Air Pollution in the UK: 2003

A report prepared by the National Environmental Technology Centre (Netcen) for the Department for Environment, Food and Rural Affairs and the Devolved Administrations.

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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 by Jon Bower, Paul Willis, Geoff Broughton, Andrew Kent and Jeff Lampert of 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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1. Executive Summary

For those of you 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 (Department for Environment, Food and Rural Affairs) and the Devolved Administrations of Scotland, Wales and Northern Ireland.

It includes data and analyses from the calendar year (January to December) 2003. The pollutants featured in this report are:

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

Because of their potential impacts on human health, welfare and natural environments, these pollutants are routinely measured at many locations throughout the UK.

The measurements reported here were made in national automatic air monitoring networks, comprising 125 stations for the year in question. 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, identifying the pivotal role of air monitoring in this process
2. Describe current UK air monitoring networks, their objectives and methodologies. Detailed site maps and site registers are also provided
3. Review current UK Air Quality Objectives and examine how and where these were exceeded during the year
4. Investigate, using detailed maps, how pollution levels vary across the country
5. Examine major periods of elevated pollution (so called pollution ‘episodes’) that have occurred recently
6. Assess long-term trends in order to identify how pollution levels in the atmosphere have changed over time
7. Provide in the second half of the report detailed statistical summary tables for each pollutant
8. Identify other published, web and media sources for information on the UK’s air quality.

The report therefore provides a comprehensive analytical picture of air pollution in the UK up to and during 2003.

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2. Introduction

An outline of what's in this report…

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

Air quality monitoring, and the results presented in this report, should not be seen as an end in themselves; rather, they offer us the best way of understanding our pollution problems, so they can be tackled effectively at local, national and international level.

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
- To assess how far air quality standards 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 reliable and up-to-date information on air pollution.

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 two parts. The first part is primarily descriptive and analytical. In it, we'll:

- Summarise current UK and European policy efforts and initiatives to tackle air pollution (Section 3)
- Review where and how air pollution is measured in this country, examining monitoring networks, site locations and measurement techniques (Section 4)
- Examine key episodes - major periods of elevated pollution that have occurred over recent years (Section 5)
- Investigate through a series of detailed maps 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 (Section 7).

The second part of the report is statistical, providing a detailed pollutant-specific summary of measurements. From Sections 8 to 16, we provide for each pollutant measured in the automatic networks:

- Information on measurement and calibration techniques, instruments utilised and estimated accuracy and precision
- A summary of relevant UK objectives for that pollutant, together with EC Limit Values and WHO Guidelines
- A map of UK national network measurement sites
- A detailed statistical summary of the measurements made in 2003
- Matching information on exceedences of UK Air Quality Objectives
- Time-series graphs showing variations in pollutant concentrations throughout the year at typical urban, rural and other site types

- Corresponding diurnal graphs showing typical variations in pollutant concentrations during the day
- Long-term time series showing trends in annual average measured concentrations.

In a series of Appendices, we'll also provide additional background information on the measured pollutants, together with regional site location maps and details of the different UK national air monitoring networks.

Air Pollution in the UK: 2003

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

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.

Air pollution is becoming an increasingly important focus of interest for national, European and international policy makers. This has been triggered, in part, by increasing evidence that air pollution can pose 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 target 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 issues of global climate change; recent years have shown the dramatic impacts of a series of unusually hot summers throughout many parts of Europe. Some of these impacts have been a consequence of elevated levels of air pollution.

3.1 European Background

Air quality is one of the areas in which Europe has been particularly active in recent years. The European Commission's aim has been to develop an overall strategy through the setting of long-term air quality objectives. Within the European Community, a series of air quality Directives and Decisions over the last decade has:

- Established Limit 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 sulphur dioxide, nitrogen dioxide, particulate matter, lead, ozone, benzene and carbon monoxide. A proposal for further extending the scope of pollutants to include polycyclic aromatic hydrocarbons, cadmium, arsenic, nickel and mercury is currently at an advanced stage of consideration.

A list of current EC Directive Limit and Target Values for air pollutants covered by the Directives is provided in the later, pollutant-specific parts of this report. Further detailed information on the major sources and impacts of these pollutants is provided in Appendix 1.

A primary objective of the EU's Sixth Environment Action Programme is to achieve levels of air quality that do not give rise to unacceptable impacts or risks to human health and the environment. The Community is acting at many levels to reduce exposure to air pollution, through:

- Legislation such as the Framework and Daughter Directives
- 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 Non Governmental Organisations
- Research undertaken in its own or Member States' institutes and universities.

There is no cause for complacency on the human health impacts of air pollution at a pan-European level. In a report [4] recently published in the Lancet, experts assessed for the first time the overall impacts of air quality and other environmental risk factors on child health in the WHO European Region: 14-24000 deaths every year, representing 6-10% of all mortality in children and adolescents from birth to 19 years of age, are caused by outdoor and indoor air pollution.

The 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].

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.

Although progress towards Europe-wide ratification has been patchy, the 1998 Århus convention[7] on environmental openness is another important instrument; this is intended 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.

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. Medical evidence shows that many thousands of people die prematurely every year because of its effects, 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. The costs to individuals, families and the national economy are substantial.

Air quality is therefore now one of the UK Government's key headline indicators of sustainable development[8]. 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. We'll be looking more closely at the latest air quality indicator levels in Section 7 of this Report.

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 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 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. Moreover, 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. 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 for each pollutant in Sections 8 to 15 of this report.

Although comprehensive and soundly science-based, these objectives are not particularly easy for the general public to understand. A simpler air quality banding system is therefore used for media-based reporting of air quality and potential health effects to the public (Box 1).

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, 2003

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, 2003

Pollutant	Air Quality Objective		Date to be achieved by
	Concentration	Measured as	
Ozone ***(for protection of human health)***	100 µg m^{-3} not to be exceeded more than 10 times a year	Daily maximum of running 8-hr mean	31.12.2005
Nitrogen dioxide ***(for protection of vegetation & ecosystems)***	30 µg m^{-3}	Annual mean	31.12.2000
Sulphur dioxide ***(for protection of vegetation & ecosystems)***	20 µg m^{-3} 20 µg m^{-3}	Annual mean Winter average (Oct-Mar)	31.12.2000 31.12.2000

Table 2b UK air quality objectives for particles not set in regulation, 2003

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

3.3 A Local Focus

Central Government and the Devolved Administrations in Scotland, Wales and Northern Ireland are responsible for overall policy and legislation affecting the UK environment, including air quality. However, over the last five years, the Air Quality Strategy has enabled and encouraged Local Government to take an increasingly important 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' and introduce an Action Plan - which may include such measures as congestion charging, traffic management, planning and financial incentives - to tackle problems in the affected areas.

The vast majority of local authorities in England, Scotland and Wales have now completed their first round of reviews and assessments against the Strategy's objectives prescribed in the 2000 Air Quality Regulations, together with subsequent amendments[10, 11].

To date 127 local authorities - over a quarter of those in UK - have established one or more AQMAs, most of these in urban areas and resulting from traffic emissions of nitrogen dioxide (NO_2) or PM_{10} particles. These local authorities are now undertaking further detailed assessments of the areas concerned and are required to submit a report within 12 months following designation of the AQMA. The authorities have been advised to prepare their action plans within 12-18 months of designation.

The situation is somewhat different in Northern Ireland. Here the national strategy's Objectives are being implemented through the Environment (NI) Order 2002 and the Air Quality (NI) Regulations 2003[12,13]. Currently all district councils in Northern Ireland are completing their first round review and assessment. Early indications are that a number of AQMAs will be declared for roads (NO_2) and area sources such as domestic heating (PM_{10}). Northern Ireland will synchronise with the UK review and assessment timetable in April 2006, when all authorities are required to submit updating and screening assessments.

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.

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 more recent global Johannesburg Summit[15] held in 2002.

The ultimate purpose of air quality monitoring is not merely to collect data (a common perception) 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
- Initial 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.

In the UK, air pollution policy development relies heavily on the national air quality monitoring networks to provide basic data on ambient 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 EU Air Quality Directives.

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 - still operational today - 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 and, as a result, road transport has now become the most important source of air pollution in many parts of the UK. In response to this historic change, the emphasis in monitoring has moved progressively to pollutants such as ozone, nitrogen dioxide and fine particulate matter.

Research measurements of air pollution using automatic analysers commenced in the UK during the early 1970s. Later, continuous measurements were increasingly required for regulatory purposes 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 1993, when the DoE-funded Enhanced Urban Network (EUN) was established. In 1997, 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 private sector involvement in the management and quality assurance of the networks was actively promoted. The net effect of these measures was to 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 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 combined to form the current Automatic Urban and Rural Network (AURN). This presently (2003) consists of 120 sites and remains the most important single monitoring programme in the UK today.

The bulk of the data presented in this report originate from this network, which presently includes 82 urban, 22 rural and 16 London Network sites: 58 sites are directly funded by Defra and the Devolved Administrations, whilst 62 are affiliated sites owned and operated by Local Authorities and other organisations. Future expansion of the network is already well underway in 2004, with the addition of ozone and NOx analysers in rural and suburban areas to meet the requirements of the third EC Daughter Directive[17].

The dramatic continuing expansion in automatic monitoring is clearly illustrated in Figures 1 and 2, where we show the increase in site numbers and total measurements made since the commencement of automatic air quality monitoring in the UK.

Figure 1. The number of automatic measurement stations in the UK has grown rapidly from 1972 to 2004

