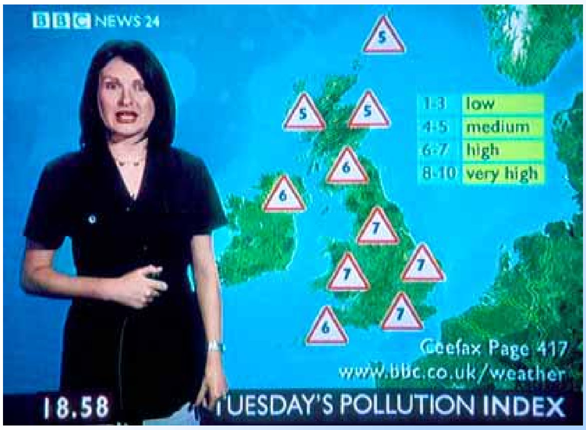
In 2004, a new air quality archive was established for Wales. Publicly available through its website at www.welshairquality.org.uk, this mirrors many of the services and functions of the UK National Archive. It provides for the first time a comprehensive one-stop resource for data and analyses covering all aspects of air quality in the Principality. The site also includes measurements from a range of monitoring sites subject to QA/QC review comparable to that employed in the AURN.

During 2006, a similar air quality archive for Northern Ireland has gone live at www.airqualityni.co.uk (Figure 15). A further web-based facility is under development for Scotland at www.scottishairquality.co.uk. This is currently subject to consultation by a wide range of air quality stakeholders and end-users.

Figure 13. The UK Air Quality Information Service

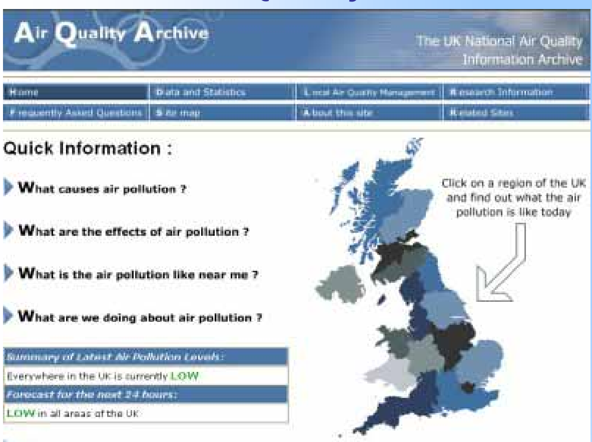
This utilises a wide variety of media, web and electronic resources to disseminate the latest air quality data and forecasts:

TV Weather Bulletins

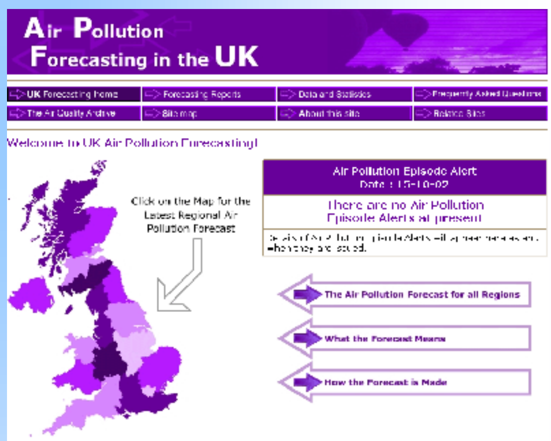


TV Teletext

The UK Air Quality Website



Twice daily web forecasts



A series of brochures & reports

Freephone 0800 556677

Figure 14. The new UK air quality website is more user-friendly

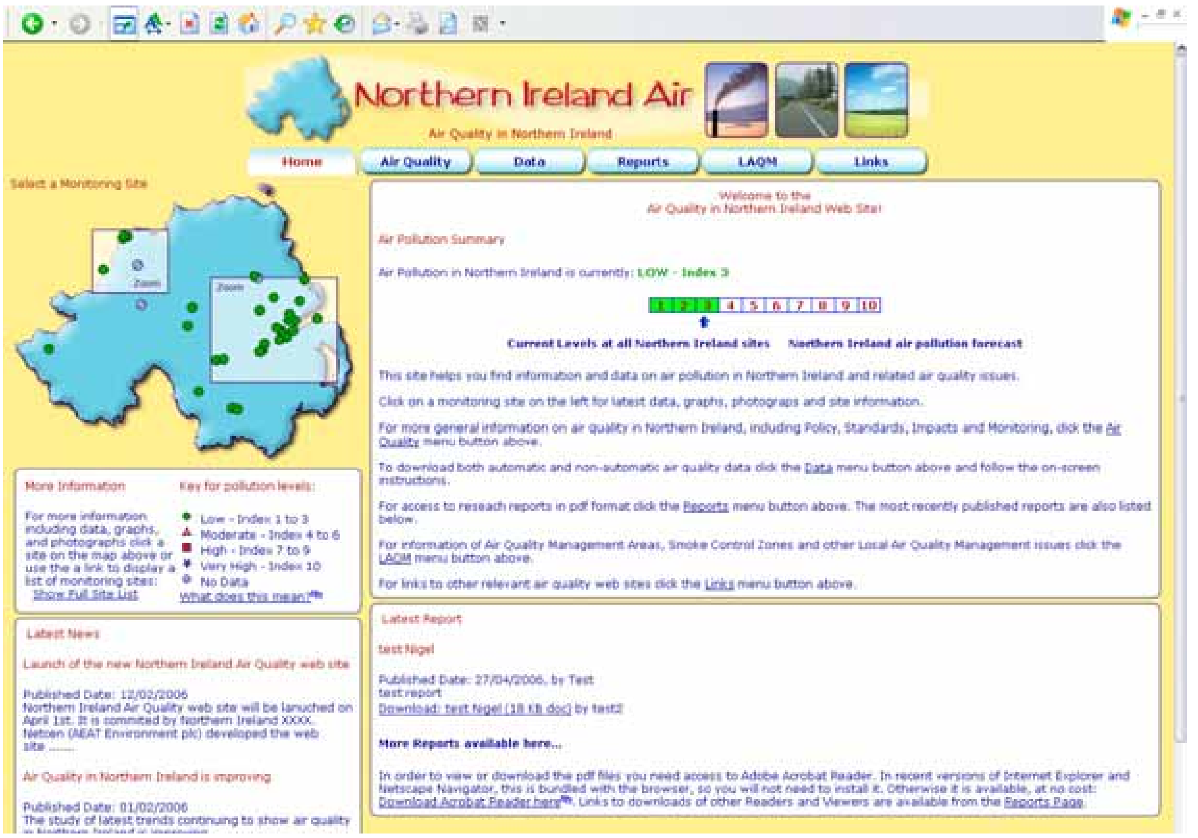


Figure 15. A new national archive for Northern Ireland has now gone live

Box 2. 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- coming soon 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 Executive 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. Information Available from the UK Air Quality Archive at www.airquality.co.uk

- Historic measurements from all national sampler and automatic air monitoring programmes
- A **new** 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 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 4. 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.

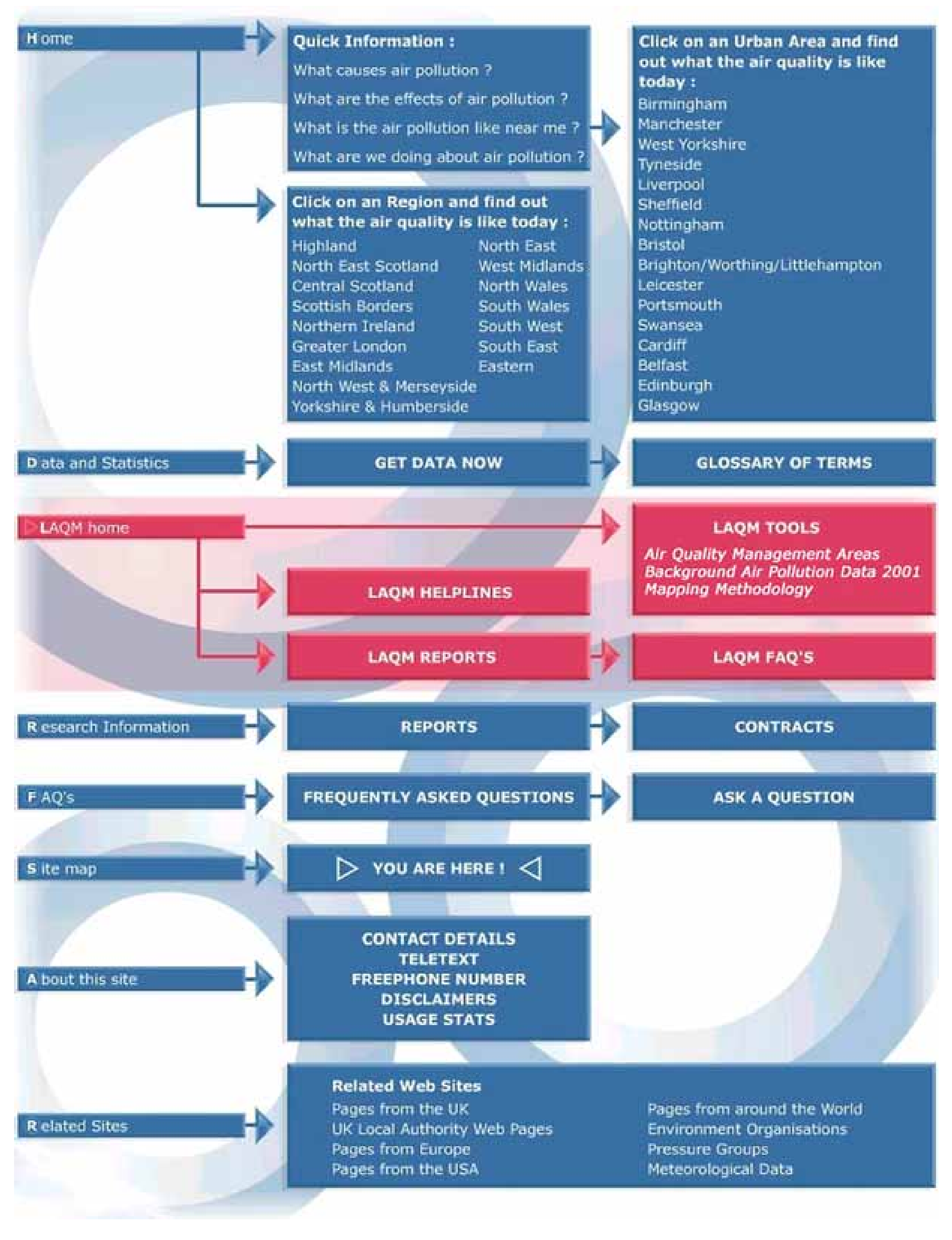


Figure 16. Map of the UK Air Quality Archive, showing the comprehensive range of available data and information from this resource

5. High Pollution Episodes

We focus in this section on periods when pollution levels during 2005 were unusually high, either locally or UK-wide. Through examining such episodes, we identify their causes and examine possible impacts.

5.1 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, result in the transport of pollutants from other areas or encourage their formation through chemical reactions.

All episodes occur because of a combination of these factors.

There are two main 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.

Bonfire night can provide an interesting example of an emissions-driven winter episode. Given cold, stable weather – poor conditions for dispersing emissions - widespread bonfires may result in elevated levels of PM_{10} particles in many urban areas of the UK.

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 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 in the UK during 2005.

5.2 Air Quality Impacts from the Buncefield Fires

We start, however, by examining a wholly exceptional event that does not fit readily into any of the pollution episode categories identified in the previous section.

On Sunday 11th December 2005, there was a major explosion at the Buncefield oil depot near Hemel Hempstead, north of London. Following the explosion, large stocks of refined petroleum product including petrol, aviation turbine fuel, diesel and gas oil stored at the depot remained on fire until Wednesday 14th December, when the last major fires were finally extinguished. A number of smaller fires continued until Thursday 15th December.

The large plume of particles and other pollutants produced by the fires could be seen from many kilometres away, and was also clearly identified in satellite images (figure 17).

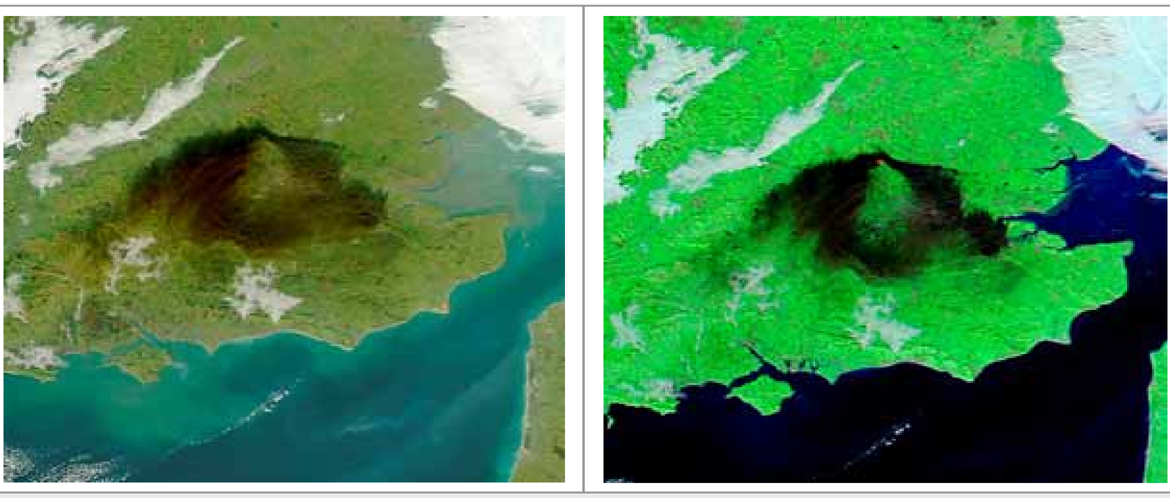


Figure 17 Visible and false colour MODIS satellite images of the Buncefield fires on 11 December- courtesy NASA and the Visible Earth Team

Due to the large scale of the fires and their dramatic visual impact, independent experts and the media expressed concerns about potential air quality effects on public health, both in the vicinity of the depot and throughout southern England.

This section is based on comprehensive initial analyses of those air quality impacts, presented in a report produced for Defra by Netcen, the Met Office and Health Protection Agency (HPA); this report was published in May 2006 and is now available from- http://www.defra.gov.uk/environment/airquality/buncefield/index.htm

We have also had regard to wide–ranging analyses and presentations from Netcen, Met Office, HPA and Kings College ERG at a technical seminar on the Buncefield incident, held in Culham, Oxfordshire in June 2006. These may be accessed in full (in PDF format) at- http://www.airquality.co.uk/archive/reports/reports.php?action=category&section_id=12

We thank all these contributing organisations for their insight and inputs to subsequent sections of this year's air quality report. In these, we examine:

- Likely emissions from the fires
- Monitoring undertaken
    - Around the plant
    - From an aircraft
    - In national and local monitoring networks
- Modelling of the plume
- Why ground level impacts were so low

Emissions

Buncefield was the largest industrial fire in Europe for over 50 years. Detailed estimates of the quantities of pollutants emitted have been undertaken in order to:

1) Enable improved modelling of the plume and
2) Understand the potential air quality impact of pollutants emitted during the fires.

The total amount of fuel at Buncefield Oil Depot was estimated from information about the terminal capacity provided by the UK Petroleum Industry Association (UKPIA) and Total Oil. Complete information on the actual quantities of fuel stored at the terminal during the event is not available at this time. These figures are therefore provisional and may need to be revised as more definitive information is made available.

Pollutant emission factors from the UK National Atmospheric Emission Inventory (NAEI at www.naei.org.uk), together with other published sources, were used to estimate the total emissions arising from the fires. The quantities of air pollutants emitted were estimated for four possible scenarios for the event:

1) 90% of fuel from BPA and 60% of fuel from HOSL depots combusted
2) LOW estimate (50% loss of fuel on site assumed)
3) MEDIUM estimate (75% loss of fuel on site assumed)
4) HIGH estimate (100% loss of fuel on site assumed)

These analyses attempt to give a picture of the different possible outcomes of the fire, including a more realistic scenario (1) as well as a possible worst-case scenario (4). The pollutants considered have air quality standards/objectives (or proposed standards/objectives), are greenhouse gas/global warming pollutants, or were considered to be most relevant for public health concern.

The results are shown below in Table 8. These demonstrate that the fires released 5% or more of annual UK air emissions of some pollutants – PM_{10}, $PM_{2.5}$ and benzo(a)pyrene. Emissions of other pollutants such as NO_2, CO and NMVOC were lower at < 0.1% of total annual emissions.