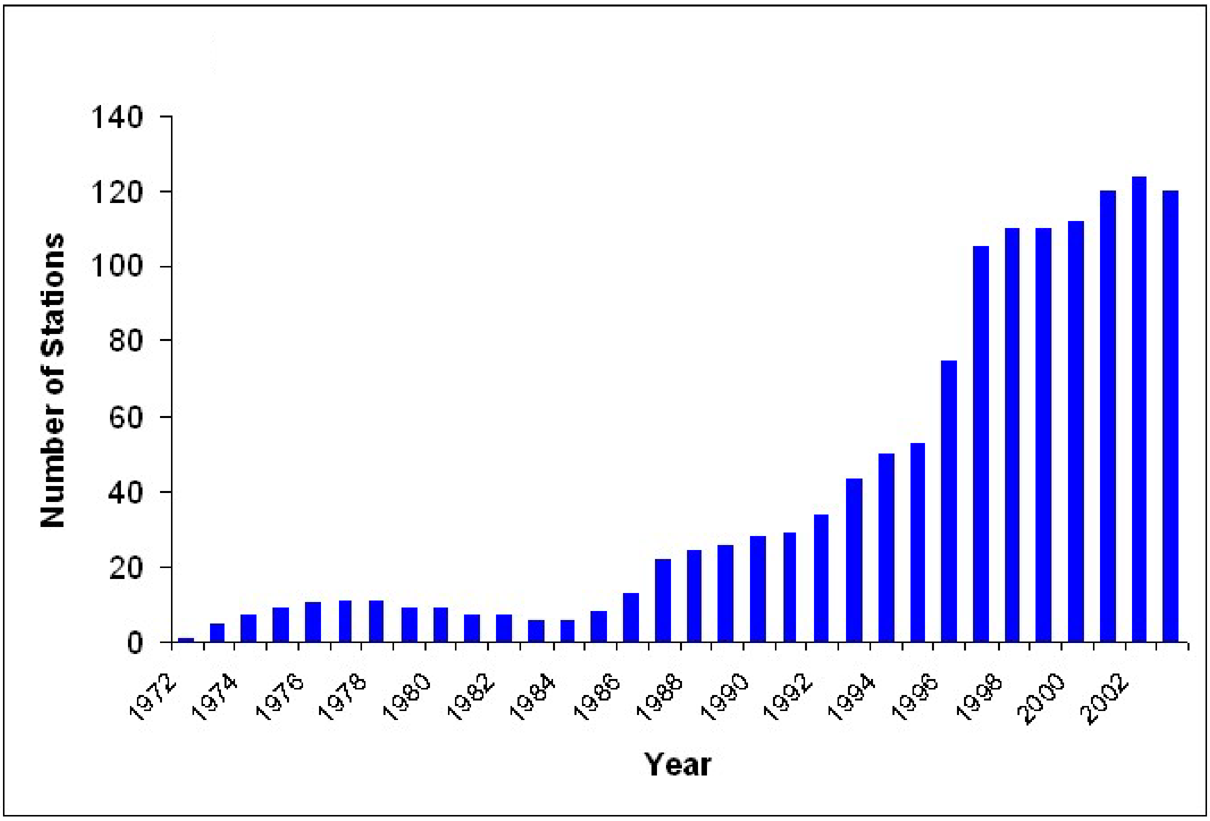
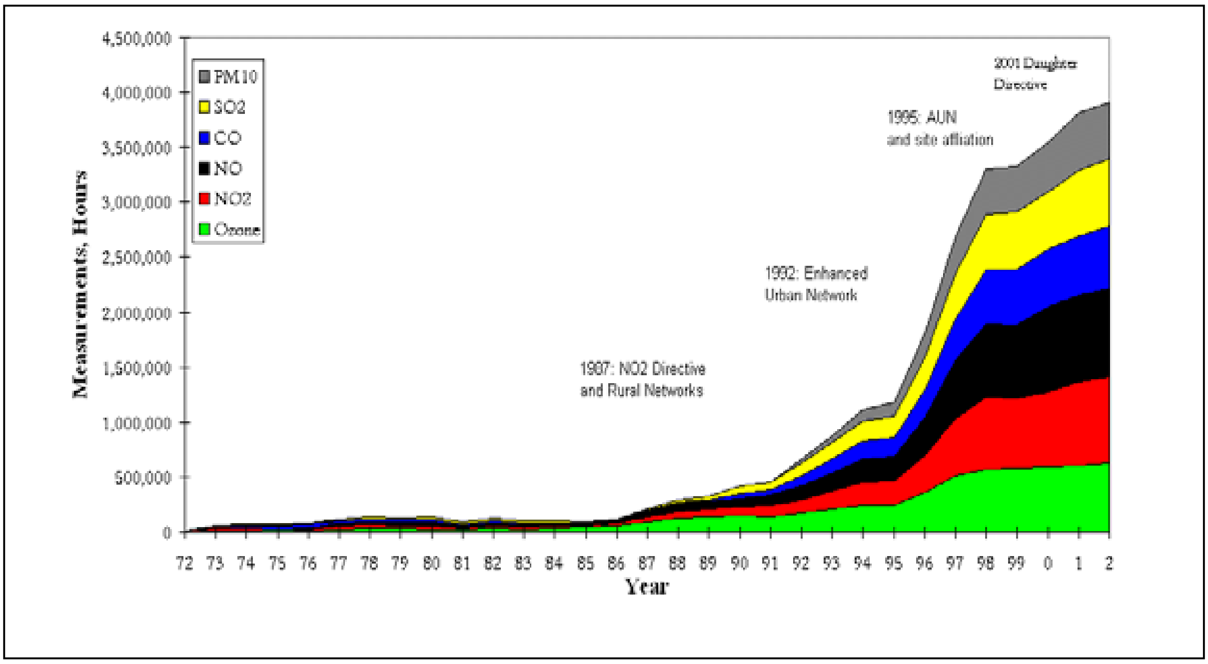


Figure 2. The number of measurements made every year has also increased dramatically for all pollutants in the inorganic monitoring networks (O_3, NO_2, CO, SO_2 and PM_{10})



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. This expansion has 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.

There has also been considerable growth 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 Sections 4.3 and 4.4). The value of air quality monitoring undertaken by Local Authorities 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 is also 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 The current situation

There are currently over 1300 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.

125 of these sites in the AURN (120) and hydrocarbon networks (5) operate automatically; these provide high-resolution hourly information on a range of pollutants that is communicated rapidly to the public. The non-automatic sites measure average concentrations over a specified sampling period (typically from a day to a month) instead of instantaneous concentrations, but still provide invaluable data for assessing levels and impacts of pollution across the country as a whole.

A map of current UK automatic monitoring sites is provided in Figure 3. In the accompanying Figures 4.1-4.3, 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 8-15 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 European Limit Values.

The pollutants measured, site numbers and areas covered in the UK's nationally co-ordinated monitoring networks are summarised in Table 3 below, whilst the main features of individual programmes are summarised in Table 4. Further information on the different UK air monitoring networks is provided in Appendix 3.

Table 3. 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	106 (Automatic) 1288 (Non-automatic)	Mostly urban
Ozone (O_3)	Sunlight and heat, acting on road transport and industrial emissions	85 (A)	All of UK- urban and rural areas
Particles (PM_{10} and $PM_{2.5}$)	Road transport, industry, construction, soil and natural sources	68 (A) 7 (NA) gravimetric 123 (NA) black smoke	Mostly urban
Sulphur Dioxide	Industry and fuel combustion	76 (A) 123 (NA) net acidity 32 (NA)	Mostly urban Rural
Carbon Monoxide (C0)	Road transport	79 (A)	Urban
Volatile Organic Compound (VOCs)	Industry, transport, solvent use and some natural sources	5 (A) 35 (NA) benzene 9 (NA) 1,3-butadiene	Mostly urban
Dioxins and PCBs	Combustion (dioxins) and past uses (PCBs)	6 (NA)	3 urban 3 rural
Polycyclic Aromatic Hydrocarbons (PAHs)	Industry and traffic (PAHs)	24 (NA)	Industrial, urban and rural
Metals- Pb, Cd, As, Ni and Hg	Industrial and other processes	17 (NA)	Industrial, urban and rural
Acid Deposition	Atmospheric reactions involving fuel burning, agricultural and other emissions	38 (NA)	Rural
Ammonia	Agricultural activities	93 (NA)	Rural
Nitric Acid	Combustion and photochemistry	13 (NA)	Rural