Table 8 – Estimates of total emissions of air pollutants emitted from the Buncefield oil fires

Pollutants	Scenario					UK Total (2003)		Scenario (%)			
	1	2	3	4	Units			1	2	3	4
NO_X	37.2	27.3	40.9	54.6	*Tonnes*	1570	*kTonne*	0.0024	0.0017	0.0026	0.0035
PM_{10}	8249.5	6054.8	9082.2	12109.6	*Tonnes*	141	*kTonne*	5.8507	4.2942	6.4413	8.5884
$PM_{2.5}$	4949.7	3632.9	5449.3	7265.7	*Tonnes*	86.9	*kTonne*	5.6958	4.1805	6.2708	8.3610
Dioxins	1.32	0.97	1.45	1.93	*g-TeQ g*	259	*g-TEQ g*	0.5087	0.3734	0.5601	0.7468
B[a]P	285.4	209.5	314.3	419.0	*kg*	4034	*kg*	7.0761	5.1936	7.7903	10.3871
CO	1712.7	1257.0	1885.6	2514.1	*Tonnes*	2768	*kTonne*	0.0619	0.0454	0.0681	0.0908
NMVOC	101.0	74.2	111.2	148.3	*Tonnes*	1089	*kTonne*	0.0093	0.0068	0.0102	0.0136
Benzene	58.3	42.8	64.2	85.6	*Tonnes*	13.6	*kTonne*	0.4290	0.3149	0.4723	0.6298
CO_2	0.144	0.105	0.158	0.211	*Mtonne*						
Carbon	39.2	28.7	43.1	57.5	*kTonne*	152324	*kTonne*	0.026	0.019	0.028	0.038

Figure 18 Inside the depot during the fires © Hertfordshire Constabulary

Figure 19 Devastated tanks after the fires © Hertfordshire Constabulary

Monitoring

1) Locally targeted monitoring

Rapid-response local monitoring was carried out around the oil depot and surrounding areas by i) Netcen on behalf of Defra and the DAs and ii) by the Fire Brigade's Scientific Advisors (Bureau Veritas) and HSL on behalf of the Health Protection Agency. These studies included:

- Particulate matter using a Grimm particulate sampler.
- Grab sampling for VOCs.
- Monitoring of CO, CO_2, SO_2, particulate matter, hydrocarbons and VOCs

This local air quality monitoring attempted to categorise both areas of maximum air quality impact (assessed on-the-spot visually) and nearby residential zones. Not surprisingly, the results obtained were highly variable in both space and time. The monitoring showed relatively high short-term concentrations of particulate matter and unburnt hydrocarbons close to the fire:

- Peak PM_{10} one-minute mean measurement - 985 μgm^{-3} on 12/12/05
- Peak PM_{10} 15-minute mean - 340 μgm^{-3} on 13/12/05
- Peak $PM_{2.5}$ 1m mean - 801 μgm^{-3} at on 13/12/05
- Peak $PM_{2.5}$ 15m mean - 318 μgm^{-3} on 13/12/05
- Peak PM_1 1m mean - 522 μgm^{-3} on 13/12/05
- Peak PM_1 15m mean -210 μgm^{-3} 13/12/05 a

To put these measurements made in the vicinity of the Buncefield depot in context, however, they are lower than those characteristic of near-roadside environments or during typical Bonfire Night. See subsequent sections and Figure 22 for further exploration of this point.

Parallel VOC sampling (meeting the requirement of the USEPA method TO-14A) showed that no measured VOC concentrations exceeded the short term Environmental Assessment Levels (EALs) for air for the protection of human health. For example, the highest recorded toluene grab-measurements around Buncefield were of the order of 700 μgm^{-3}. By way of comparison, the EAL for this species is 8000 μgm^{-3}.

2) Monitoring from the instrumented FAAM aircraft

The Facility for Airborne Atmospheric Measurements (FAAM) BAe146-301 aircraft, operated jointly by the Met Office and NERC, flew on the 12th and 13th December to study the position and composition of the plume (Figures 20, 21). These flights were made more complex by their proximity to several airports; this part of southern England has one of the highest air traffic densities on earth.

The aims of the flights – which included runs through, around and downwind of the plume were:

1) To provide real-time information on the position of the plume
2) To provide the *in-situ* data on its chemical composition and pollutant levels

Airborne measurements showed that the plume was mainly composed of black soot. The maximum particle level recorded was (only) 100 $\mu g/m^3$ (max of 30-sec averages) so instantaneous peaks may have been higher. Carbon monoxide (CO) and oxides of nitrogen (NO_x) were detected, but not in large quantities. Concentrations of PAHs and dioxins measured in the plume were also surprisingly small.

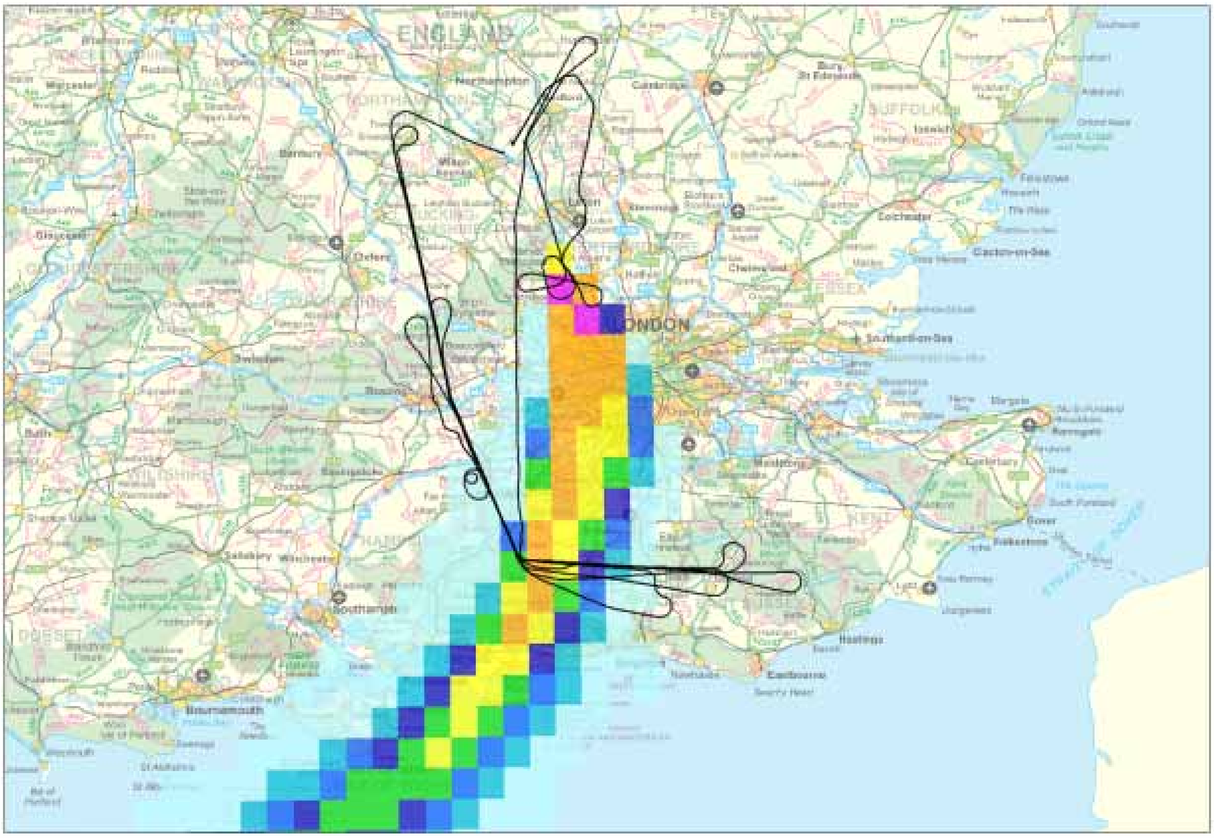


Figure 20- Flight paths of the FAAM aircraft sampling the plume on the 13th, together with Met Office NAME model predictions for that day.

Figure 21 The FAAM Aircraft used for plume monitoring

3) Observations from national networks

Hourly measurements continued throughout the fires in the UK national automatic monitoring networks (AURN and Hydrocarbon); data were disseminated in real-time, together with twice-daily forecasts, on the air quality website at www.airquality.co.uk, a range of media outlets and email bulletin services.

As noted in Section 3.2, the UK Air Quality Index (AQI) is used to report hourly air quality concentrations. This index provides a simple measure of how clean or polluted the air is, together with an indication of possible health impacts.

Analysed in detail, AURN measurements did not show any instance during the Buncefield incident with PM_{10} levels of MODERATE or above that were attributable to the fire. Although Bradford Centre exhibited levels into the HIGH AQI band (24hr average 50-75 $\mu g/m^3$ TEOM), this site was affected throughout this period and throughout the entire year by localised construction work; Camden Kerbside and London Marylebone recorded MODERATE PM_{10}, but these are located close to major roads (less than 1 metre from the kerb) and are therefore substantially affected by local transport sources.

In short, AURN PM_{10} measurements show no evidence of significant ground level air quality impacts from the Buncefield plume. It is interesting to note that similar analysis of national monitoring data from parts Northern France that could have been directly affected also showed no evidence of any ground-level impacts.

Figure 22 compares PM_{10} concentrations measured throughout the AURN during the Buncefield incident with those recorded during a range of recent Bonfire Night weeks. Bonfire Night particle concentrations depend critically on weather conditions and timing, and therefore vary markedly from year to year, The graphed Bonfire Night events (1995, 2001, 2005) have been selected as being typical of high, medium and low-intensity events of this type, respectively.

Please note that the running 24-hour average metric plotted here conforms to the Defra Health bandings for PM_{10}. Note, also, that the data graphed are network averages over the whole of the AURN (for sites with >75% data capture).

Although the different time series in Figure 22 are not strictly comparable, because they do not cover the same time periods or the same geographical scale (Bonfire Night being nationwide and Buncefield more localised), they nevertheless serve broadly to demonstrate the magnitude of the Buncefield event. It is clear that this was associated with UK-wide PM_{10} concentrations similar to those observed during Bonfire Night 2005. However, as the result of favourable meteorological factors, the 2005 event did not exhibit any significant increase in particle levels above background.

Briefly examining results from other national networks, London Marylebone is the closest automatic hydrocarbon network station to Hemel Hempstead. Levels here were unexceptional during the Buncefield week. However, ratios of individual species to benzene show a spike for toluene, xylene and trimethylbenzenes on the 12^{th}. This is the only unusual observation here, although absolute levels remain low. The observed ratios are broadly consistent with evaporative emissions of fuel, but different to those collected by grab sampling near to fires. It cannot be ruled out that this spike in hydrocarbon species was due to the Buncefield fires.

Levels of PAHs (Polyaromatic Hydrocarbons) rose in London during the week of the fire. However, we know very little about week-on-week variations of these species. Moreover, the lack of consistency in individual concentration of PAHs and dioxin profiles and ratios actually suggests a different causation at the three London sites; this may indicate local sources, or simply ‘noise’ in the week-on-week concentrations.

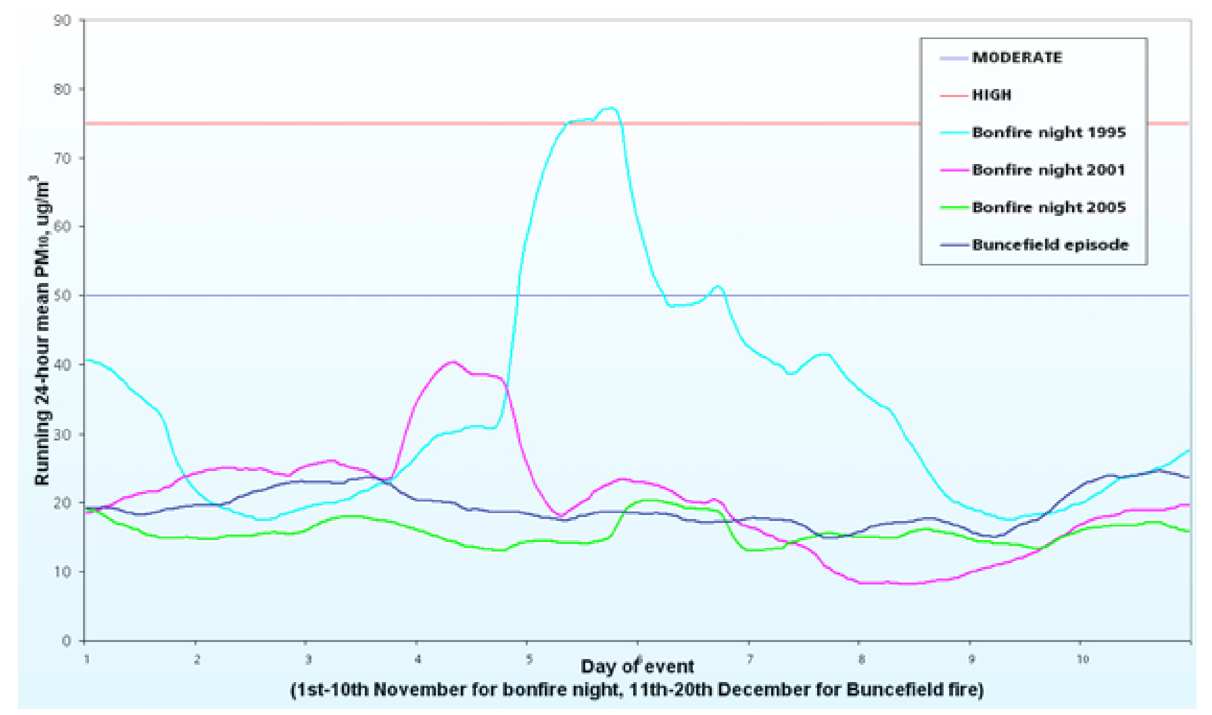


Figure 22 PM_{10} Concentrations averaged over the AURN- Buncefield week compared to typical Bonfire Nights

4) Local Network Monitoring

In addition to the national monitoring networks operating in the southeast of England, a number of local programmes – often with denser geographical spacing of monitoring sites - exist in this part of the country. These include:

- Herts & Beds Air Pollution Monitoring Network (HBAPMN) www.hertsbedsair.org.uk
- London Air Quality Network (LAQN) www.londonair.org.uk
- Kent Air Quality Monitoring Network (KAQMN) www.kentair.org.uk
- Sussex Air www.sussex-air.net

Additional data available from these local and regional monitoring networks co-ordinated by King's College Environmental Research Group has shown some small and short-term (15-minute) PM_{10} peaks at a few sites in Hertfordshire, North London, Surrey and Sussex. Modelling by the Met Office using the advanced NAME III system (see next section) confirms that the air arriving at these sites at the times of the peaks could have come from the Buncefield area.

Despite these sporadic and transient events, comparison of ground-level air quality data with health-based air quality standards shows that pollution levels during the incident remained LOW or just into the MODERATE category at regional monitoring locations in the southeast,

Modelling

Using its well-established NAME dispersion model[42,43], the Met Office undertook detailed modelling of the plume, both before and after the event. This involved large uncertainties, especially in the early stages when the composition and amount of fuel burning was not known accurately. Observations by civilian aircraft helped to fine-tune the Met Office model results. Some typical NAME results are shown in Figure 23.