Figure 3. Current UK Automatic Air Quality Monitoring Stations

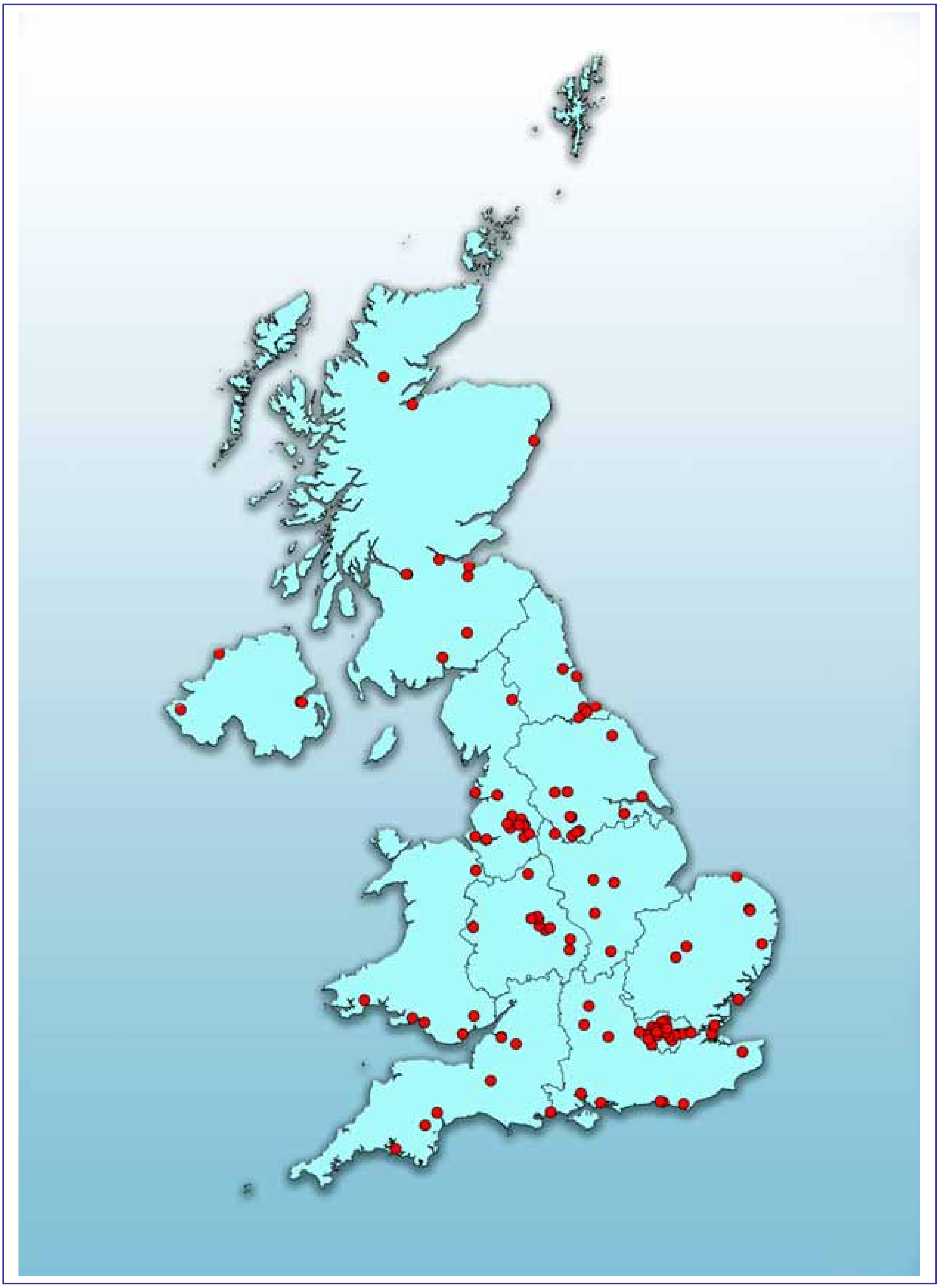


Fig 4.1 Current UK sampler-based measurement programmes in urban areas

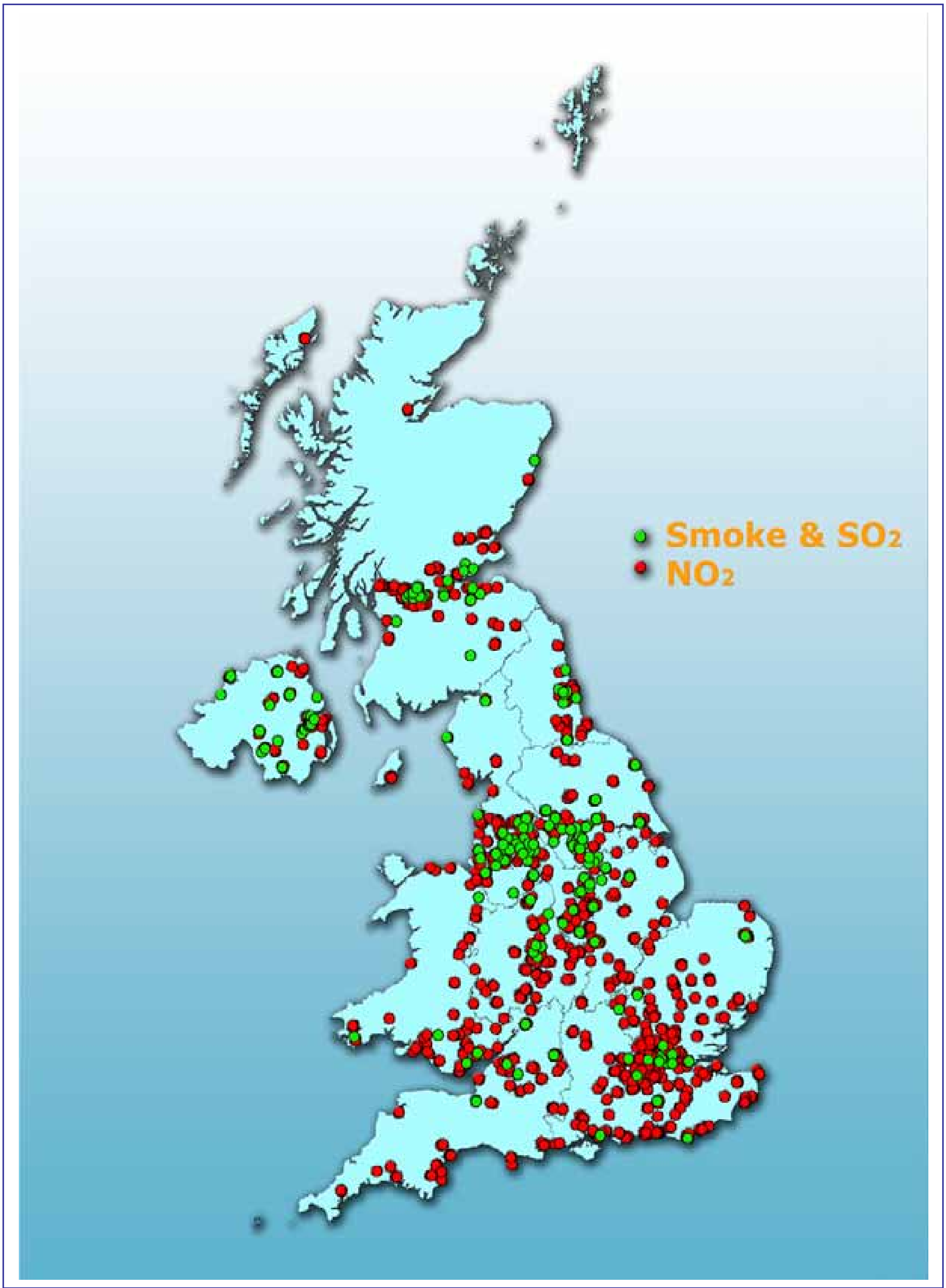


Fig 4.2 Current UK sampler-based measurement programmes for Persistent Organic Pollutants (POPs) and metals

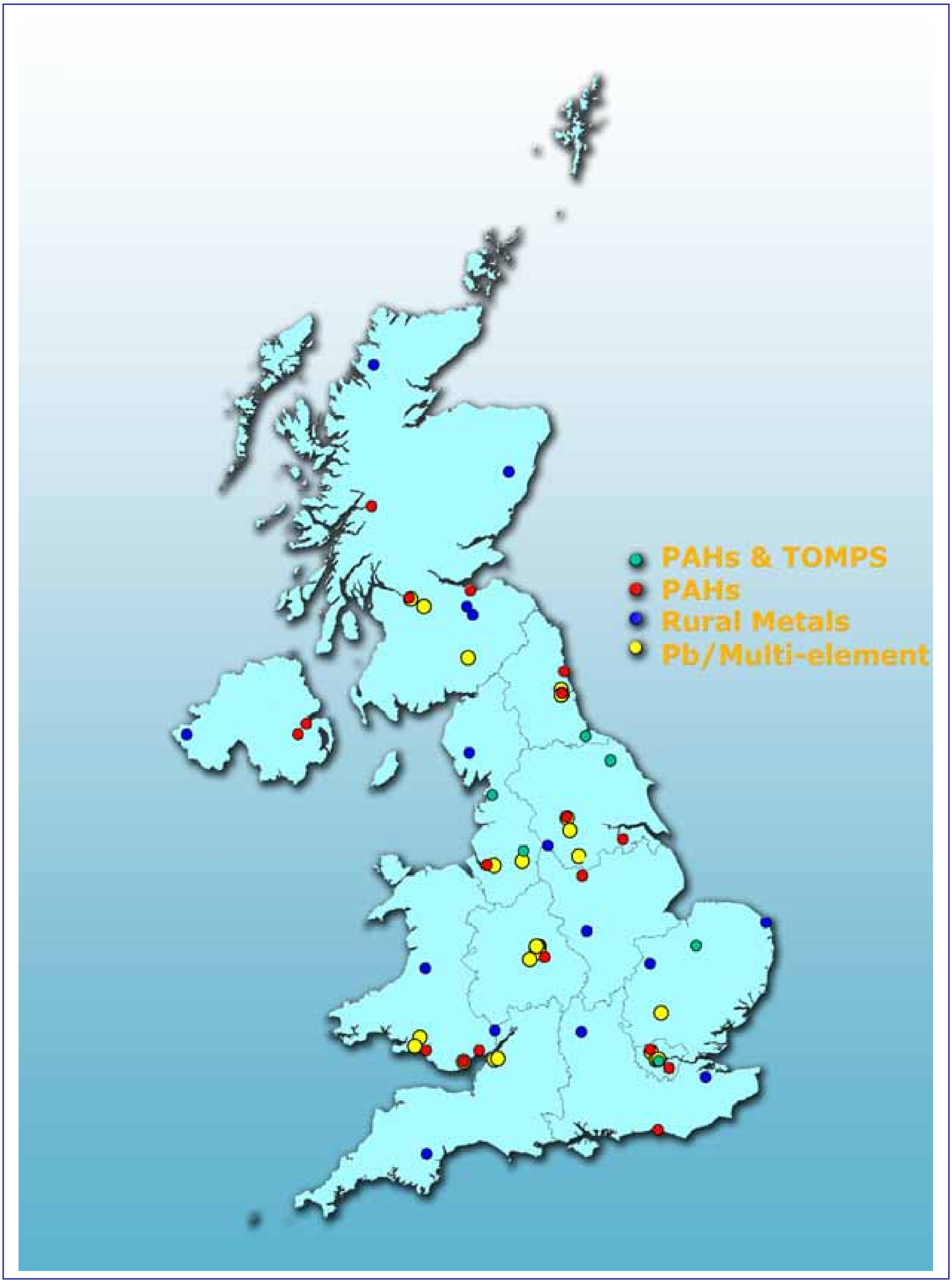


Fig 4.3 Current UK sampler-based measurement programmes: Acidification and Eutrophication

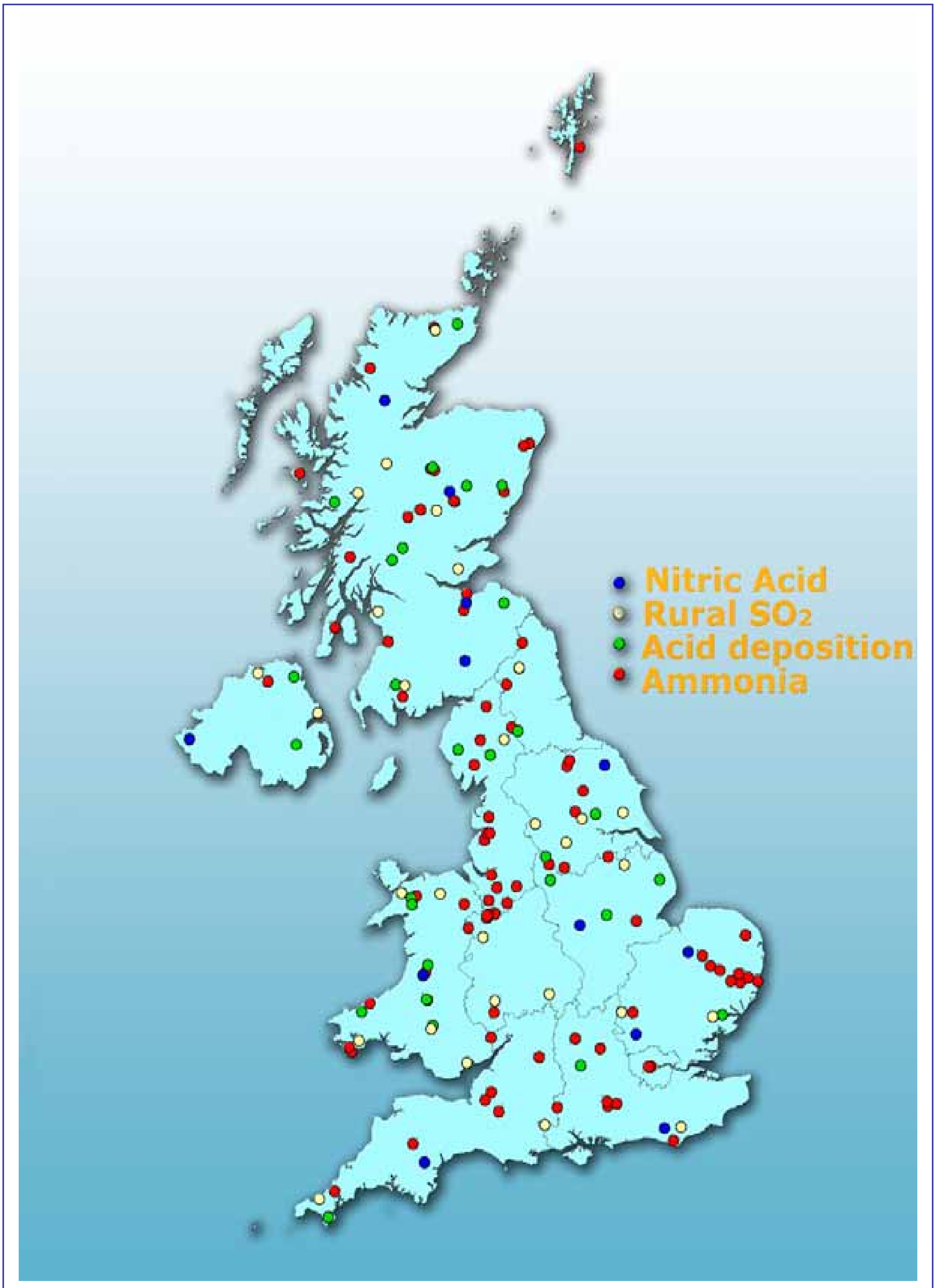
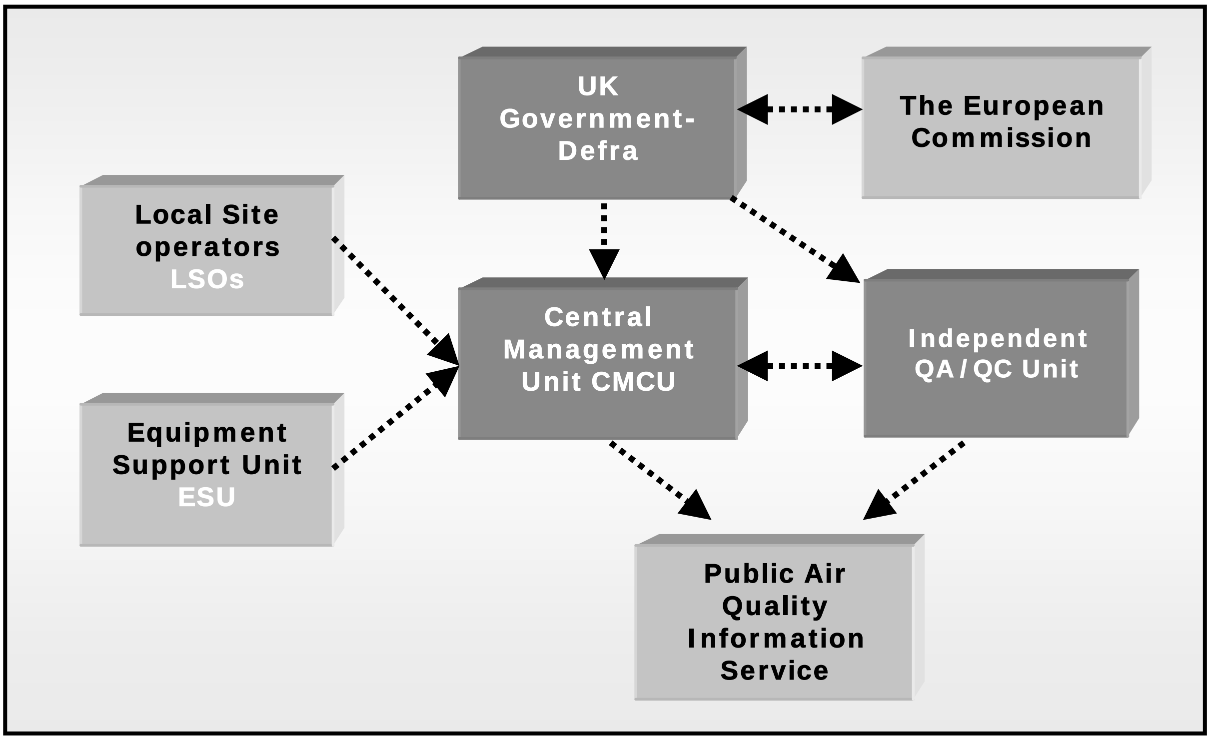