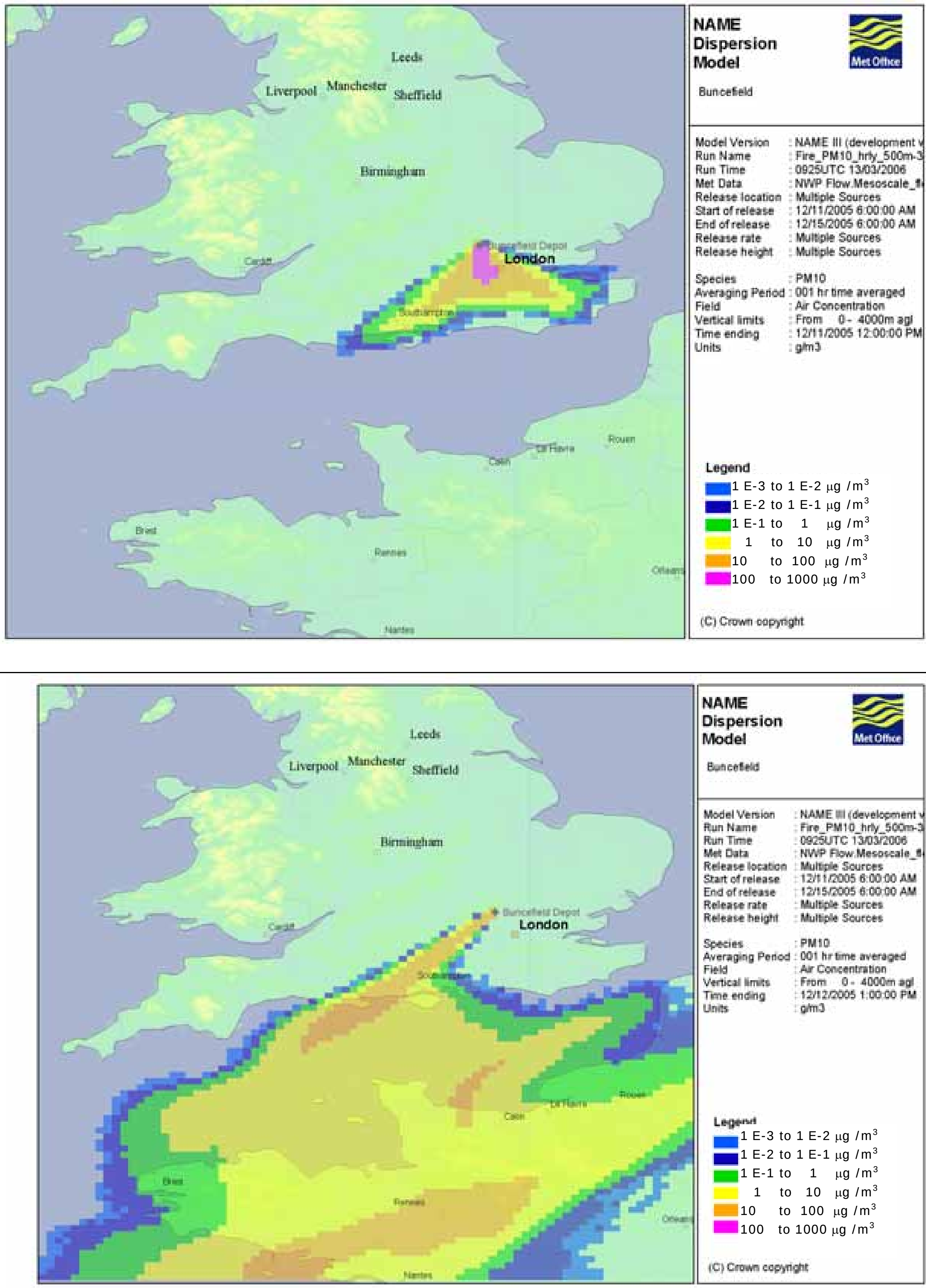


Figure 23 NAME predicted hourly averaged PM_{10} concentrations between 0 and 4000 m at 12:00 pm on 11/12/05 (top) and at 13:00 pm on 12/12/05 (bottom)

We have seen earlier that, despite the very large quantities of pollutants emitted, a wide range of air pollution monitoring undertaken before, during and after the event showed that UK ground-level concentrations of a wide range of pollutants remained LOW to MODERATE over local, regional and national scales. Although there was limited evidence of sporadic and episodic plume grounding on occasions, it appears – and the models confirm this - that the high plume buoyancy and favourable meteorological conditions resulted in the overwhelming bulk of the pollution rising high into the atmosphere, with minimal mixing to the ground. As a result, we saw little evidence of widespread or significant air quality impacts at ground level due to the pollutants emitted from the Buncefield fires.

Were we lucky? To answer this question, the Met Office has modelled several “what-if?” scenarios as follows:

- Windy conditions.
- Uncontrolled burning.
- Summer convective conditions.

The conclusion was that, even under this wide range of conditions, the model predicted ground-level pollution concentrations that would not have been significantly worse than those actually observed.

Health Impact Assessment

The Health Protection Agency has carried out three surveys to assess possible public health impacts of the incident:

1) Review of A&E case notes (acute effects)
2) Population survey (public concerns)
3) Occupational Health survey (‘high exposure’ group)

The Accident & Emergency case notes review discovered that 77% of those attending A&E due to the impact of Buncefield were from the emergency services. In most cases, this was because standard advice was issued suggesting that they should do so. Of the 244 cases reported, only 22 required further attention such as admission or referral to GP. This included the physical injuries from the explosion itself. There was an initial 65% increase in A&E workload but, after 24-hours, this returned to normal.

A random sample of 5,000 local people was also surveyed for their concerns following the explosion; a 40% response was obtained- typical for this kind of study. Almost half of the people surveyed were worried about potential long-term health impacts, whilst around a quarter were worried about short-term effects. Only 6% said they were specifically concerned about the smoke plume. Over 40% indicated that they were satisfied with the advice obtained.

A comprehensive survey of occupational health departments in the agencies directly involved in the incident is currently underway.

5.3 A photochemical smog episode: June/July 2005

HIGH levels of air pollution were measured across the Automatic Urban and Rural Network (AURN) during June 2005. This was the first – and only – extended photochemical episode of this type during the year.

Levels were highest in the South East area and Greater London. Ozone levels in index 7 of the Defra HIGH band (180-239 μgm^{-3}) were recorded at seven stations - see Table 9. The highest hourly concentration during June was 202 μgm^{-3} (index 7); this occurred at Weybourne at 19.00 on 24th June. High levels of ozone were measured during 5 consecutive hours at Weybourne between 18.00 and 23.00.

The 3rd Daughter Directive (Directive 2002/3/EC) on ozone in ambient air has established an alert threshold of 240 μgm^{-3} as an hourly average over three consecutive hours. However, this alert threshold was not exceeded during the episode.

Table 9. Number days of Moderate and High levels at each station across the AURN

Site	Number of Days		Max hourly if High (μgm^{-3})	Date of hourly max concentration
	Moderate	High		
Weybourne	18	2	202 & 192	24/06/05 & 19/06/05
Sibton	18	2	190	23/06/05 & 24/06/05
London Bexley	10	1	192	23/06/2005
St Osyth	17	1	186	19/06/2005
Bournemouth	16	0	180	19/06/2005
London Eltham	14	0	180	23/06/2005
Lullington Heath	16	0	180	23/06/2005

As can be seen in Figure 24, the episode started on 19th June, when more than 47 stations measured MODERATE levels of O_3 and 2 stations measured HIGH levels (index 7). The episode ended on 24th June, when only 23 stations measured levels in the MODERATE band and 2 stations measured HIGH levels (index 7).

There was a second period of elevated O_3 levels between 9th and 17th July. However, the levels rarely reached MODERATE index 5; the highest levels were measured in Wicken Fen at 172 μgm^{-3} (index 6) on the 14th July. This July period provides an illuminating contrast to the June episode, and is therefore investigated here.

Reasons for the episode

The June summer ozone episode was characterised by rising temperatures and air masses re-circulating over northern Europe and the UK. These conditions typically result in summer smog episodes as the ozone precursor chemicals react in the presence of sunlight. Similar summer episodes in the UK have previously been reported [44,45] and discussed in earlier annual reports in this series.

Comparisons between the contrasting June and July periods clearly show that both high temperatures and re-circulation of air masses over Europe and the UK were required to produce elevated ozone concentrations during the earlier period. High temperatures alone were insufficient to produce an episode in July.

1) Temperature

During June and July, there were two periods of high ambient temperatures in the UK:

- 18th to 24th June (the first period)
- 10th to 15th July (the second period)

During the first period, maximum temperatures reached *circa* 35ºC, with a daily average *circa* 26ºC a (Figure 24). These high temperatures were measured predominantly in the South East. During the second period, maximum temperatures reached 29ºC, with a daily average ~ 24ºC.

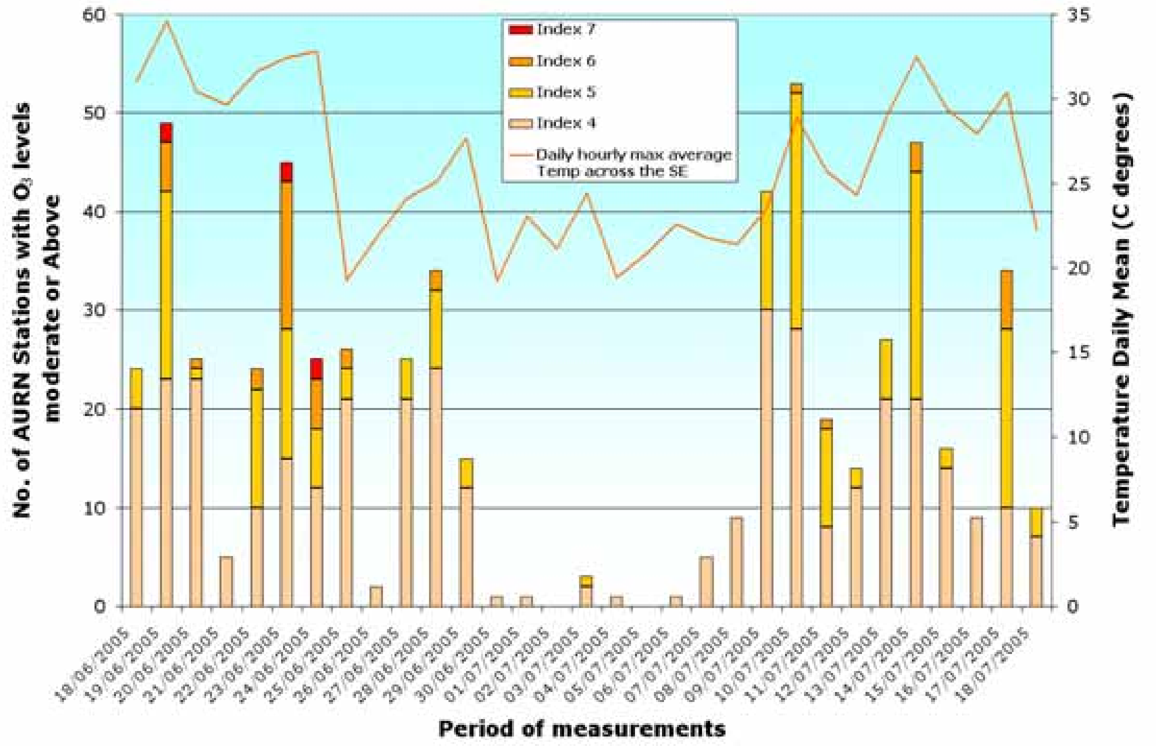


Figure 24. Ozone Episode Days – Number of Stations with MODERATE and HIGH levels between 18th June and 18th July 2005 with temperature profile across the South East.

As shown in Figure 24, however, only the first period of high temperatures resulted in HIGH levels of ozone. These were particularly noteworthy on 19th, 23rd and 24th June. Other factors were clearly necessary to bring about elevated ozone concentrations:

2) Re-circulation of air masses

96 hours airmass back-trajectories for the two periods of elevated temperatures in June and July were analysed. These clearly demonstrate the importance of air masses re-circulating over Europe and the UK. Figure 25 shows an example of the different back-trajectories prevailing during the two periods. During days of HIGH levels of ozone (19th, 23rd and 24th June), the re-circulation was over Europe and the UK. For the second period, despite the high temperatures, clean air masses originating in Ireland or in the Atlantic prevented ozone levels reaching HIGH.

Episode observed in local networks

The ozone episode was also measured across three local networks in the South East: Kent Air Quality Network, London Air Quality Network (LAQN) and the Hertfordshire & Bedfordshire Air Pollution Monitoring Network (HBAPMN).

As can be seen in Table 10, the highest hourly average was measured at Sevenoaks 2 Urban Background (UB) station at 195 on the 24th June. HIGH levels of O_3 were measured at Sevenoaks 2 UB and Greenwich 4 stations on the 23rd June, at Sevenoaks 2 UB, Bromley 4, Luton Background (UB) and Folkestone Suburban on the 24th June and at Mid Beds Silsoe (Rural) on the 14th July.

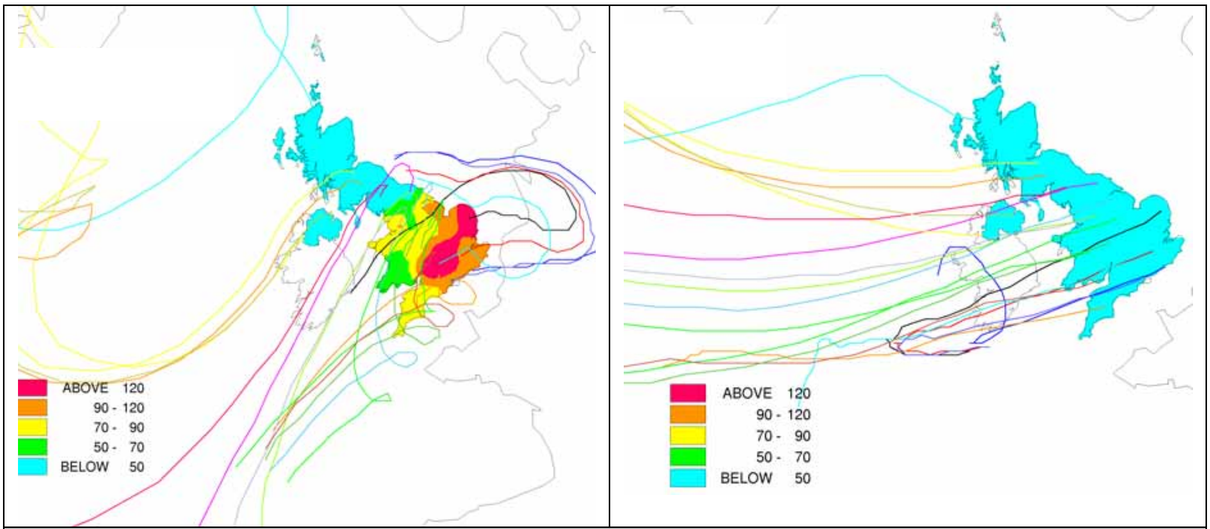


Figure 25. 96-hour air masses back trajectories

1st Period – 24/06/05 **2nd Period – 15/07/05**

Table 10. Defra's HIGH O_3 levels measured across Local Networks in the South East

Station Name	Type	Network	Date & hour	O_3 Hourly average (μgm^{-3})
Sevenoaks 2 - Greatness	Urban Background	Kent AQN	24/06/2005 11:00	195
Luton Background	Urban Background	Kent AQN	24/06/2005 11:00	189
Luton Background	Urban Background	Kent AQN	24/06/2005 10:00	187
Mid Beds Silsoe	Rural	HBAPMN	14/07/2005 16:00	185
Folkestone Suburban	Suburban	Kent AQN	24/06/2005 17:00	184
Bromley 5 – Biggin Hill	Suburban	LAQN	24/06/2005	184
Sevenoaks 2 - Greatness	Urban Background	Kent AQN	23/06/2005 16:00	183
Greenwich 4 – Eltham	Urban Background	LAQN	23/06/2005	180

Episode observed across Europe

The ozone episode on the 23rd and 24th of June was also observed in Belgium and the Netherlands. Figure 26 shows the following sequence of hourly ozone measurements in the UK, Belgium and the Netherlands on 23rd June between 12:00 and 23:00 (note that these data are provisional):

The episode on the 19th June was only measured in the UK (southeast England), while that on the 23rd and 24th affected both Europe and the UK.

The re-circulation of air masses between the UK and Europe, in conjunction with high temperatures across the UK and Europe, were clearly the dominant causes of this transboundary episode.