Table 4. The major UK Air Quality Monitoring Networks

Network	Auto or Sampler?	No of Sites
The Automatic Urban and Rural Network (AURN)	A	120 (82 urban, 22 rural, 16 London)
The non automatic network for smoke, SO_2 and NO_2	S	131 (Smoke and SO_2) 1288 (NO_2)
Rural acid deposition, gases and particles	S	38 (acid deposition) 32 (SO_2)
Automatic Hydrocarbon	A	5
Toxic Organic Micropollutants (TOMPS)	S	6
Polycyclic Aromatic Hydrocarbons (PAHs)	S	18
Lead and Multi-element	S	17
Rural metal deposition network	S	10 particle and rain 3 rainwater 2 cloud water all rural
Benzene and 1,3-butadiene	S	35 (benzene) 9 (1, 3-butadiene)
Ammonia Network	S	93
Nitric Acid	S	13

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 5). 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 5. 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 and air quality information services in more detail.

4.4 Emphasis on Data Quality

The UK air monitoring networks produce over 12 million individual measurements every year. 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

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 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.

For the AURN, these activities are tasked to an independent QA/QC Unit (Figure 5), which carries out the following functions:

Quality assurance (of measurement processes):

- Advice on network design, site selection and siting
- Support in instrument selection and sample system design
- Development of operations manual and monitoring compliance
- Operator and personnel training

Quality control (of outputs):

- Monitoring routine site visits and operations
- Monitoring calibration gases and instrument response
- Routine data inspection review and validation
- Data ratification/finalisation before archival

Quality Assessment

- Regular network audits and site inspections

Through these activities, we ensure that the data produced by this network and reported here are fit-for-purpose, reliable and accurate.

4.5 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, transformed into useful information and communicated to government, technical, local authority and public users in timescales and formats meeting their needs. This process of turning raw data into useful information, depicted in Figure 6, is vital to the success of the UK monitoring networks. 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.

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. 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 150 million measurement and statistical records, making it one of the largest publicly accessible online databases in the world.

Data collected from the automatic networks are also rapidly collated, checked and compared with UK and European air quality targets and objectives. Exceedences of high or very high air quality bands (see Box 1) initiate a range of co-ordinated actions by Government and the media to further inform and advise the public. Air quality data from the UK automatic networks, together with twice-daily pollution forecasts, are widely disseminated by a range of electronic and web-based media; these include a free telephone service, and TV Teletext, as well as globally via the World Wide Web (Figure 7 and Box 2). Information on UK air quality is also frequently exchanged with other countries in Europe, to enable us to track pollution being transported over long distances.

The UK's Air Quality Archive is the national repository for ambient air quality measurement and emissions data. It contains measurements from national automatic measurement programmes dating back to 1972, together with sampler measurements dating back to the early 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).

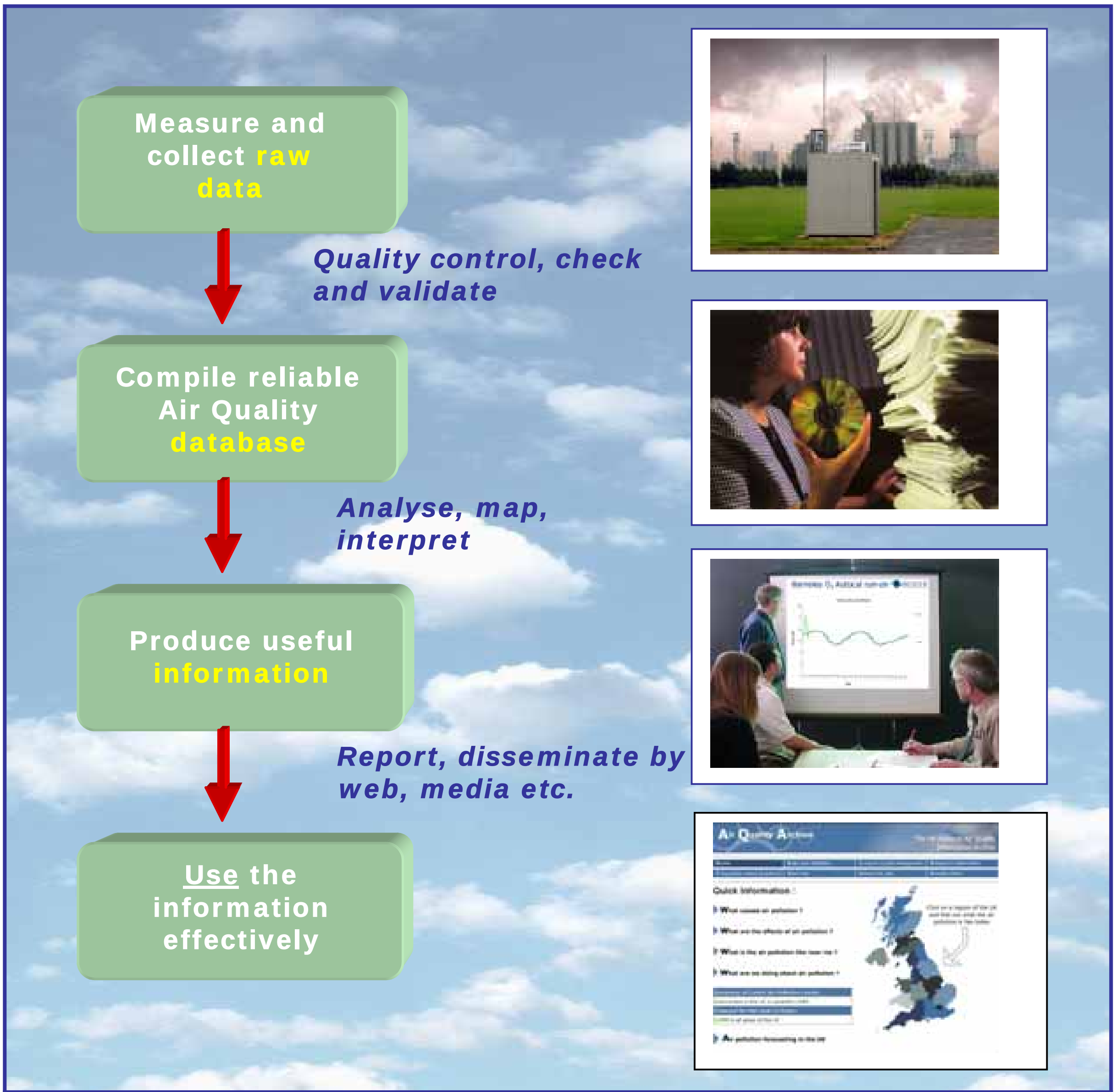


Figure 6. This report has been made possible by turning large quantities of raw air quality data into useful information

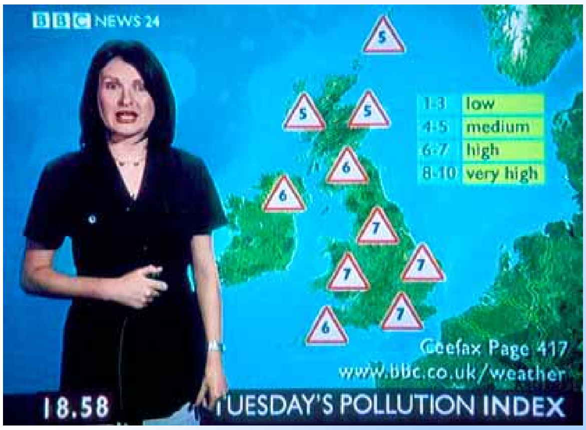
All data and information stored in the UK's Air Quality Archive are freely available at www.airquality.co.uk The website provides user-friendly but comprehensive access to information on all air pollutant concentrations and emissions, together with up-to-date bulletins and measurements from the UK national monitoring networks. It also provides a twice-daily air quality forecast, which is further disseminated via TV Teletext, newspapers and a free telephone service. 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 8 for a map of the site.

The UK's national air quality web site currently records over 4,000 hits each day and is a key resource for UK education and research. It has received wide praise, both within the UK and internationally.