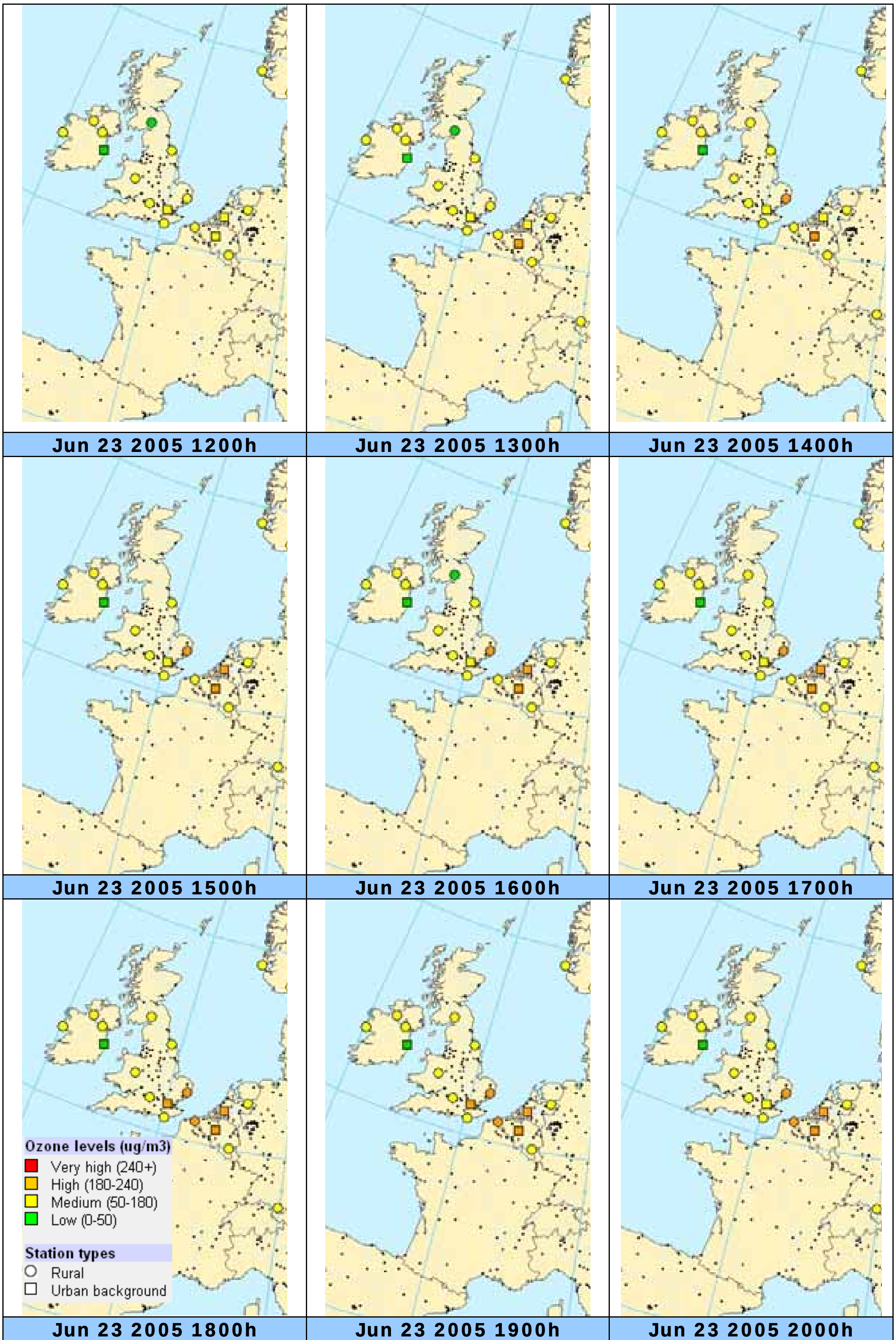


Figure 26. O_3 levels measured across Europe on 23rd of June between 12:00-20:00.

*** Data and maps from http://ozone.eionet.eu.int***

*** *All data are provisional***

5.4 Near-road episodes and objective exceedences

On Friday May 26th 2005, the 36th day of the year with PM_{10} 24-hour averaged concentrations measured in excess of 50 μg m^{-3} was recorded at London Marylebone Road. As the attainment date for the daily PM_{10} objective in the 1st European Daughter Directive was December 31st 2004, the air pollution episode measured at Marylebone Road on this day represented the first formal breach in the UK of the 35 days per year allowed under the Directive.

The PM_{10} problem at this location can be directly linked to the huge volume of motor vehicles on the road at that location each day. At the end of the year, a total of 118 days of exceedences were recorded at Marylebone Road. The only other roadside site in the UK with more than 35 days above 50 μg m^{-3} in 2005 – and therefore in non-compliance with the Directive - was Camden Kerbside, with 52 such days. These two sites exceeded the objective, despite the fact that 2005 was a relatively unsettled year in terms of meteorology, and would therefore be expected to record lower numbers of pollution episodes than in years with cold, stable winter weather or heatwave summers.

The annual mean NO_2 objective of 40 μg m^{-3} was also exceeded at 27 urban monitoring sites in 2005. These were mainly at roadside and background sites in London or at roadside sites elsewhere across the UK. Exceedences of this NO_2 objective are likely to continue to be a problem in the future, especially at roadside locations.

One of the main topics of discussion regarding near-road NO_2 concentrations at present is the increase in direct emissions from vehicle exhausts. Unfortunately, a side effect of the fitting of particulate traps to a many diesel vehicles is an increase in NO_2 emissions. Thus reducing PM_{10} concentrations at roadsides can have a knock-on effect of worsening the NO_2 situation. The relative lack of success of current emission control technologies in addressing the problem of NO_2 is discussed further in Section 7.4.

Figure 25 Gridlocked traffic in Central London © Jon Bower

5.5 Episodes around industrial locations

Grangemouth SO_2

Short-term elevated levels of primary pollutants can be observed in the proximity of major emission sources such as power stations, refineries or large industrial plant. Such episodes tend to be intermittent, highly localised and are often associated with rapidly fluctuating concentrations. In the case of sulphur dioxide, for instance, increasingly stringent emission controls and the move towards lower-sulphur or clean fuels such as natural gas mean that such events are now becoming increasingly rare - but not unknown.

The Grangemouth monitoring site is located in a heavily industrialised area of Central Scotland; nearby pollution sources include a number of small industrial plants, the Longannet Power Station and the large INEOS petrochemical and refinery complex situated 1km from the measurement point.

In 2005 at Grangemouth, there were only 4 exceedences of the 15-minute SO_2 concentration target level of 266 $\mu g\ m^{-3}$ on 2 days, compared to 60 over 18 days in 2004; this large decrease is most likely to have been caused by different meteorological conditions. The figures vary considerably from one year to the next, depending on how many incidents of plume grounding are caused by the meteorology in the vicinity of the monitoring site. Across the UK, there were generally fewer exceedences of the 15-minute SO_2 concentration target level in 2005 compared to 2004, and the Air Quality Objective of 35 or fewer exceedences was achieved at all locations.

Figure 26 Grangemouth refinery after heavy rainstorm © Jon Bower

An Air Quality Management Area (AQMA) has now been established for the region encompassing Grangemouth petrochemical complex and adjacent areas; this is one of the few to have been declared in the UK due to sulphur dioxide (Table 3).

Port Talbot PM_{10}

Another example of short-range transport of industrial pollutants causing local problems may be seen in Port Talbot, Wales, although here the problem pollutant is PM_{10} rather than SO_2. An important characteristic that this area shares with Grangemouth is the multiplicity of pollution sources; these include the M4 motorway, port activities (iron ore offloading) and the large Corus steelworks.

29 exceedences of the PM_{10} daily mean of 50 $\mu g\ m^{-3}$ were recorded here during 2005, just below the permitted number of 35 exceedences allowed by the UK Air Quality Objective. This Objective was not met in 2003 or 2004, when there were 43 and 38 such exceedences respectively. As mentioned earlier, it is likely that the relatively unsettled weather in 2005 led to the improvement in air quality at this location compared to previous years.

There continues to be much debate about the cause of the high levels in this area; this is being investigated by the Environment Agency. The discussions continue despite the commissioning of a new blast furnace at the Corus plant in 2003, as well a range of measures adopted to minimise fugitive particle emissions from ship offloading, ore stockpiling, containment and transport at the nearby dock area.

In order to tackle the continuing problems at this location, an area covering the majority of land and properties between the Corus Steel Works and the M4 Motorway has been declared an AQMA by Neath Port Talbot due to PM_{10}.

6. How air pollution varies across the UK

We examine how levels of air pollution vary across the UK, and see how these variations relate to both emissions and the behaviour of pollutants once emitted into the atmosphere. We also assess how UK-wide levels of air pollution are predicted to change in the coming decades.

6.1 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, nitrogen dioxide and volatile hydrocarbons (VOCs) such as benzene and 1,3-butadiene; it also emits a significant proportion of particles (PM_{10}). Concentrations of all these pollutants are therefore usually highest in built-up urban areas.

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; they are characteristically less dependent on emission patterns, and tend to be more strongly influenced by 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.

6.2 Mapping methods

We use two different approaches for modelling and mapping levels of air pollution across the UK for 2005 and future years.

For SO_2, 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 which now enable us to produce detailed maps (1km resolution) of average or peak pollutant concentrations across the country. The mapping method is detailed in a number of published reports on the UK Air Quality Archive- for example, Stedman et al (http://www.airquality.co.uk/archive/reports/cat16/0604041050_scenarioprojectionsreport8.pdf).

An important feature of these models is that they are directly related to the real-world measurements. Unlike monitoring, however, modelling can help 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 UK-wide air quality problems in the most direct and cost-efficient manner.

For ozone, the Ozone Source-Receptor Model (OSRM) is used to create detailed maps of current and future ozone concentrations. This model (see Hayman et al http://www.airquality.co.uk/archive/reports/cat16/0604031524_ED47154_OSRM_Modelling_for_AQS_Issue1.pdf) explicitly represents the photochemical processes occurring in the atmosphere in the formation of ozone. This means it can be used to predict future ozone concentrations; this would not be possible using an empirical modelling approach.

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

- Uncertainties surrounding the emission inventories
- Uncertainties relating to the atmospheric dispersion model
- Complexities of the atmospheric chemistry
- Uncertainties relating to the source apportionment of ambient concentrations; this is particularly important for PM_{10}, for which a number of the sources are not well characterised.

The mapped concentrations in Figures 27 to 30 have been verified by comparison with automatic monitoring data, including data from non-national network sites that are of known high quality.

All predictions of future concentrations are subject to additional uncertainty, including that associated with economic and energy forecasts, political policy decisions and possible changes in the behaviour of the atmosphere.

6.3 Maps of current and future levels

Maps showing current and projected concentrations for the future years of 2010 and 2020 for SO_2, NO_2 and PM_{10} are presented in figures 27-30. The projected maps have been calculated from a 2004 base year, rather than from 2005. These are the most up to date projections available. This means that the projected maps are not directly comparable with the 2005 maps, but they do give an indication of how concentrations are likely to change in the future.

SO_2

A map showing average SO_2 levels across the country in 2005 is shown in Figure 27a. This clearly shows the impact of power station and industrial emissions in Northern England, the Thames Estuary and Forth Valley, as well as domestic emissions focussed around Belfast in Northern Ireland.

Figures 27b and 27c show a similar geographical distribution of predicted average SO_2 levels for 2010 and 2020, with the impact of power station and industrial emissions still evident. These figures show a progressive decline in overall levels of this pollutant, due primarily to the expected reduced emissions from power stations and industry.

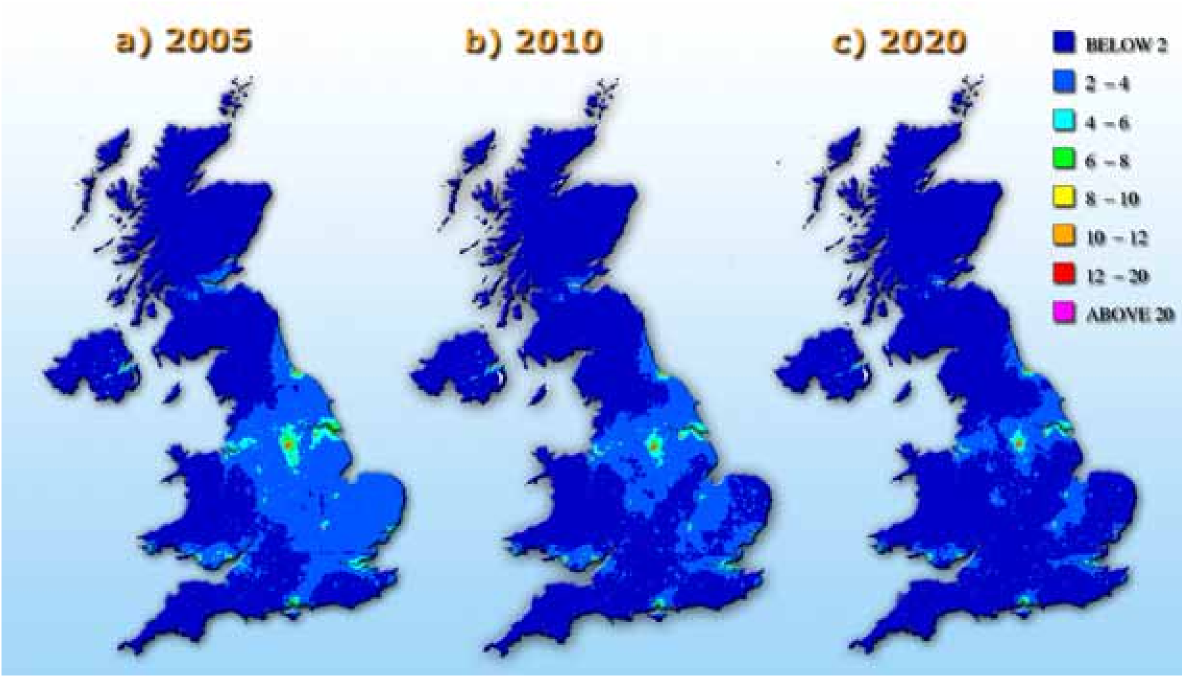


Figure 27 Background SO_2, annual average concentrations (µgm^{-3}), 2005-20

NO_2

UK-wide patterns of nitrogen dioxide concentrations in 2005 and predicted concentrations in 2010 and 2020 are shown in Figures 28a-c. These are markedly different from those of sulphur dioxide; 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.

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. Concentrations in future years are expected to have a similar geographical distribution to concentrations in 2005, but to decrease with time. This reflects the fact that emissions from traffic are expected to decline over time.

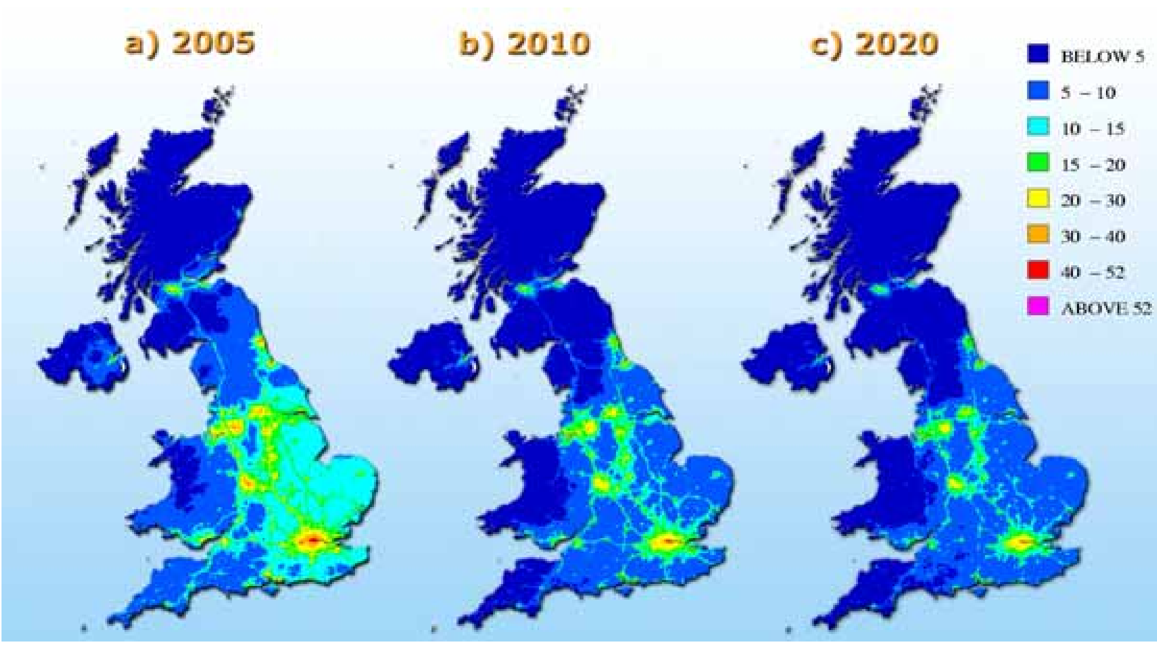


Figure 28 Nitrogen dioxide (NO_2) maps for 2005- 2020 (µgm^{-3})

PM_{10}

Particles are not a distinct chemical species like the other pollutants measured in the automatic networks; rather, they consist of material from many sources and are usually classified on the basis of size and not chemical composition. In the UK automatic monitoring networks, particles of average aerodynamic diameter less than 10 microns (where one micron is a thousandth of a millimetre) are measured. These fine particle fractions can be inhaled deep into the lungs and therefore provide a better indication of potential health impacts than larger particle size ranges.

The sources of primary PM_{10} particles are diverse. They are produced from motor vehicles, fuel burning, building work, industrial emissions, soil and road dust and quarrying. A significant proportion of PM_{10} particles are 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 particles can therefore be produced considerable distances from the emission sources.

This diversity of PM_{10} source types and influences is reflected in the maps of average concentrations in Figure 29; these shows markedly less variation across the country than for the other pollutants assessed here. In terms of future PM_{10} levels, concentrations are predicted to decline in future years, reflecting declining emissions from the majority of significant sources of primary and secondary PM_{10}.

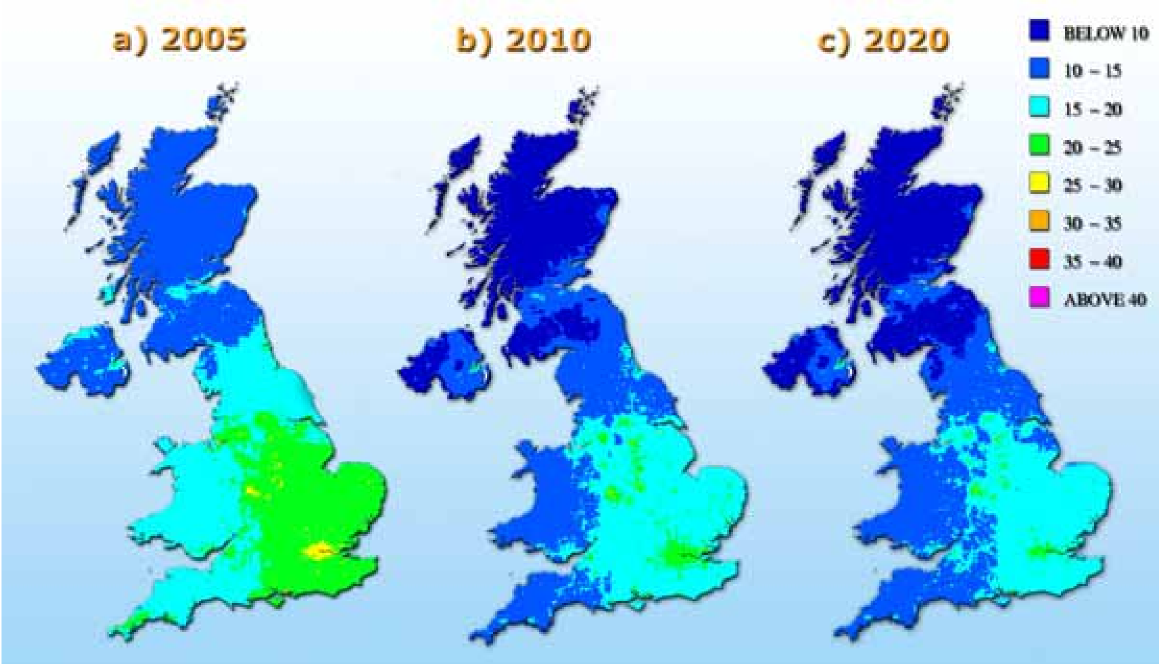


Figure 29: Background PM_{10} levels (μgm^{-3} gravimetric) for 2005- 2020

Ozone

UK-wide concentrations of ozone (expressed here as the accumulated hours above 80μg m^{-3}) in 2003 are shown in Figure 4. This way of expressing ozone has been chosen to represent the impact of this pollutant on vegetation. Values of this metric will be highest at locations with either higher average concentrations or where concentrations are elevated due to summer ozone episodes.

As highlighted previously, 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 ozone to generate NO_2.

The net result of these effects, acting together, is shown in Figure 30a, which shows ozone concentrations in 2003. 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 ozone 'hole' around London, that levels of this pollutant are characteristically depressed in urban areas, as a result of its 'scavenging' from the atmosphere by road transport emissions.

Projected ozone concentrations, presented in Figures 30b and c, show that concentrations of this pollutant are generally expected to increase across the country in future years. By 2020, the highest concentrations are expected to remain in the South and southwest England, with lower concentrations in Scotland, Northern Ireland and more urban areas of England. This general projected increase in UK-wide ozone levels reflects a combination of i) predicted increases in hemispheric background ozone levels and ii) the continuing control of NO_x emissions from traffic.

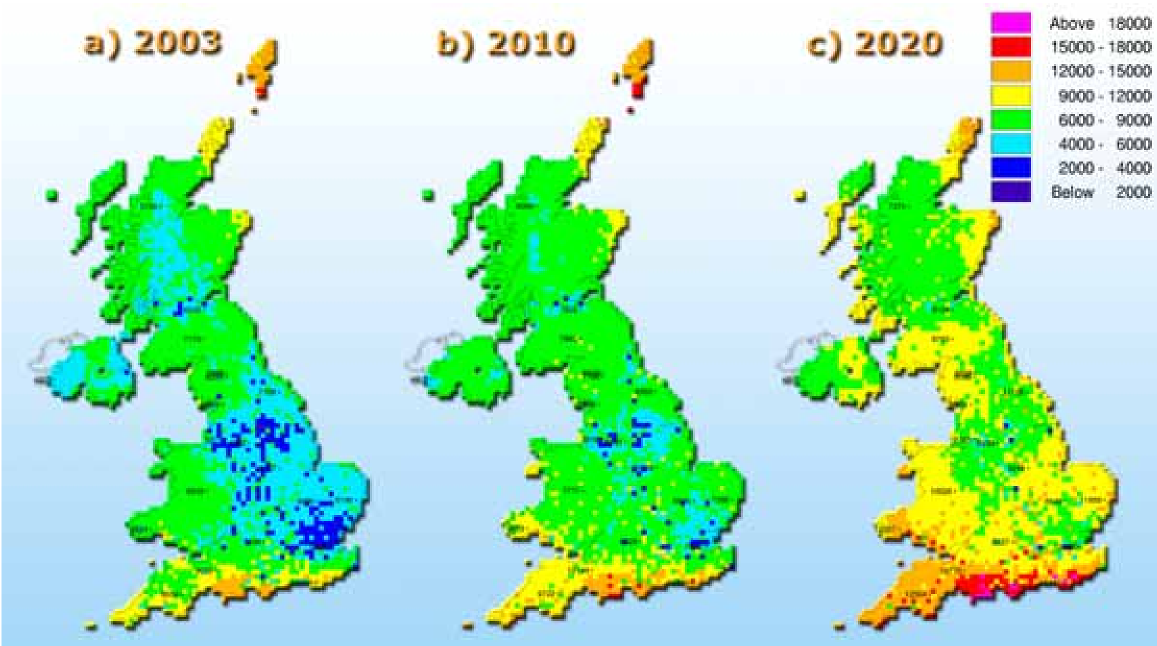


Figure 30. Accumulated ozone hours over 80 μgm^{-3} (μgm^{-3}.hours), 2003-20

7. How air pollution has changed over time

Is air pollution getting better or worse? Here we find out, but the answers are not always clear-cut.

7.1 Introduction

The concentrations of different pollutants can vary markedly over many 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 magnitude, timing and distribution of their emission sources. By contrast, 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 human health and other impacts, both the short and the long-term. 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 examining long-term trends in UK air quality; these show how our overall exposure to harmful air pollutants is changing over time. Changes in our pollution climate are also important in assessing whether current regulations and controls on emissions are effective, or if new measures are needed at local national, or international level (see Section 3).

In this section, we examine the changing levels of air pollutants over many years and seek to answer the question "*is air quality improving or declining and to what extent?*" This involves an examination of black smoke and sulphur dioxide monitoring data extending back as far as the 1950s and 1960s, when air quality legislation and monitoring networks were in their infancy. More recent trends are examined in the context of:

1. The UK Government's new air quality indicators (Section 3.2) and
2. Assessing compliance with UK Air Quality Objectives (Tables 1 and 2)

7.2 Historic trends in black smoke & sulphur dioxide

Air pollution in the UK has changed significantly since the middle of the last century. The 1950s and 1960s were eras of industrial and domestic smogs that were closely associated with the emissions of black smoke (very fine particles) and sulphur dioxide from coal burning. Figure 31 presents monitoring data from the UK black smoke and SO_2 network. This network, which ceased operation this year (Section 4.3), was originally established in response to these serious smogs. It was one of the earliest examples of a national monitoring network in the world, comprising at its peak over 1200 monitoring sites.

Figure 31 shows how levels of both black smoke and SO_2 ('net acidity concentration') have dramatically declined since the inception of the monitoring network to around 2000. Since the turn of the century this long-term decline has flattened out, with current background levels of around 15 $\mu g\ m^{-3}$ SO_2 and 6 $\mu g\ m^{-3}$ black smoke. The marked decline in measured ambient concentrations has closely accompanied falling emissions of these pollutants; these, in turn, were strongly influenced by a number of factors.

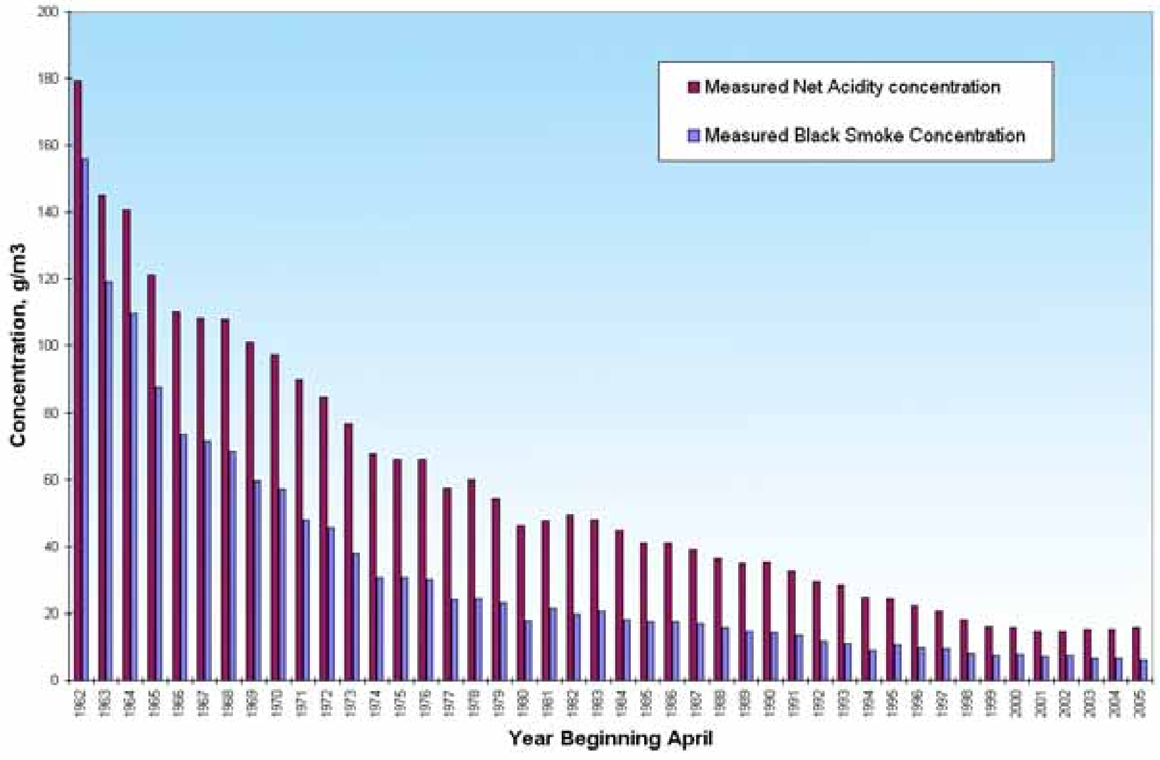


Figure 31 Trends in UK SO_2 and Black Smoke from the inception of the national monitoring network to 2005

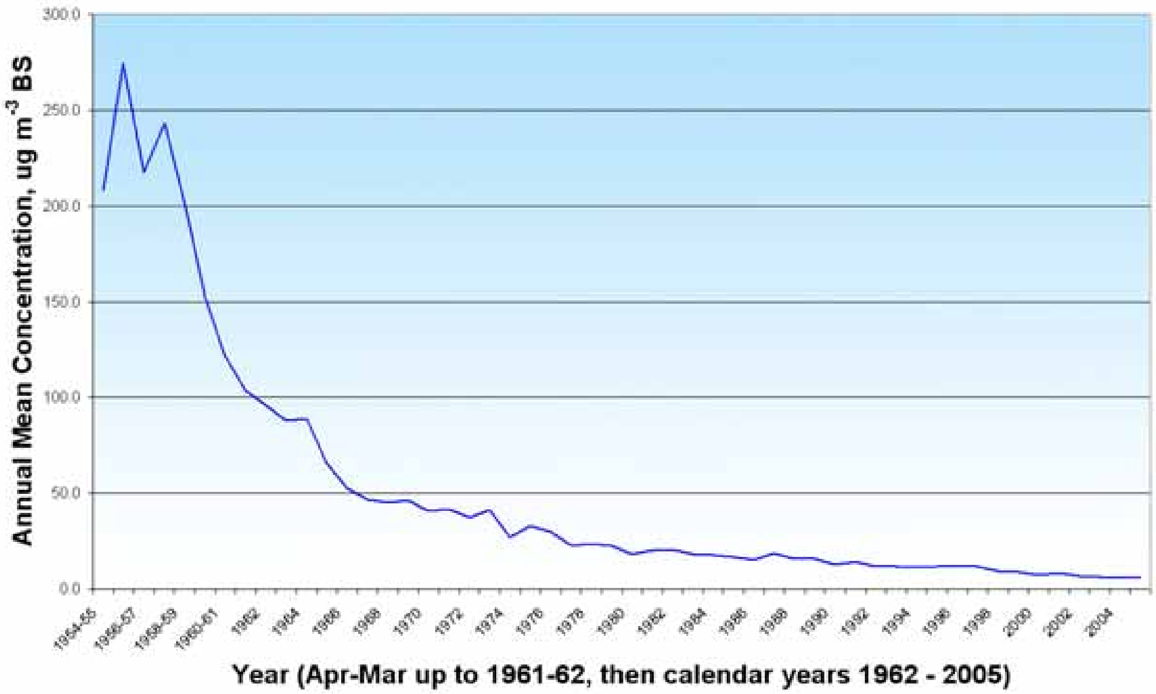


Figure 32 Decline in black smoke concentrations in London, including data from 1954 to 2005

These include:

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

Most notable among these controlling factors, however, has been the strict enforcement of smoke control measures in industry through a succession of Clean Air Acts from the early 1950s onwards.

The immediate impact of this legislation is shown in Figure 32. This may be viewed as broadly equivalent to Figure 31, but covering an even greater period of time; in fact, this includes black smoke monitoring data gathered before the formal establishment of the national black smoke and SO_2 network. It is important to realise that this graph is based on fewer monitoring sites than the network data from 1962 onwards; however, it shows even more clearly the precipitous fall in smoke levels in London from 1954 onwards. In fact, the steepest decline actually occurred from 1957 to 1960, before the network was even established.

Despite the success of legislative controls and the decline in SO_2 and black smoke, the UK has a broad range of air quality concerns that are still being addressed today. The establishment of automatic air quality monitoring networks in the early 1970s allowed us to track ambient levels of a much wider range of pollutants across the UK. The national networks have expanded substantially in the 1990s, and this extended monitoring has enabled us to:

- Analyse pollution trends in more detail
- Highlight important differences between rural and urban areas
- Assess variations in different pollutants across different regions of the UK (see Section 6)
- Determine key relationships between interrelated pollutants, particularly secondary pollutants.

Industrial pollutants are now extensively regulated throughout the UK. However, pollutants associated with traffic have typically increased as a result of rising numbers of road vehicles; these reached a maximum in the early 1990s. Concentrations of traffic-related pollutants have - since then - broadly declined as a result of the progressively tighter regulations (Euro Standards) applying to the emissions from road vehicles.

As medical research continues to identify and quantify the risks of air pollution to human health, increased importance is now being attached to pollutants such as NO_2, ozone and, especially, particulate matter. It is with these risks to health in mind that the Government has established a new range of air quality indicators (Section 3.2); these have been designed to simply present monitoring data from the national network and help assess resulting public health impacts over time.

The indicators for Air Quality and Health provide two measures of how the air quality has changed in the period from 1990-2005.

7.3 Pollution indicator 1- PM_{10} and ozone

The first of these indicators, graphed in Figure 33, is a new statistic that shows trends in the levels of two specific pollutants, ozone and particulate matter (PM_{10}). These pollutants have been given special prominence in this indicator because they are now believed to pose the most significant threats to public health through long-term exposure.

Figure 33 shows that annual average PM_{10} levels have been decreasing since the early 1990s, although the trend appears to be levelling off in more recent years. There is a very slight upward trend in background ozone levels. Ozone levels appear to be stable in rural areas while, at the same time, there has been a marked increase in urban ozone.