Figure 7. 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:

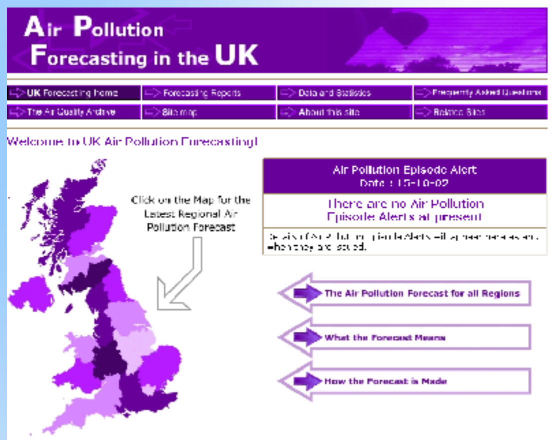
TV Weather Bulletins



TV Teletext

The UK Air Quality Website

Twice daily web forecasts



A series of brochures & reports

Freephone 0800 556677

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
- 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/about/ERADEN/ACEU-AQT/00016215/homepage.aspx
- The Welsh Assembly Government Environment link at http://www.wales.gov.uk/subienvironment/index.htm
- The Northern Ireland Environment and Heritage Service website at http://www.ehsni.gov.uk/environment/environment.shtml
- 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@iforcegroup.com** or 08459 556000

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

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
- 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

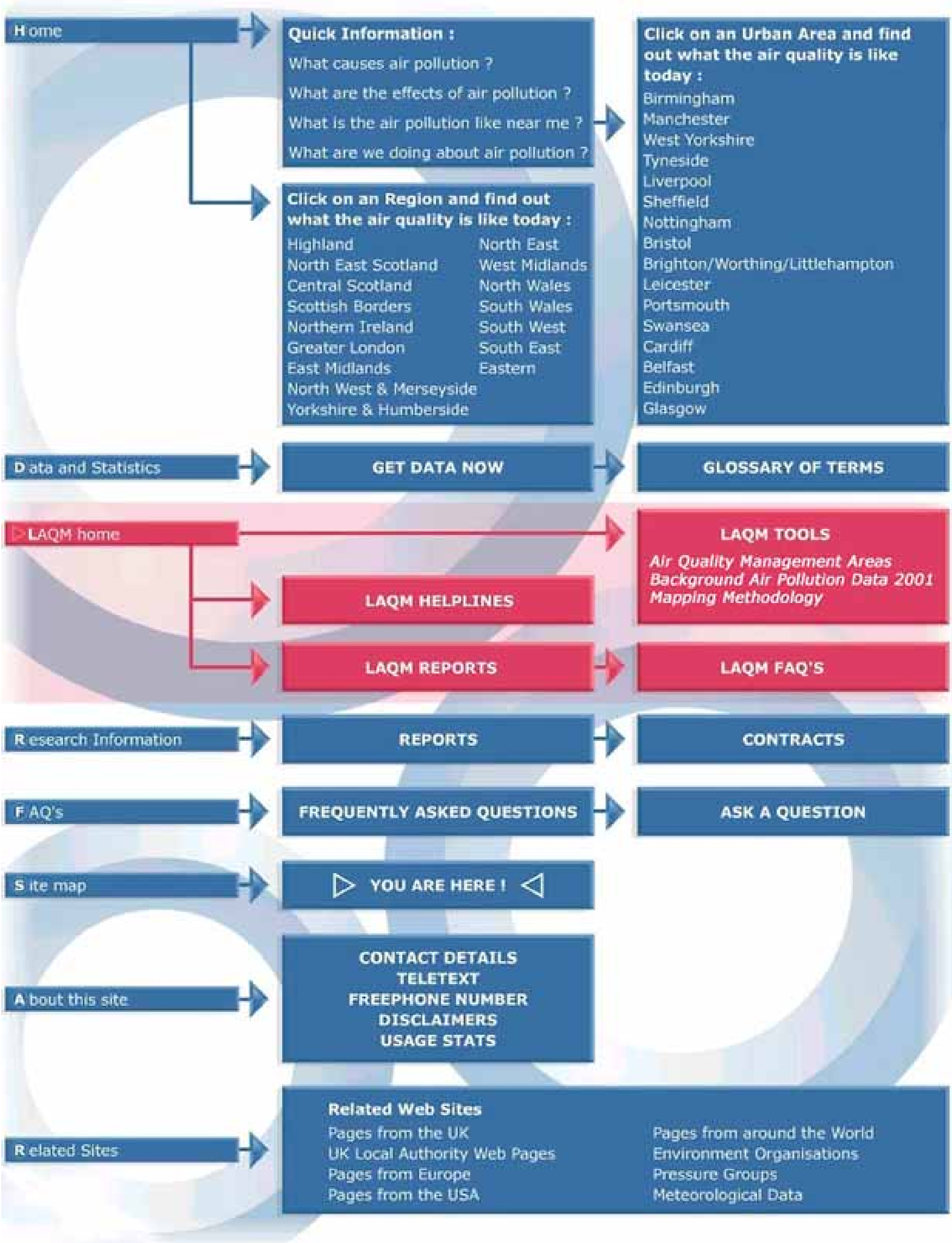


Figure 8 Map of the UK Air Quality Archive, showing the comprehensive range of available data and information from this resource

5. High Pollution Episodes

We focus on periods when pollution levels are unusually high, either locally or UK-wide. Through examining some recent episodes, we identify causes and examine their possible impacts.

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, we focus more on variations in pollution levels from area to area.

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 or result in the transport of pollutants from other areas.

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

By contrast, ***summer smogs*** occur in hot, still 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 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 to human health and vegetation, as well as damaging some man-made materials.

Long-range transport of pollutants from Europe, or occasionally from North Africa or North America, can on occasions cause another type of pollution episode. 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 large industrial plant.

Air pollution episodes in the UK vary widely in terms of the size and location of the areas they affect, duration and seriousness. Here we examine five episodes, one of each specific type described above.

5.1 A winter smog episode: December 2001

Historically, the first half of December is particularly associated with winter smogs in the UK; in fact, many of the most notorious coal-burning smogs occurred at this time of year. The historic London smog of 1952, which first galvanised Government and public action to tackle air pollution, occurred in the first week of December. As discussed in Section 7, where we examine long-term pollution trends, these smogs no longer occur in most of the UK. However similar episodes, albeit of reduced severity, can still occur in areas such as Northern Ireland, where coal is still widely burnt for domestic space heating.

The cold, stable weather that initiates winter smogs also allows pollutants from motor vehicles and other sources to accumulate over time. As a result, winter smogs can now be associated with elevated levels of a wide range of pollutants. A good example of winter smog associated with road transport emissions occurred between the 7^{th} and 18^{th} December 2001. The main pollutants involved were PM_{10} particles and nitrogen dioxide, although sulphur dioxide levels were elevated throughout the period in Belfast.

High atmospheric pressure dominated the UK weather patterns during this pollution event. This is a characteristic weather pattern for winter smogs; it is usually associated with low wind speeds, cold, misty or foggy conditions and well-defined atmospheric temperature inversion layers which act as a barrier to the dispersion of pollutants, trapping them close to the ground. As a result, pollutant concentrations during winter smogs tend to build up slowly over time - the longer the stable conditions last, the higher the levels of pollution reached. In Figure 9 overleaf, we graph the number of monitoring sites exceeding the moderate, high and very high air quality bands for PM_{10} during the episode; this clearly shows the build-up and decline in overall pollutant levels over time.

During the episode's peak from the 11^{th} onwards, the high-pressure system was centred over Northern Britain and Ireland (Figure 10), resulting in elevated concentrations of a range of pollutants over this part of the country, Central Scotland and Northern Ireland. Overnight levels of PM_{10} reached the VERY HIGH band in Glasgow (104 and 119 μgm^{-3}) and HIGH in Edinburgh, Manchester and Belfast. These levels were primarily attributable to road transport emissions, although local sources (nearby construction and a Christmas Fayre) also influenced peak PM_{10} levels in Edinburgh. Domestic heating was an important factor at Belfast, resulting not just in elevated PM_{10} but also sulphur dioxide concentrations in the city. From the 14^{th} onward, wind directions shifted to northerly and speeds increased. The resulting improvement in atmospheric dispersion brought the episode to an end.

5.2 A Bonfire Night Episode: 5 November 2002

Although bonfires and firework displays occur in many parts of the UK every November 5^{th}, as well as during adjacent weekends, meteorological conditions strongly affect the resulting pollutant concentrations. Wet, windy or unsettled conditions result in low concentrations; cold and still weather may result in elevated levels of PM_{10} particles and other pollutants.

Generally, PM_{10} levels in 2002 were lower than in previous years, with elevated measured concentrations being confined to a few small areas, often at sites having comparatively high background levels. The uncharacteristically low pollutant concentrations were attributable to unsettled weather, with moderate to strong westerly winds bringing clean Atlantic air masses and providing effective dispersion conditions over most areas of the UK. Heavy rain showers will also have helped to remove particulate matter from the atmosphere, as well as discouraging firework displays and bonfire night celebrations. In some parts of England, however, winds dropped and more stable conditions prevailed during the 4^{th} and 5^{th}. This resulted in PM_{10} concentrations rising to the moderate band at several measurement sites, mostly in London.

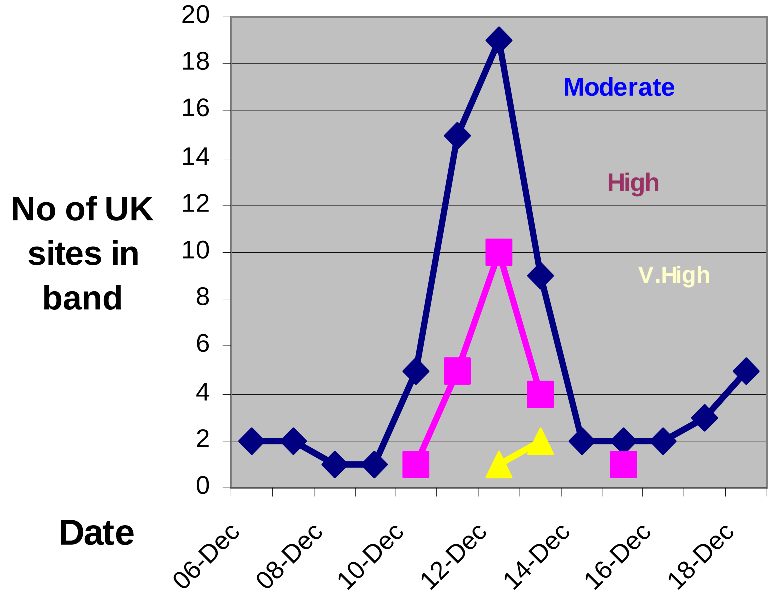


Figure 9. Pollution levels build up slowly during winter smogs

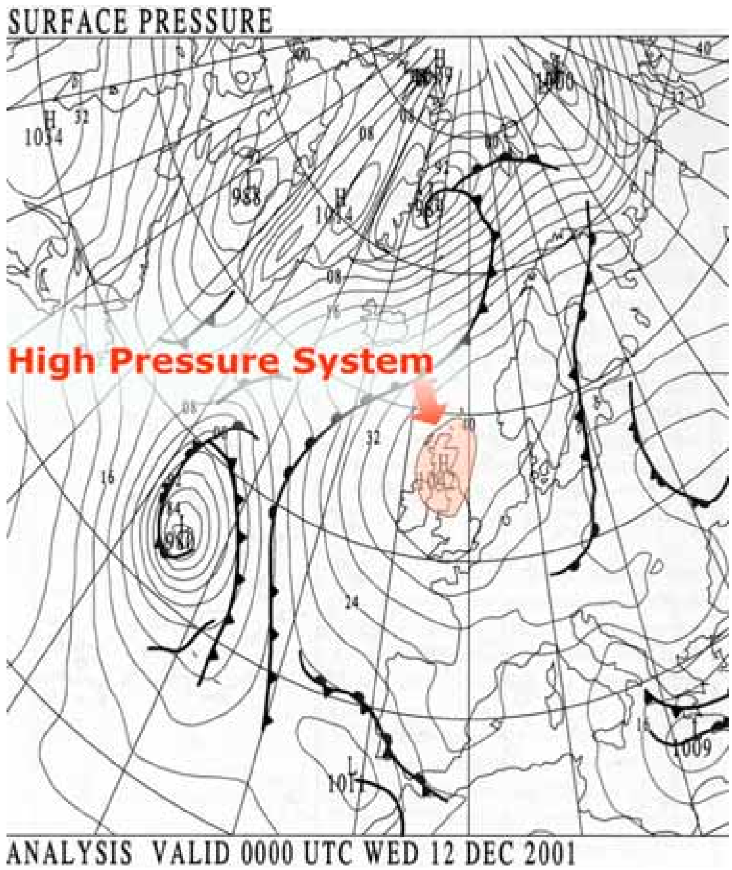


Figure 10. High-pressure systems like this on 12th December are closely associated with winter smog episodes in the UK (Crown Copyright)

Figure 11 shows very clearly how Bonfire Night particle concentrations can vary markedly from year to year. It confirms 2002 to have been a relatively quiet year, with 1994 and 1995 being the most recent years characterised by UK-wide exceedences of the current 24-hour running average PM_{10} objective of 50 µg/m³.