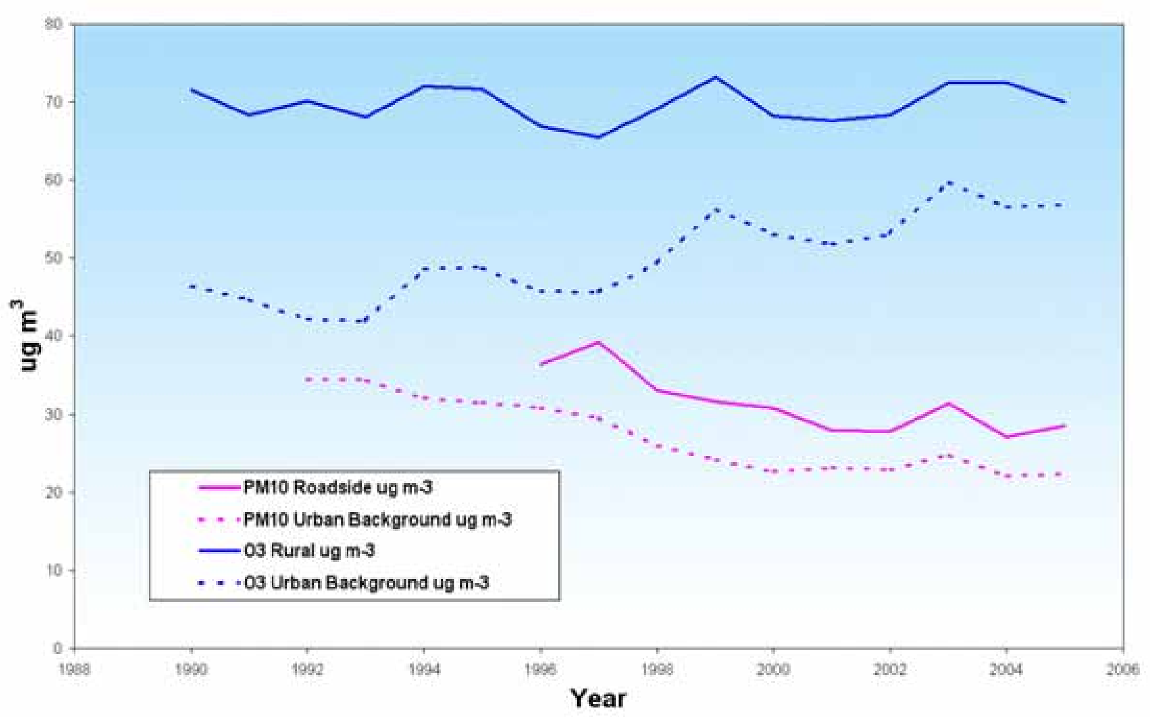


Figure 33 Trends in Air Pollution Indicator 1- gravimetric PM_{10} annual mean and ozone annual mean of the daily maximum running 8-hour mean, 1990-2005.

This rise of ozone levels in urban areas has been attributed to reductions in urban emissions of nitrogen oxides (NO_x) from road traffic leading to diminished ‘scavenging’ of ozone by chemical reaction. This, in turn, is a consequence of cleaner fuels and improved engine technologies. This shows that levels of pollutants - especially secondary pollutants formed in the atmosphere –can often be inter-related; as a result, measures to control one can sometimes have wider effects which are not always wholly desirable.

7.4 Pollution indicator 2- number of moderate or higher air pollution days

The second of the UK Government’s air quality indicators has been established for several years and analysed in detail 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 3.2 (Box 1). These bands represent defined levels associated with different levels of health risk. When air pollution is ‘moderate’, sensitive people may notice mild effects, but these are unlikely to need action. When levels enter the high band, sensitive people may notice significant effects and may need to take action.

Figure 34 shows how the number of moderate or greater air pollution days in the UK has changed over the period 1990 - 2005. The number of such days at urban sites has declined significantly since 1993, with the exception of a notable peak in 2003. The weather can cause significant variation from year to year in the number of days of moderate or higher air pollution. 2003 stands out in this analysis because of its unusual weather conditions, which were discussed in detail in our 2003 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 exceptionally hot weather; this in turn led to series of photochemical ozone episodes and the high number of pollution days shown in Figure 34.

The number of rural high pollution days in Figure 34 shows no clear trend; this is mainly because the pollutant causing most problems here is ozone. As highlighted earlier, this is a secondary pollutant which is a much more difficult to control because it has no direct emissions sources to regulate. Although we cannot control the weather- the main influence on this pollutant - the Government is working at international level to reduce emissions of the pollutants that lead to ozone formation.

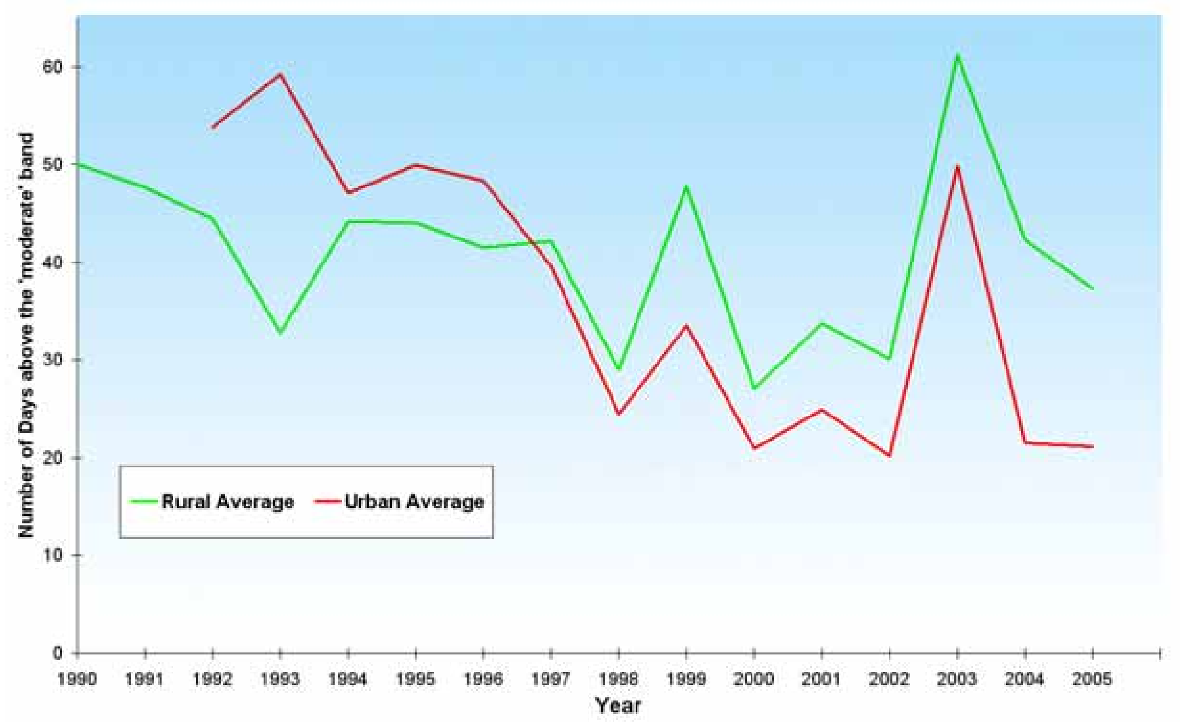


Figure 34 Trends in the number of days exceeding the 'moderate' air quality band from 1990- 2005.

7.5 Nitrogen dioxide trends

Excepting particulate matter and ozone, the pollutant of most concern in urban areas is now nitrogen dioxide (NO_2). This is both a primary pollutant (directly emitted from road vehicle exhausts) and a secondary pollutant (created by the same chemical reactions that are responsible for ozone formation). Unfortunately, the controls put in place to limit pollutants from road vehicles do not appear to be controlling levels of NO_2 as much as expected; this issue is one that is currently occupying the minds of scientists and policy-makers worldwide. For much more on this see, for example, the recent AQEG report at www.defra.gov.uk/environment/airquality/aqeg/reports.htm.

Legislation applied to vehicle manufacturers has targeted emissions of nitrogen oxides (NO_x), of which NO_2 is a component part; however, there have been no specific controls on NO_2 emitted from vehicles. Recent evidence from roadside monitoring sites in the UK suggests that, although NO_x levels have been declining, NO_2 levels remain either stable or may even be increasing in recent years. Figure 35 illustrates trends in annual mean NO_x and NO_2 between 1998 and 2005 at a selection of roadside and kerbside monitoring sites. While most of the sites show a decline in NO_x, NO_2 concentrations exhibit for the most part little change or even – in the case of the extremely traffic-intensive London Marylebone Road - an increase over time.

Figure 36 shows this trend even more clearly, by illustrating that the NO_2/NO_x ratio has increased at some sites by more than would be expected due to the decrease in NO_x on its own. At Glasgow Kerbside, the proportion of NO_2 in NO_x is relatively flat whilst, at other sites, the NO_2 to NO_x ratio is increasing. Recent emissions inventory calculations are consistent with these observations; these suggest that the proportion of NO_x emitted as NO_2 has increased from 11% to 14% between 2002 and 2005 across the UK and from 15% to 20% in Central London. These changes are thought to have resulted from the increase in the proportion of diesel vehicles on the roads, together with the exhaust after-treatment technologies employed.

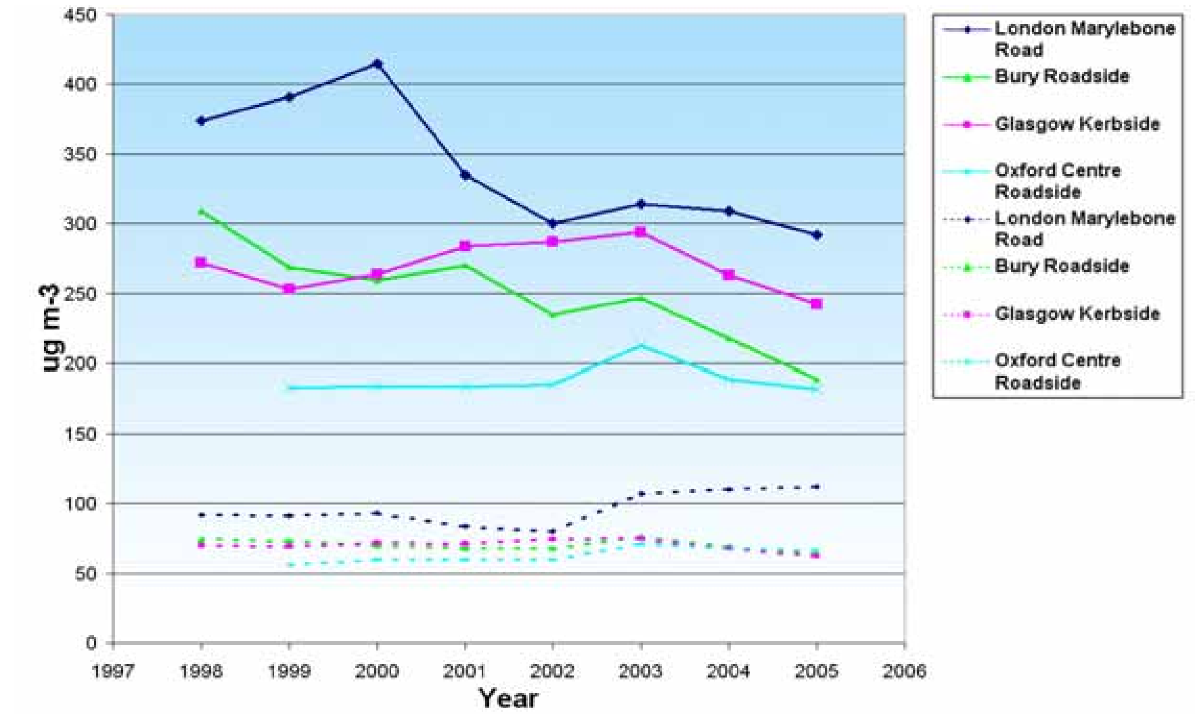


Figure 35 Annual mean NO_x (solid lines) and NO_2 (broken lines) at selected national network roadside and kerbside monitoring sites ($\mu g\ m^{-3}$).

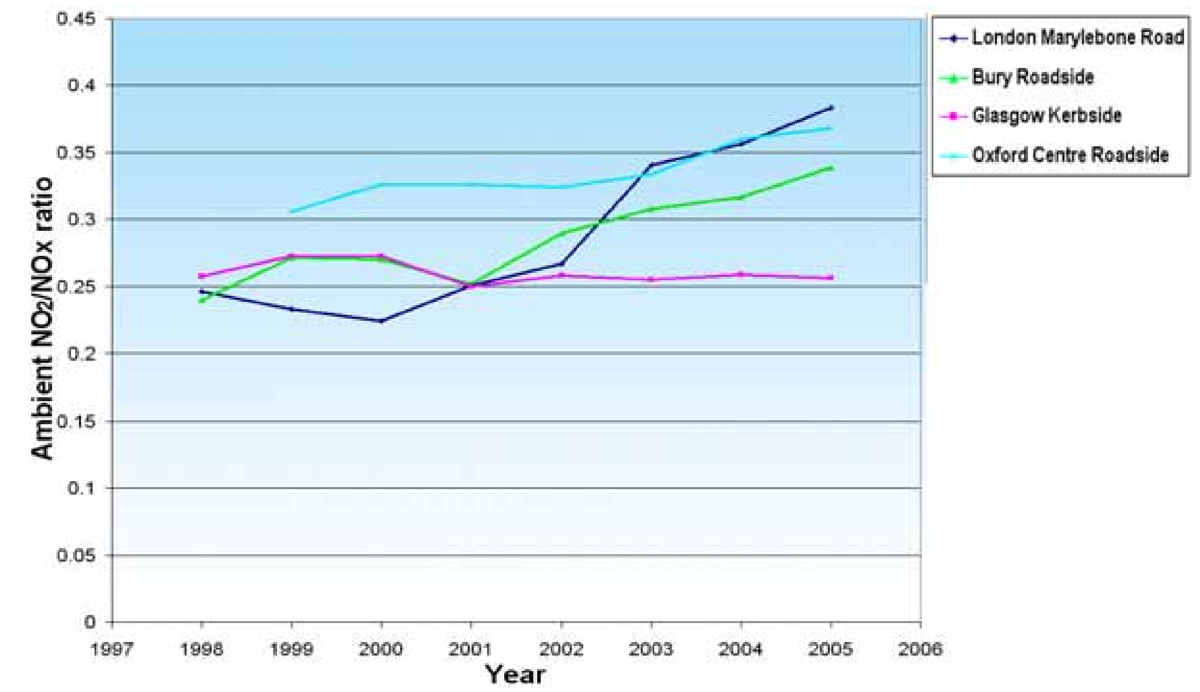


Figure 36 Ambient annual mean NO_2 / NO_x concentration ratios at selected national network roadside and kerbside monitoring sites.

7.6 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 Objectives – both those established in Regulation (and summarised in Table 1 of section 3) and those not in Regulation or of more localised coverage for London and other parts of the country. Results from the latest such analysis carried out for 2005 are summarised in Figures 37 and 38.

In Figure 37 (a so-called 'box and whisker plot') the mean compliance statistics, averaged over all measurement sites, are normalised and expressed as a percentage of that Air Quality Objective. To provide additional information, the maximum site statistic is also graphed. The height of each yellow bar in the figure therefore shows how that all-site average statistic in 2005 compares with the relevant national objective, whilst the blue line show how the 'worst' site compares with that objective. The methodologies utilised to produce Figure 37 are discussed in greater details in Appendix 6.

Figure 37 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. Of particular concern is PM_{10}, because the average of the sites (rather than just the highest concentration) is above the 2010 provisional objectives.

Figure 38 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 $\mu g\ m^{-3}$, not as percentages of the objective value. These graphs show how levels are changing over time in relation to each objective.

Figure 38a indicates that BaP concentrations are on average close to the objective; there may also be a slight downward trend. The maximum concentration measured for BaP is significantly above the objective value and does not show any indication of falling. The highest BaP concentration was recorded at Scunthorpe, where industrial emissions are known to make a substantial contribution.

The annual mean NO_2 objective is presented in Figure 38b. This shows that average concentrations across the network are declining slightly and are now below the objective; this trend looks set to continue. However, it is not all good news for this pollutant; as discussed earlier in this section, the highest concentrations are actually steadily increasing at several roadside monitoring sites.

Both maximum and average ozone concentrations (Figure 38c) have risen slightly over the last decade and it is likely that these will both exceed the objective value in the next few years. It has been suggested that background levels of ozone are increasing in the northern hemisphere; moreover, climatic change is predicted to result in longer summer seasons with increased sunshine intensity; this will further accelerate the chemical reactions that create ozone. It should be noted that the increase in average ozone concentration measured across the network also reflects the changes observed in urban areas as a result of tighter control of NO_x emissions, as discussed in Section 7.4.

Figure 38d shows corresponding trends in average and maximum PM_{10} when compared against the daily objective. It shows a slight decline in average levels; however, 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 38c and 38d) clearly show the unusually high concentrations of these pollutants measured in 2003.

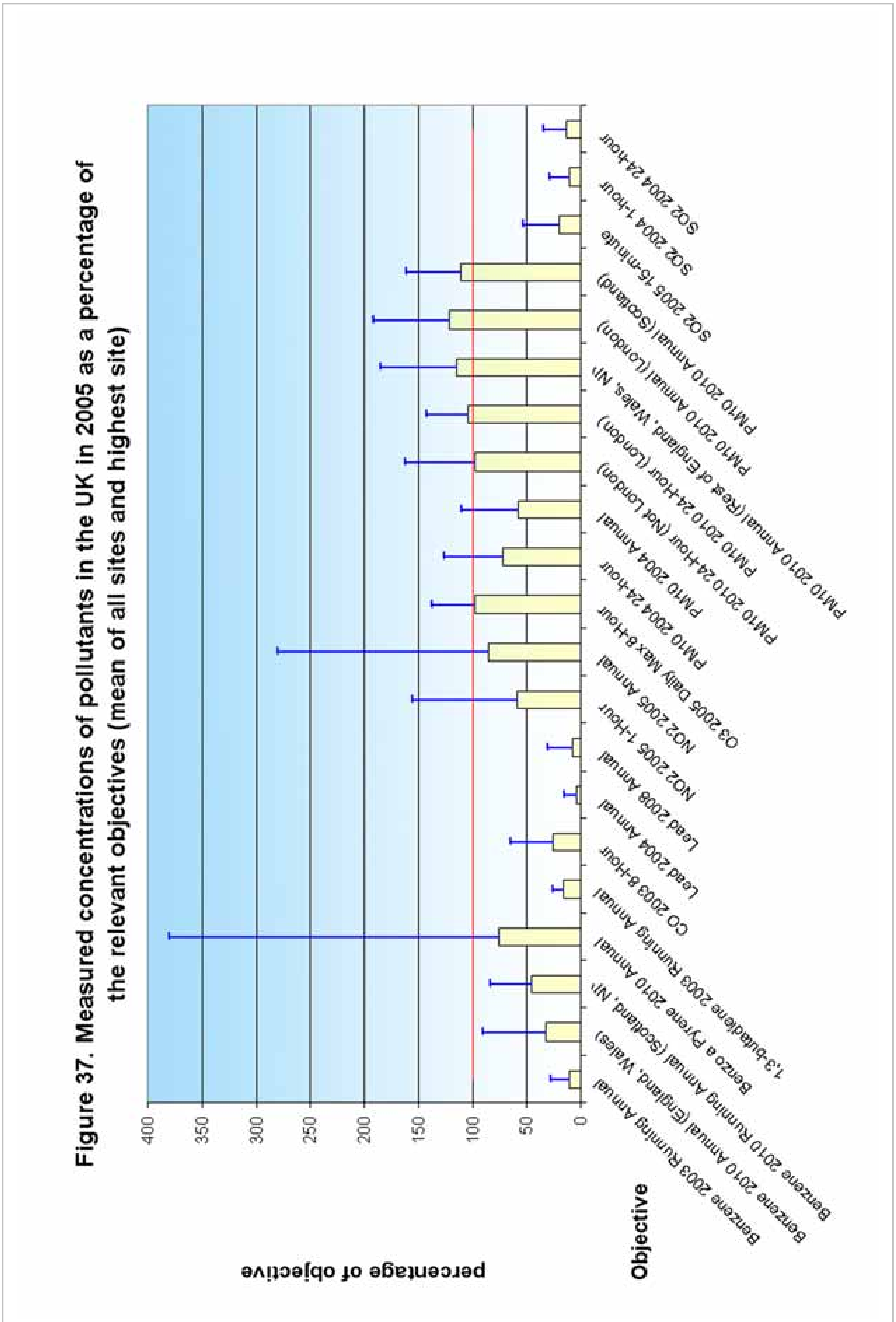


Figure 37. Measured concentrations of pollutants in the UK in 2005 as a percentage of the relevant objectives (mean of all sites and highest site)

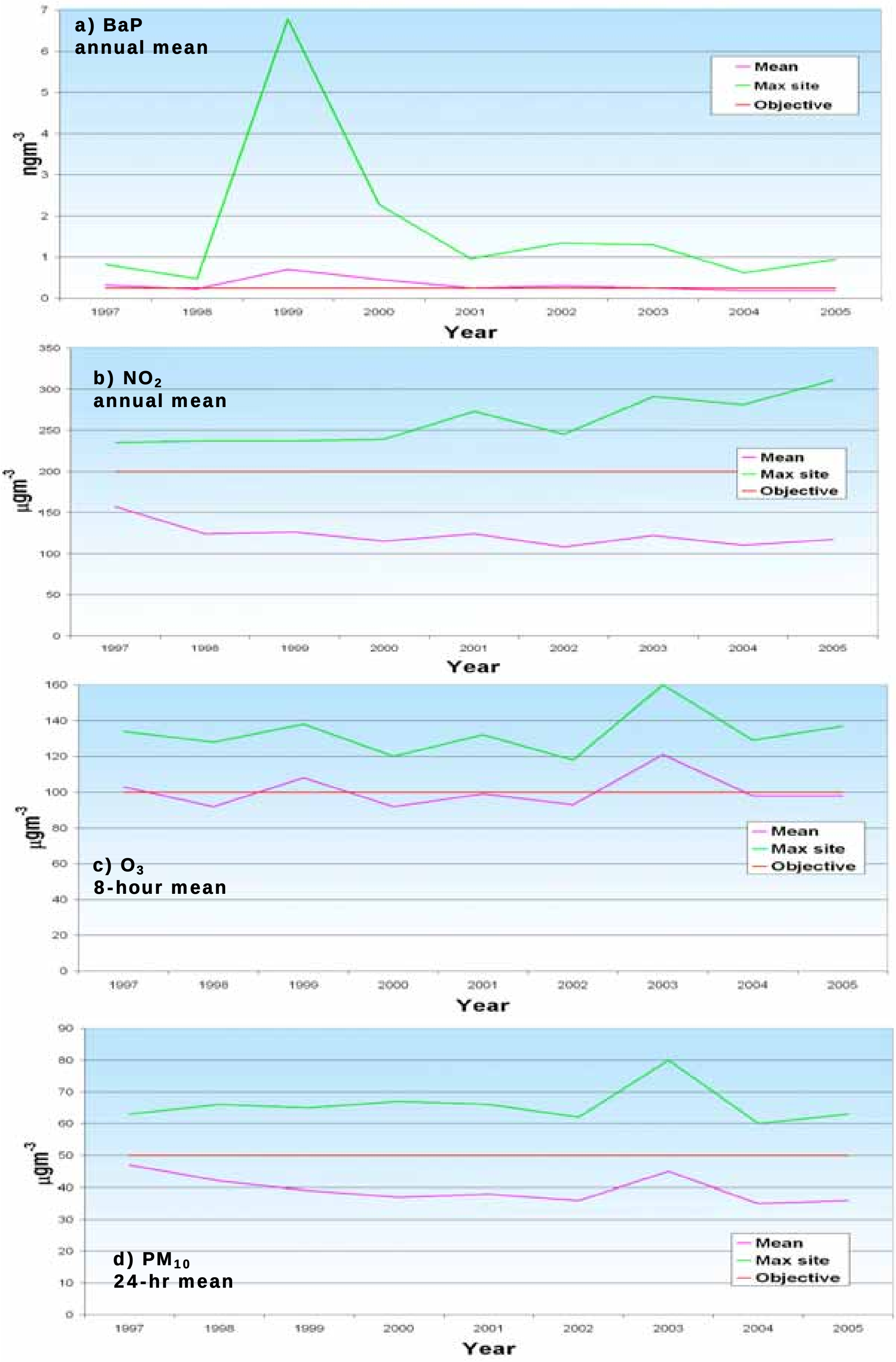


Figure 38 a) to d) Trends from 1997 to 2005 in mean and maximum measured site concentrations for four selected pollutants against corresponding UK AQS Objectives

8. Social aspects of UK air pollution

Which communities are most affected by air pollution? Here we examine the UK-wide distribution of air pollution, and assess whether more deprived of our communities experience the highest levels of pollution.

In recent years, there has been increasing recognition of the importance of identifying and tackling environmental inequalities. An environmental inequality arises where one community's access to a certain standard of environmental quality differs from another. This can be measured by assessing the different levels of air pollution, water quality, proximity to industrial facilities, noise levels or access to green spaces experienced by different communities.

A commonly held view is that it is the most deprived areas that tend to suffer the worst environmental quality; this may be due to such circumstances as:

- Living near areas with high levels of industrial pollution, or waste sites,
- Living in inner city areas close to major roads with high traffic densities
- Having limited access to areas of high environmental quality.

In this section, we examine whether this is true. In particular, we summarise the findings of a recent wide-ranging report prepared for Defra and the Devolved Administrations[46] to assess the issue of environmental inequalities associated with air quality. The main focus in the report is on assessing whether poorer communities live in areas of the UK with the highest levels of air pollution. We address the same key question in this section, together with a range of other issues associated with the linkage between air quality and social deprivation in Britain today.

8.1 Do the most deprived communities experience the worst air quality?

Our analysis has focussed on comparing the levels of air pollution across all part of the UK with levels of multiple deprivation experienced by different communities.* The objective of the analysis was to understand whether deprived communities experienced worse air pollution compared to other communities, and statistically examine that level of inequality.

Figure 39 shows the resulting comparison for each constituent country of the UK between the level of pollution, as measured in terms of NO_2, and the level of deprivation. Similar patterns are seen if we substitute PM_{10} for NO_2. Figure 39 shows that, across all countries, the most deprived communities (deciles 1-3, the 30% of the population that is most disadvantaged) experience higher than average pollution. In addition, in England, Northern Ireland, and Scotland, it is clearly the most deprived communities that experience the highest pollution levels. In Wales, by contrast, this is not the case; it is the least deprived communities that experience the highest pollution levels.

The main reason for these observations is that, for most of the UK, areas with the highest levels of deprivation tend to be urban. In those same areas, concentrations of most pollutants except ozone are highest (primarily as a result of emissions from road

* *Deprivation here refers to unmet needs due to a lack of resources, whether that be in terms of income, employment, education or housing. Multiple deprivation is a combined measure of all of these different types of deprivation.*

transport and - in Northern Ireland - solid fuel burning). In Wales, a different pattern is observed. There tends to be a higher proportion of deprived communities in less densely urbanised locations (such as South Wales valleys), and relatively fewer deprived communities in the main urban centres of South Wales. The location of the most deprived areas (decile 1) in Wales are shown in Figure 40; it is clear that areas of highest pollution tend to be in the urban centres of the south.

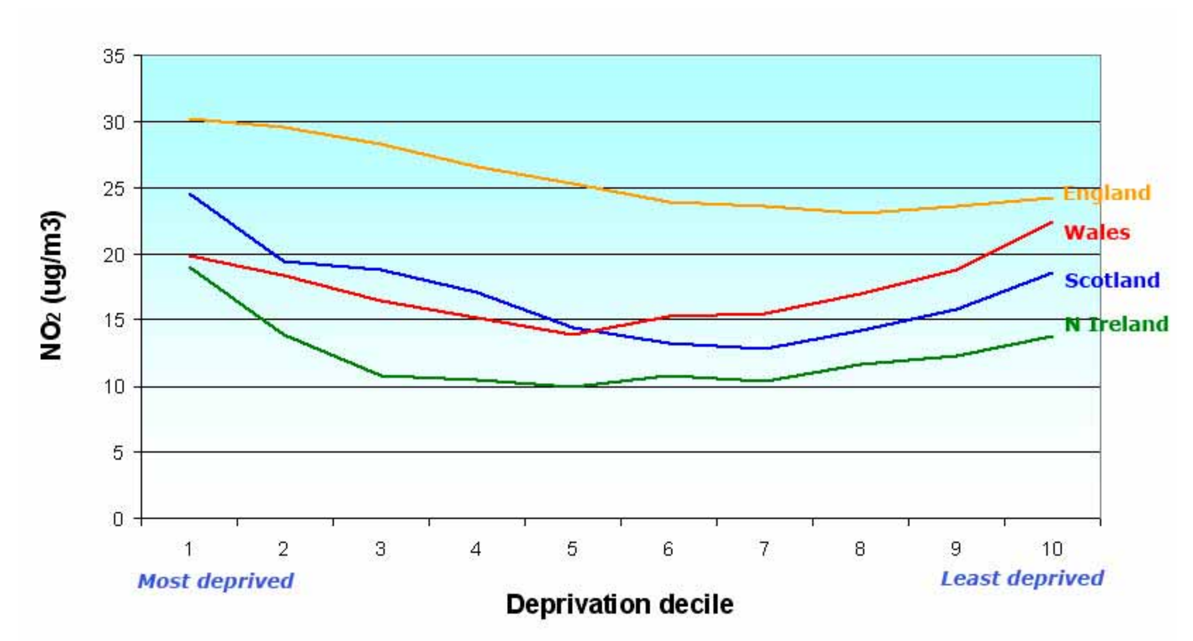


Figure 39. Mean concentrations of NO_2 by decile and country, 2003

Country	England	Scotland	Wales	NI
Average µg/m^3	25.86	16.86	17.30	12.34

In all parts if the UK except Wales, the most deprived communities experience the highest average levels of air pollution (as measured both by NO_2 and PM_{10}). The pattern will be different for ozone, of course- see Section 6.3. However, Figure 39 also shows that the least deprived communities, often located in urban centres, also experience higher than average pollution levels. This suggests that inequalities can also be found even in areas of relatively low deprivation.

The inequalities experienced by the most deprived communities are even more pronounced if the most polluted areas of the UK are considered in isolation. Such an analysis helps us to understand which communities are located in areas of highest air pollution, and whether the population in such areas is disproportionately deprived. The analysis suggests that the most deprived communities account for the majority of the population living in the 10% most polluted areas (as measured by concentration levels of NO_2 and PM_{10}).

In England, over 70% of the population living in the most PM_{10} polluted areas is categorised as being in the most deprived deciles (1-4). In Scotland, the equivalent figure is over 60%. In Northern Ireland, it is the most deprived communities (decile 1) that account for almost half of the population living in these high pollution areas. A similar pattern can be seen for the NO_2 analysis. However, for the reasons already discussed, this pattern is not evidenced in Wales.

In summary, inequalities in access to a given standard of environmental quality, in this case measured by levels of air pollution, exist across many parts of the UK. The most deprived communities are more likely to experience higher levels of pollution than the rest of the population. The least deprived communities also experience above average pollution levels (except in England). In the most polluted areas, a disproportionate section of the community also experiences high levels of deprivation.