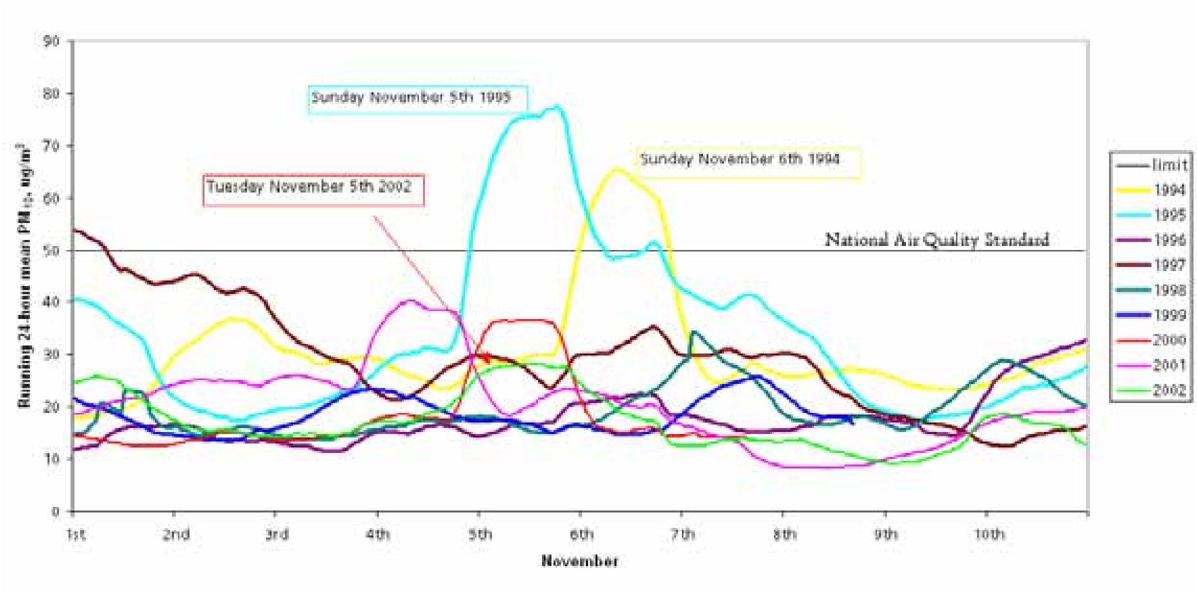


Figure 11. Bonfire night PM levels (running 24-hour average over all UK sites) compared to objective of 50 µg/m³ for all years from 1994 to 2002

5.3 A Summer Smog Episode: August 2003

2003 proved to be a record-breaking year for the UK and global climate. It was the sunniest on record for England and Scotland, the warmest ever in Scotland, and the second driest year in England and Wales since 1766. The highest ever UK temperature of 38.5°C was recorded in Faversham, Kent on 10th August. Taken overall, 2003 was the fifth warmest for Britain as a whole since records began in 1659.

The extreme conditions were not just confined to the UK. 2003 was the third warmest year worldwide since global records began in 1861, and the hottest ever over many parts of Europe (Figure 12). It is interesting to note that all of the planet's ten hottest years have occurred since 1990, providing solid evidence of a worldwide climate trend.

These extreme weather conditions caused photochemical ozone production over large areas of UK and Europe. 2003 was notable both for very early (April) and late (September) summer smogs in the UK. The most exceptional of these was the episode that occurred during the very hottest part of the year, the first half of August (Figure 13). During the period from 1st to 15th August, many rural and urban monitoring stations across England and Wales recorded hourly ozone levels in the HIGH (180-360 μgm^{-3}) band; the highest single hourly measurement was 250 μgm^{-3} at Lullington Heath (East Sussex) on the 11th. Moreover, high concentrations were recorded for 10 consecutive days, an unusually long period for an ozone episode. During much of this period, air transported from continental Europe strongly influenced pollution levels over much of the UK (Figure 14).

However, despite record-breaking temperatures, cloudless skies, sunshine and a persistent, stable high pressure system - all conditions closely associated with photochemical episodes - corresponding pollution levels in August did not break UK records. In fact, comparisons with the similar 'heat wave' summer of 1976 showed that maximum hourly ozone concentrations in 2003 were approximately 50-60% of those recorded during that year. This is consistent with the marked UK and Europe-wide decline in emissions of 'precursor' pollutants (nitrogen oxides and volatile organic compounds) in the years between 1976 and 2003.

During the August heat wave, severe temperatures and elevated ozone levels were recorded in many parts of Europe, together with large numbers of reported deaths. It is often difficult to distinguish deaths caused by heat stroke, dehydration and exhaustion from those due to air pollution. Very often, multiple factors are involved. The UK Office for National Statistics has reported an additional 2045 deaths in England and Wales for period from 4th to 13th August 2003, when compared against the 1998-2002 average mortality figures for that time of year. Using previously well-established medical data on the effects of ozone and PM_{10} on human health, it has been estimated that between 423 and 769 of the additional deaths were associated with elevated concentrations of these pollutants. This represents between 21% and 38% of the total excess deaths recorded during this period.

5.4 An Episode involving Long-range Transport: March/April 2003

This period was interesting for a number of reasons. From mid-March to the end of the month, elevated PM_{10} particle levels in the MODERATE (24 hour running average exceeding 50µgm^{-3}) or HIGH bands (over 75 µgm^{-3}) were observed at an increasing number of sites. A VERY HIGH measurement of 104 µgm^{-3} was recorded in Sheffield on the 24th March. This may well have been due to nearby city centre or industrial sources. For much of the period, however, meteorological analyses showed that air quality nationwide was strongly influenced by primary pollutant emissions from Central or Northern Europe, together with secondary particles subsequently produced by chemical reactions in the atmosphere. When cleaner Atlantic airflows became dominant in early April, levels of all pollutants dropped drastically.

On the 12th April, levels of both ozone and PM_{10} began to increase at many monitoring stations. This rise was associated with unusually warm and sunny weather for the time of year, combined with air transported from Scandinavia and Central Europe. From the 14th onwards, however, winds became stronger and more southerly and elevated PM_{10} levels up to the VERY HIGH band (118 µgm^{-3}) were recorded in Northern England. Images from the US SeaStar satellite, part of NASA's Earth Science Enterprise, provide a fascinating glimpse of global long-range transport of dust and pollution during this period (Figure 15). The images show the UK almost hidden beneath tan-coloured swirls of Saharan dust and grey haze associated with polluted continental air.

As particle levels rose, so did those of ozone, reaching the HIGH band at several locations. As noted previously, April is unusually early for elevated levels of ozone to be observed in the UK. Long-range transport of air dominated throughout this period, bringing in continental ozone and its precursors, with particle levels also likely to have been influenced by the large-scale Saharan dust storms.

5.5 An Episode involving Short-range Transport: May 2002

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 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. The most recent clearcut example of such a point-source episode for SO_2 was seen in May 2002 in Grangemouth, ~ 1km from the nearby large refinery, where measured peak 15-minute average concentrations up to 1346 µgm^{-3} were observed; by comparison, the relevant short-term UK objective for 2005 states that a concentration of 266µgm^{-3} should not be exceeded more than 35 times per year.

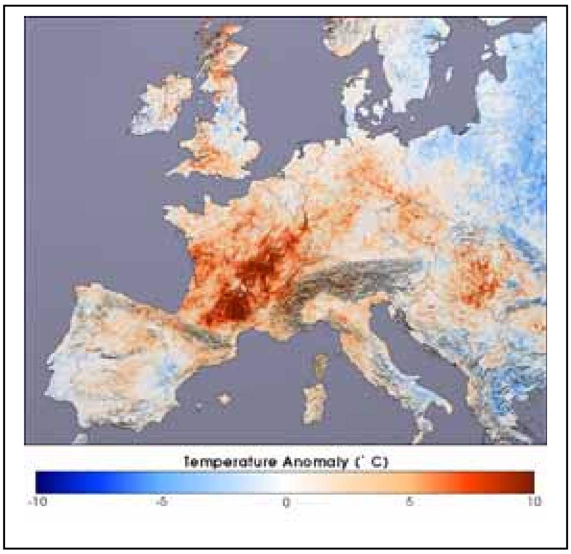


Figure 12 NASA analysis of MODIS satellite data showing temperature anomalies (above normal) across Europe during July 2003 (Courtesy the Visible Earth Team)

Figure 13 London's Canary Wharf during the height of the August 2003 summer smog

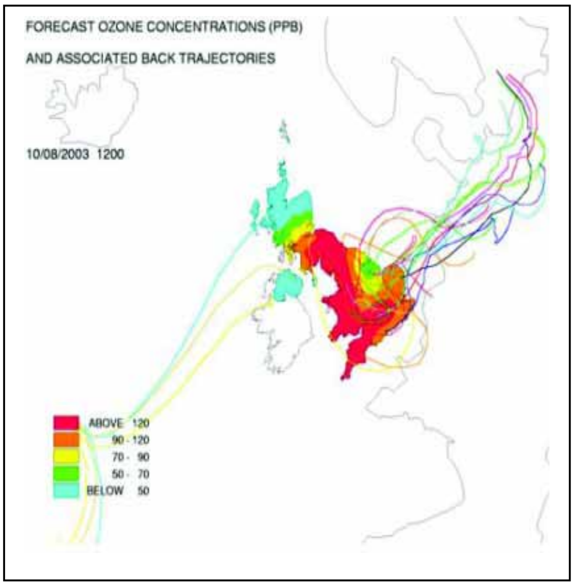


Figure 14 Meteorological analysis showing transport of air from Continental Europe to different parts of the UK during the August 2003 summer smog

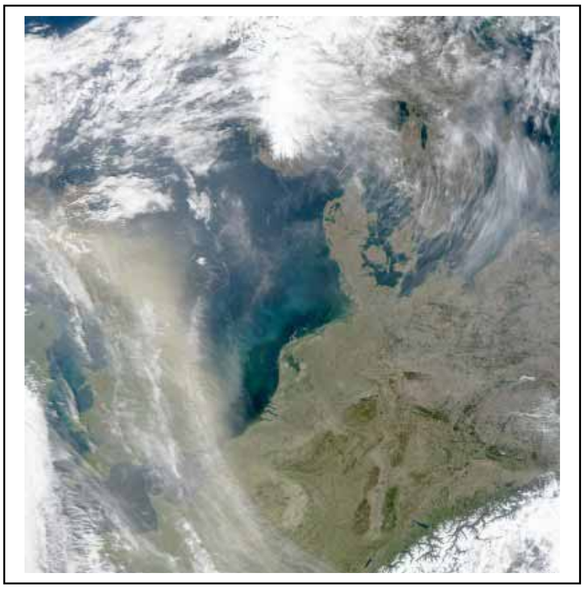


Figure 15 NASA SeaStar satellite image showing strong transport of air and dust to UK from the south on 15 April 2003 (Courtesy the Visible Earth Team)

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.