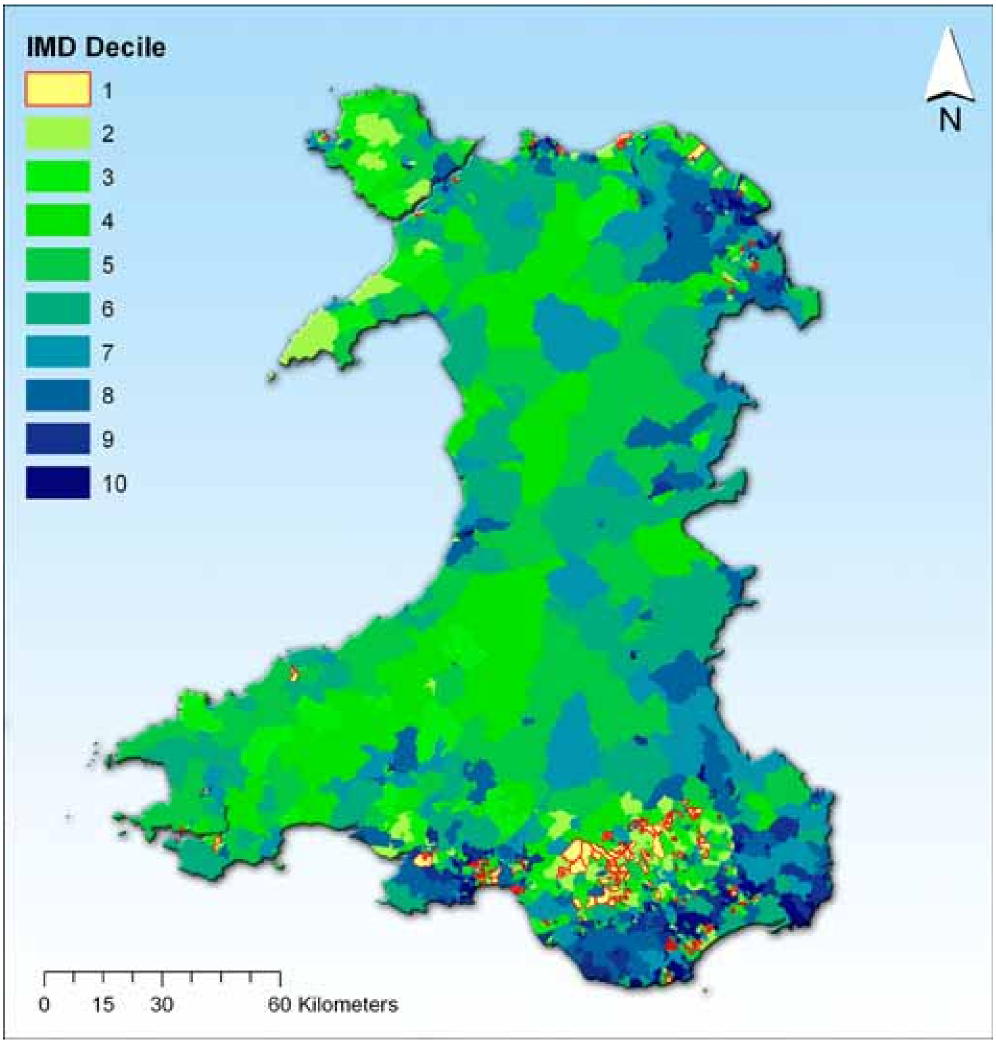


Figure 40. Levels of deprivation in Wales by super output area *(based on NAW (2005), Welsh Index of Multiple Deprivation 2005, National Assembly for Wales, Cardiff*

8.2 In future years, do the most deprived communities continue to experience the worst air quality?

For policy makers to address the issue of environmental inequalities, it is important to understand the current effectiveness of policies at the national and local level designed to reduce inequalities. We have therefore assessed the projected level of inequalities across the UK in 2010, relative to the modelling baseline year of 2003 [47]. This is a complex analysis, with some significant uncertainties associated with the modelled pollution data for 2010, together with the representation of current and future policy measures.

Nevertheless, Figure 41 shows the percentage of the population in areas of England where PM_{10} concentrations are predicted to be greater than 25 µg/m^3 in 2003 and 2010. The level of inequality is shown to be greater in 2010, with a steeper trend line observed; this suggests a higher proportion of more deprived communities in high pollution areas in future years. It also indicates that current inequalities – as shown in Figure 39 – may worsen in the future. The corresponding NO_2 trend shows a persistence of inequalities but not a worsening for that particular pollutant.

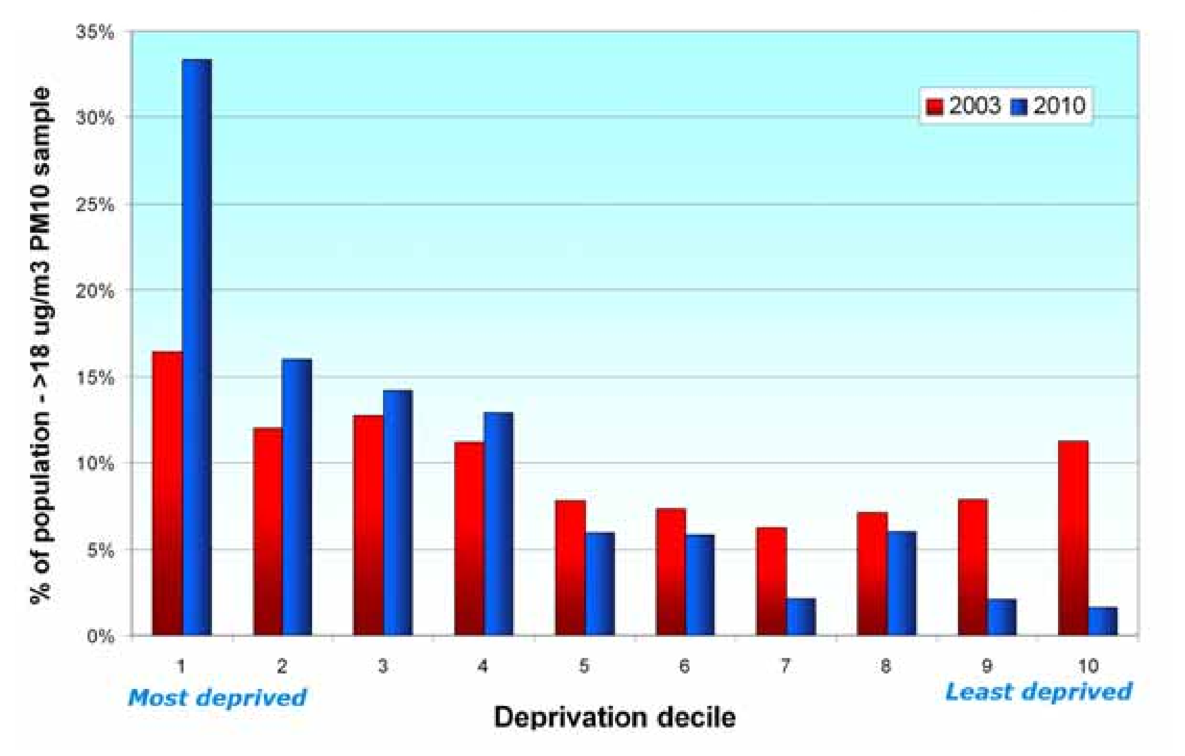


Figure 41. Distribution by decile of population in England in areas where PM_{10} >25 μg/m^3 in 2003 and 2010 (Population in sample - 11,808,185 in 2003 and 1,046,288 in 2010)

What is important to stress here is that the **total** population living in areas of high pollution significantly declines in future years, highlighting the predicted success of UK policy in reducing the number of people living in areas of high NO_2 and PM_{10} air pollution. However, while UK Government strives to improve air quality across the board, there is still an important issue to recognise over the coming years - continuing inequalities faced by the most deprived communities.

8.3 How important are AQMAs in addressing the inequalities faced by deprived communities?

As discussed in Section 3.3, Air Quality Management Areas (AQMAs) are an important local measure for tackling areas of high pollution. These are often located in urban areas where both air pollution levels and levels of deprivation are high. The emission controls introduced in such areas may therefore be important in reducing air pollution, together with some of the inequalities described earlier.

An analysis has been undertaken to assess whether populations covered by AQMAs in England are more deprived than the UK population as a whole and, in particular, whether they cover high pollution-high deprivation areas where inequalities are greatest. Figure 42 shows the areas of deprivation in some of the major English urban areas relative to AQMA location.

The analysis concluded that English AQMAs have disproportionately more deprived communities than England as a whole. This adds to the weight of evidence that deprived communities are likely to be in areas of higher pollution. It also suggests that AQMAs may provide a powerful tool for helping to address inequalities, by disproportionately benefiting more deprived communities; this would be based on the assumption that they would successfully tackle the identified air quality problems across the entire AQMA.

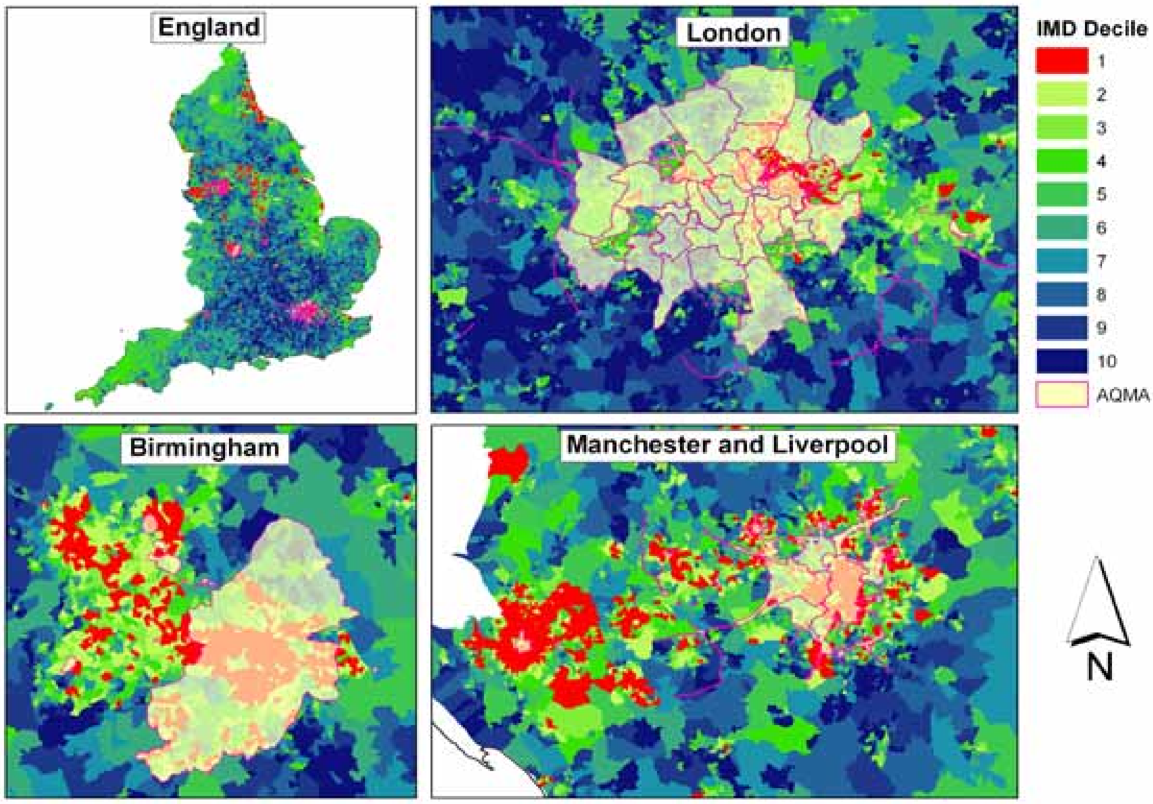


Figure 42. AQMA location in selected English urban areas classified by deprivation deciles

AQMAs may also be an important measure for addressing the high pollution-high deprivation areas, where inequalities are most significant. Almost 2000 distinct areas were identified in England that had both high pollution (as measured by NO_2) and deprivation levels. AQMAs are shown to cover or part cover approximately 80% of these areas.

This analysis indicates that AQMAs offer an important policy instrument, already in place in England, to reduce concentrations in urban areas where a significant number of deprived communities with high concentrations are located.

8.4 Are the inequalities experienced by deprived communities further compounded by their increased susceptibility to air pollution impacts?

This section has shown that air quality inequalities do exist in the UK, with the most deprived communities often experiencing the worst air pollution. A further issue is whether such inequalities may be made worse if deprived communities are more susceptible to health impacts associated with air pollution. If they are, for an equivalent level of pollution, the most deprived communities would then experience worse impacts than a less deprived community.

Understanding population susceptibility to health impacts associated with air pollution is extremely difficult, as this will be affected by many factors. These include the state of general health of the community (often determined in part by lifestyle factors such as diet, level of exercise, and smoking) and the daily exposure to different pollutants (influenced by factors such as daily patterns of movement, housing conditions, and work environments).

One important factor influencing susceptibility, that is easily measured using available data, is age. This is recognised in most health impact assessments as an important element in determining certain health impacts, with the young and elderly often considered the most susceptible. We have therefore assessed whether deprived communities had a higher proportion of elderly or young populations.

As shown in Figure 43, it is clear that a greater proportion of children live in areas of higher deprivation than in areas of lower deprivation. However, the opposite is true for the elderly. Therefore, based on age, it is not possible to say that one type of community is more susceptible than another, as the most deprived communities are likely to have a higher young but lower elderly population).

An important finding that does emerge from this analysis, however, is that the young are more likely to live in areas of high deprivation, and in areas of high pollution (as measured by NO_2 and PM_{10}). Therefore, as a population group, they experience higher levels of inequality than other population age groups.

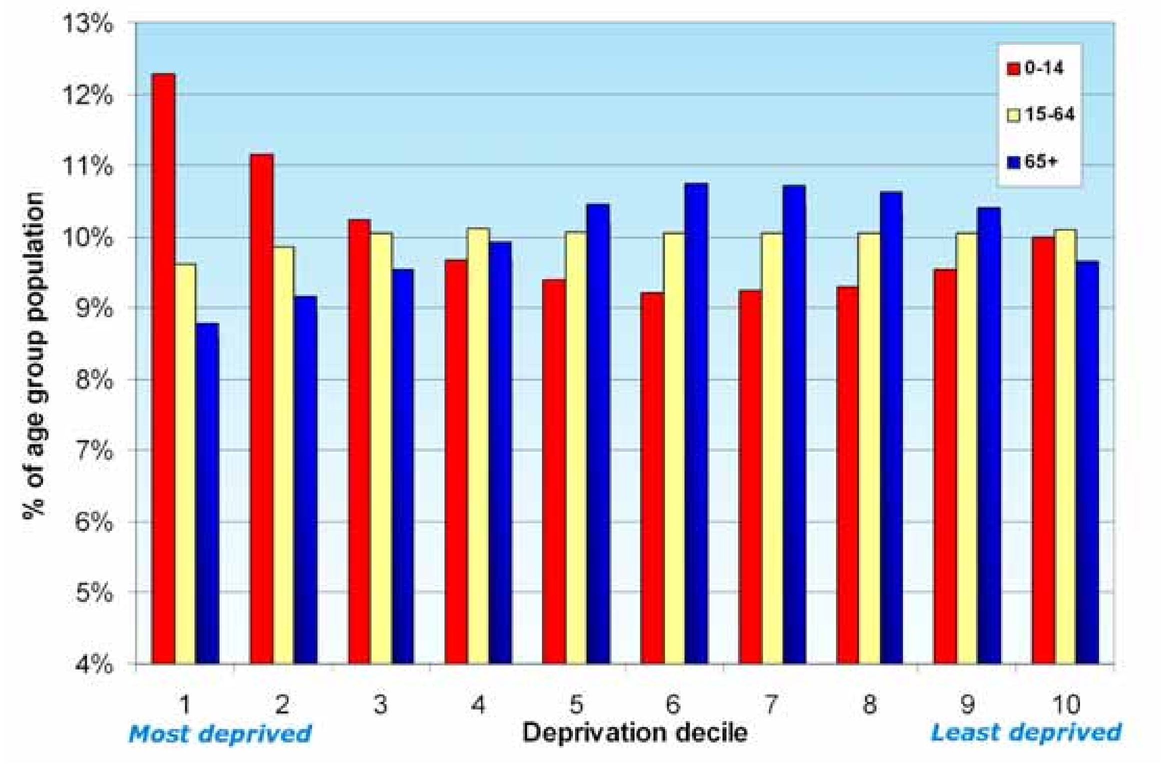


Figure 43. Percentage of age group by deprivation decile in England

The issue of susceptibility, and how it could result in increased inequalities, is very important. More research is needed in this area to better understand:

- Whether certain communities are more susceptible
- The complex issues surrounding exposure and different human responses to pollution levels
- The role of susceptibility in determining the level of inequalities.

8.5 How important do the Government consider the issue of environmental inequalities?

Over recent years, the issue of environmental inequalities has been seen as an increasingly important policy area across Government. The UK Sustainable Development Strategy[48] has identified the issue of environmental inequalities as a priority area for attention. The importance of the issue is highlighted by the following quote in the Strategy, taken from a report by the Sustainable Development Research Network:

> *'Poor local and environmental quality and differing ease of access to environmental goods and services have a detrimental effect on the quality of life experienced by the deprived communities and socially excluded groups and can reinforce deprivation if not tackled alongside access to employment, health and tackling crime[49].'*

In other words, the environmental quality we all experience contributes to our quality of life, and can have an important impact on deprivation levels. In recognition of this problem, the Strategy goes on to state that

> *'The Government will fund further research on the causes of environmental inequality and the effectiveness of measures to tackle it in order to establish the best ways to tackle these issues in communities.'*

The analyses presented in this section[46], funded by the Office for National Statistics (ONS) and the Department for Communities and Local Government (DCLG), add to the growing literature in the UK on environmental inequalities. Such an evidence-base will be vital in future:

- Firstly, in establishing whether or not inequalities exist and to what extent, and
- Secondly to enable us to develop effective policies and regulations designed to reduce inequalities

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:
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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.

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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
www.airqualityni.co.uk/laqm_sca.php

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