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. As illustrated in the last section, the highest sustained levels of this pollutant are often found during winter in parts of Northern Ireland, where solid fuel is still used extensively for domestic heating.

Measurements from the UK monitoring networks can be combined using empirical models with detailed pollutant emissions data from the UK's National Atmospheric Emissions Inventory (NAEI). Together, these provide the basis for robust, empirical 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, the report for Defra and the Devolved Administrations entitled 'Mapping of nitrogen dioxide and PM_{10} in the United Kingdom for Article 5 Assessment' and subsequently published at http://www.aeat.co.uk/netcen/airqual/reports/aeat-env-r0707.pdf. The main benefit of the model is that it is simple and directly related to the measurements. No complicated meteorological fields, emissions factors or local information is required.

These maps enable the UK to fulfil its European commitments to assess nationwide pollution patterns prior to 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.

A map showing average SO_2 levels across the country is shown in Figure 16. 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.

Motor vehicles are now a major source of air pollution in many large cities. In particular, most of the carbon monoxide, nitrogen dioxide, and volatile hydrocarbons (VOCs) such as benzene and 1,3-butadiene are emitted from traffic, together with 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 - 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. UK-wide concentrations of ozone are shown in Figures 17.

As highlighted previously, ground-level ozone is formed by a series of chemical reactions involving precursors 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 react very quickly with ozone to remove it from the atmosphere. Because ozone is very reactive, it is also readily deposited onto the ground or adsorbed onto vegetation. These removal processes tend to be more important in sheltered, lowland areas than exposed higher altitudes. As a result, ozone levels are usually higher on elevated ground.

The net result of all these effects, acting together, is shown in Figure 17. The highest summer ozone concentrations (here graphed as accumulated total hours over $80\mu gm^{-3}$ for 2001) are seen in the rural parts of South and South East 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. Elevated concentrations are also seen in parts of Central/Eastern Scotland, due to its altitude. However, the fine detail in these annual ozone maps changes from year to year, and other years have shown evidence of elevated concentrations in hilly parts of Wales. Although not mapped here, ozone levels are characteristically depressed in urban areas, as a result of its 'scavenging' from the atmosphere by road transport emissions.

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. We'll now examine UK-wide patterns of these pollutants more closely.

UK-wide patterns of nitrogen dioxide concentration are shown in Figure 18; these are markedly different from those of ozone or sulphur dioxide. Although some NO_2 is emitted directly from vehicles or other sources, most is formed by rapid chemical reaction in the atmosphere. This pollutant therefore has both secondary and primary characteristics. Concentrations of nitrogen dioxide tend to be highest in urban areas such as in London, where traffic densities are high. Although the data mapped in the figure are background rather than roadside pollution levels, they clearly follow closely the country's major motorways and road network infrastructure.

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 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 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. Particles of ammonium sulphate and ammonium nitrate are produced by the same photochemical reactions that give rise to ozone. Like ozone, secondary particles can therefore be formed considerable distances from the emission sources. This diversity of PM_{10} source types and influences is reflected in the map of average concentrations in Figure 19, which shows markedly less variation across the country than for the other pollutants assessed here.

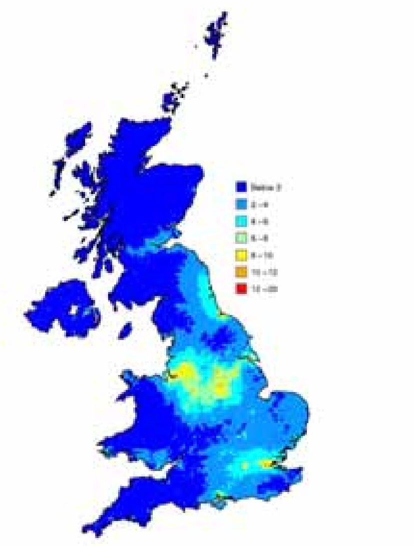


Figure 16. Background **SO_2**, annual average concentrations in 2003 (µg/m^3)

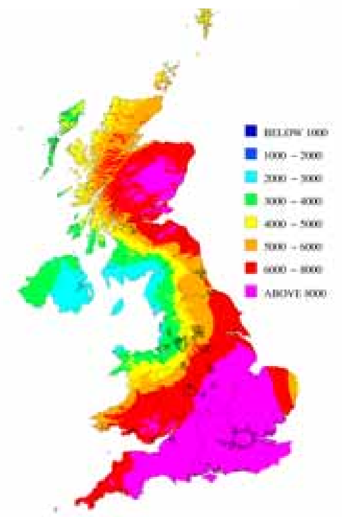


Figure 17. Accumulated **ozone** hours over 80 µg/m^3, summer 2001

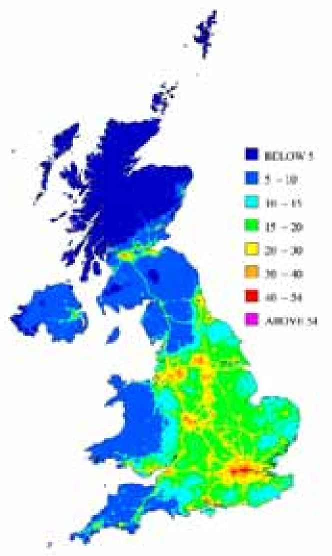


Figure 18. Annual average **NO_2** levels in 2003 (µg/m^3)

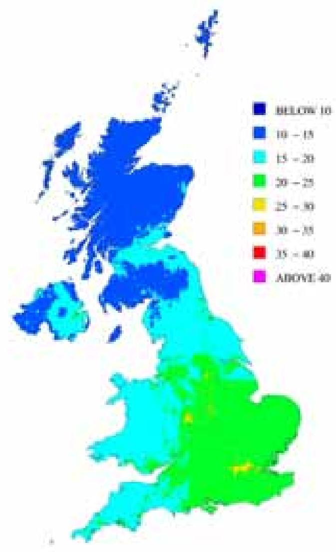


Figure 19. Background **PM_{10}** levels in 2002 (µg/m^3 gravimetric)

Figures 16-19 show mapped concentrations of four major pollutants (SO_2, O_3, NO_2 and PM_{10}); these have been estimated using models based on national monitoring and emissions inventory datasets.

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 clearcut.

As highlighted in previous sections, the concentrations of air pollutants in the atmosphere can vary over the course of a day, the seasons of a year and from year to year. In this section, we focus on long-term trends in the UK's air quality, and attempt to answer the perennial question - 'are things getting better or worse?' As always, the answer to such a straightforward question is not clearcut. It really depends on what pollutants we're examining, and over what timescales.

Very reliable indications of long-term trends can be derived from UK monitoring data. As noted previously, large-scale national measurements of black smoke and sulphur dioxide began in the early 1960s. This national network, established in response to the recurring serious smogs of that era, was probably the earliest air quality measurement programme of this scale and sophistication in the world. At its peak, it included over 1200 measurement sites. The main objectives of this network were to assess nationwide levels of these ingredients of coal smog, and to analyse how these have changed over time; over the 40 years of its operation, both of these network goals have been met in full.

In Figure 20, we show annual average levels of both pollutants from the establishment of the network in the 1960s. The picture shown here is most encouraging. It demonstrates that overall levels of sulphur dioxide have fallen nearly 10-fold, and smoke levels 20-fold. Corresponding measurements from later automatic measurements since 1970 tell the same story, with urban background SO_2 levels now barely distinguishable from those in rural areas.

The dramatic decline in atmospheric concentrations of these pollutants mirrors closely the fall in national emissions of both pollutants. This is because far less coal is used for domestic and small-scale heating, smoke control measures have been universally applied through a series of Clean Air Acts, and cleaner fuels and fuel-burning technologies have been widely adopted. Overall, the successful regulation and taming of coal burning and its emissions represent a remarkable success story for air quality management in the UK.

However, this did not mark the end of air pollution problems in the UK. Road transport and industry remain major sources of pollution, with vehicle emissions being the most important factor affecting air pollution in our cities. The shift from an air pollution climate dominated by coal burning to one most influenced by road transport has occurred in countries world-wide. In many parts of China, for instance, we see pollution climates in a state of transition, with coal burning and a burgeoning vehicle fleet both adding to the urban air quality burden.

Long-term trends of a wide range of air pollutants can be tracked in Britain since the early 1970s; this was when automatic measurements of many other species- including secondary pollutants and those produced primarily by road transport- commenced in earnest. Even clearer trends have become apparent since the massive expansion of the scale and coverage of national measurements over recent years.

Long-term trends for individual pollutants are graphed for a range of site types- urban, rural, near-road and others- in Part 2 of this report.

In Figure 21, we show the UK Government's air quality headline indicator of sustainable development since 1987; urban and rural trends are shown separately. This figure shows the average number of days on which levels of any one of a basket of five pollutants (carbon monoxide, nitrogen dioxide, ozone, fine particles and sulphur dioxide) were 'moderate or higher' according to the Air Pollution Information Service bandings listed earlier in Section 2 of this brochure. These five pollutants are recognised as the most important for causing short-term health effects.

To supplement this information, we show separately in Figure 22 the average number of days of pollution at urban sites since 1993 caused by each individual pollutant.

There is a wealth of information contained in these figures, from which we can extract a number of key conclusions. Firstly, it's clear that 2003 was an exceptional year as regards both weather conditions and air pollution. Although the headline indicator had been showing an overall downward trend in both UK urban and rural areas since the early 1990s, 2003 showed a sharp rise, due primarily to an increased number of poor ozone days. In urban areas, ozone accounted for approximately 70% of the increase over previous years, with the remainder due to PM_{10} particles. The increase in the rural indicator figures was due overwhelmingly to ozone.

The main causes of days of moderate or higher air pollution at urban sites are now ozone and fine particles (PM_{10}). The number of days caused by ozone pollution has fluctuated in both rural and urban areas, with no overall trend being evident. As noted previously, the production of ozone is strongly influenced by the weather; as a result, the exceptionally hot, sunny summer in 2003 led to the greatest number of days of moderate or higher ozone pollution since this modern air quality indicator series began in 1987.

Ozone causes the overwhelming majority of pollution days in rural areas but, since 1999, it has also caused more days of poor air quality in urban areas than particles or any other pollutants. Between 1993 and 2002, the average number of days of pollution at urban sites caused by fine particles, solely or in combination with other pollutants, fell from an average per site of about 43 days to 6 days per year, but rose again to 17 days in 2003. UK-wide emissions of particles have declined substantially in recent years, but the number of pollution days can still fluctuate from year to year due to variations in weather conditions and the impacts of long-range transport from outside the UK.

Sulphur dioxide, which used to make a significant contribution to the index, has now fallen to relatively very low levels. Short-term levels of the other two pollutants included in the index, carbon monoxide and nitrogen dioxide, have very rarely reached moderate or higher levels since 1993. However, long-term exposure to nitrogen dioxide remains a problem in many parts of the UK; this is why it triggers the declaration of Air Quality Management Areas in many urban areas with high traffic densities.

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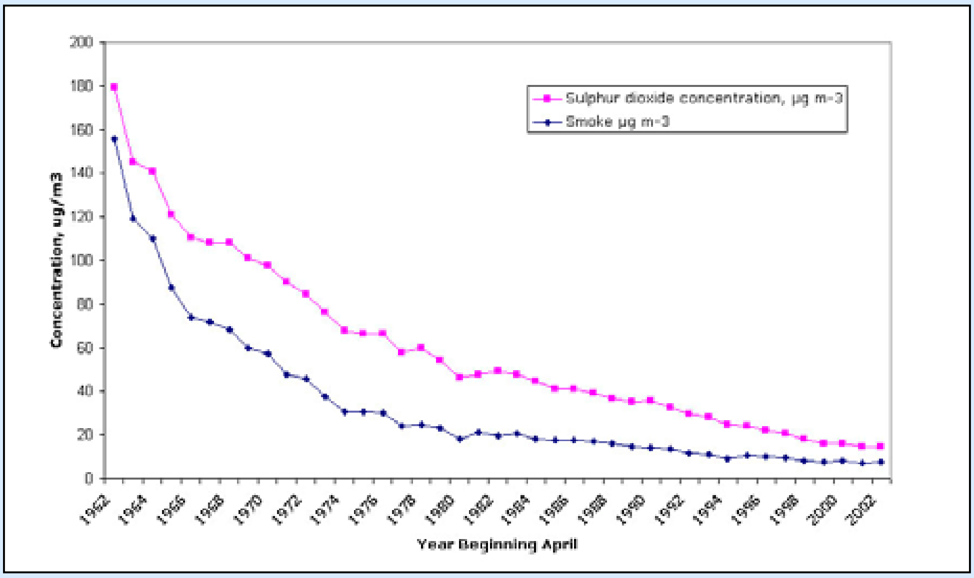

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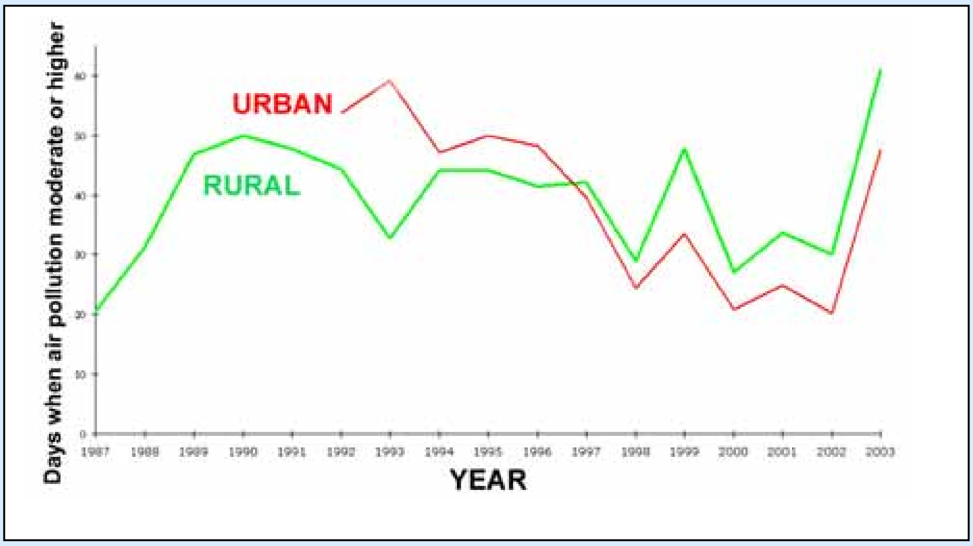

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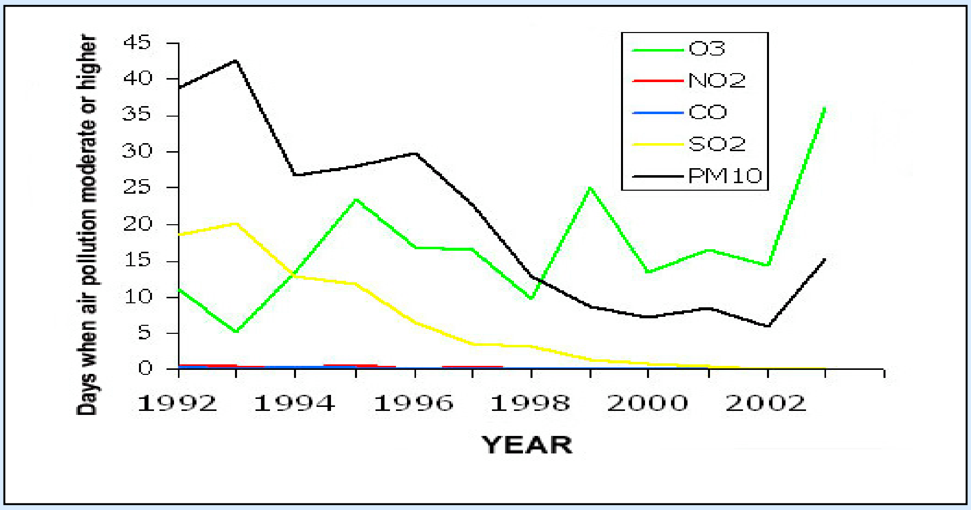


Figure 20- Smoke and SO_2 trends over the last 40 years
Figure 21- Number of days of moderate or higher pollution at urban and rural sites, 1987-2003
Figure 22- Number of days of moderate or higher pollution caused by the different pollutants, 1992-2003

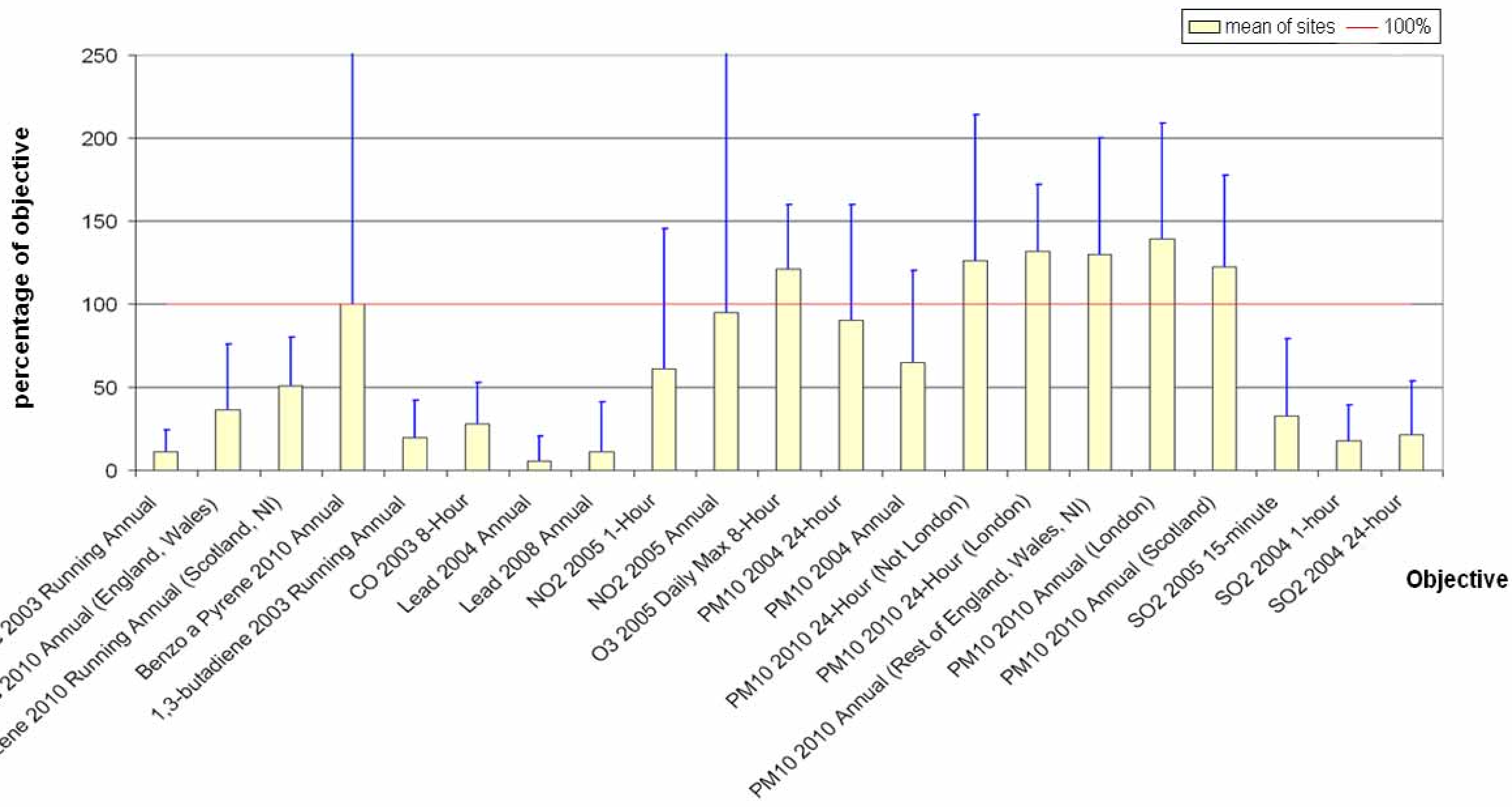
Every year, a comprehensive analysis is undertaken of how UK-wide air quality measurements from the national networks compare with the Air Quality Objectives –both those established in Regulation (and summarised in Table 1) and those not in Regulation or of more localised coverage for London and other parts of the country. Results from the latest such analysis carried out in 2003 are summarised in Figure 23. In this figure, 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 2002 compares with the relevant national objective, whilst the blue line show how the 'worst' site compares with that objective.

For example, Figure 23 shows that current site-averaged annual average benzo[a]pyrene levels substantially exceed the relevant 2010 objective of 0.25µg m^{-3}. Similarly, whilst the overall site-average annual NO_2 level is less than the 2005 objective of 40µg m^{-3}, many sites still exceed this objective, with a maximum of over twice this value. The figure also shows widespread non-compliance with a range of 2004 and 2010 PM_{10} objectives. Clearly, there remains cause for concern in relation to levels of these pollutants.

By contrast, the Objectives for many pollutants- including benzene, 1,3-butadiene, lead, CO and SO_2- are already being met throughout the UK.

It is interesting to examine how the situation now compares with that revealed by similar analyses undertaken in previous years. Comparisons with corresponding analyses undertaken in 1997, for instance, demonstrate improvements for all pollutants, and particularly for PM_{10}. So, although there is no room for complacency, the overall long-term trends for UK-wide levels of most air pollutants continue to show progressive improvement over time.

Figure 23 **Measured concentrations of pollutants in the UK in 2003 as a percentage of the relevant objectives (mean of all sites and highest site)**



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

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/about/ERADEN/ACEU-AQT/00016215/homepage.aspx

The Welsh Assembly Government Environment link:
www.wales.gov.uk/subienvironment/index.htm

The Northern Ireland Environment and Heritage Service website:
www.ehsni.gov.uk/environment/environment.shtml

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

Defra Publications
Admail 6000
London SW1A 2XX
Tel: 08459 556000, Fax: 020 8957 5012
e-mail: defra@iforcegroup.com

Health Effects of Air Pollution

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

Local Air Quality Issues

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

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

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