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Air Pollution in the UK 2009

Edition B

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Title	Air Pollution in the UK 2009 – Edition B
Authors	AEA: Agnieszka Griffin, Andrea Fraser, Andrew Kent, Alison Loader, Carlos Martinez, John Stedman, Ken Stevenson, Keith Vincent, Paul Willis, Rachel Yardley, Tony Bush Defra: Emily Connolly and Clare Bayley

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Department for Environment, Food and Rural Affairs
Nobel House
17 Smith Square
London SW1P 3JR
Telephone 020 7238 6000
Website: www.defra.gov.uk

Executive Summary

The UK is required to report air quality data on an annual basis under the following European Directives:

- The Council Directive on ambient air quality and cleaner air for Europe (2008/50/EC).
- The Fourth Daughter Directive 2004/107/EC under the Air Quality Framework Directive (1996/62/EC).

The report provides background information on the pollutants covered by these Directives and the UK's own Air Quality Strategy; their sources and effects, the UK's statutory monitoring networks, and the UK's modelling methodology. The report then summarises the UK's 2009 submission on air quality to the EU Commission, presenting air quality modelling data and measurements from national air pollution monitoring networks. This includes details of the exceedences reported in 2009, with an overview of trends.
The pollutants covered in this report are:

- Sulphur dioxide (SO_2)
- Nitrogen oxides: (NOx) comprising NO and NO_2
- PM_{10} and $PM_{2.5}$ particles
- Benzene
- 1,3-Butadiene
- Carbon Monoxide (CO)
- Heavy Metals
- Polycyclic aromatic hydrocarbons (PAH)
- Ozone (O_3)

These data are produced on behalf of Defra (the Department for Environment, Food and Rural Affairs) and the Devolved Administrations of Scotland, Wales and Northern Ireland.

The 2009 results can be summarised as follows.

- No exceedences of the SO_2 limit values were reported in 2009 or in recent years.
- The UK exceeded the limit value plus margin of tolerance for hourly mean nitrogen dioxide in two zones, and for annual mean nitrogen dioxide in 40 zones (out of a total of 43 zones). This is similar to the numbers of zones exceeding (both measured and modelled) in previous years.
- Only one zone was reported as exceeding the 24-hour limit value for PM_{10} during the year, after subtraction of the contribution from natural sources. This is the same as last year.
- Exceedences were reported for the long term ozone objective for human health in 39 zones, and exceedences were reported for the long term ozone objective for vegetation in 10 of the 15 non-agglomeration zones where it applies.
- Two exceedences of the target values for nickel were reported in 2009, as was the case in 2008.
- Six exceedences of the target values were reported for benzo[a]pyrene in 2009, as was the case in 2008.

Copies of previous annual submissions can be found on the Commission website: http://cdr.eionet.europa.eu/gb/eu/annualair. For more information on air quality in the UK visit the Defra website at www.defra.gov.uk/environment/quality/air/index.htm and the UK Air Quality websites at www.airquality.co.uk, www.scottishairquality.co.uk, www.welshairquality.co.uk and www.airqualityni.co.uk.

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1 Introduction

The quality of the air that we breathe can have important effects on our health and quality of life. It can also have major impacts on ecosystems and our climate. It is therefore important to monitor air pollution, in order to understand the problems and how they can be managed effectively, at local, national and international level. Monitoring is also essential for the assessment of progress towards compliance with EU limit and target values. The broad objectives of monitoring air pollution in the UK are:

- To fulfill statutory air quality reporting requirements, particularly those developed within Europe.
- To provide a sound scientific basis for the development of cost-effective control policies and solutions under UK Air Quality Strategy and Local Air Quality Management (LAQM).
- To assess where 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.

All Member States of the European Community must comply with EC Directives on ambient air quality. These require all Member States, including the UK, to undertake air quality assessment, and to report the findings to the European Commission on an annual basis. Between 1996 and 2008, these were:

- The Air Quality Framework Directive (1996/62/EC)[1]
- Its four "Daughter Directives" (DDs) covering different groups of pollutants (1st DD - 1999/30/EC[2], 2nd DD -2000/69/EC[3], 3rd DD -2002/3/EC[4] and 4th DD- 2004/107/EC[5]).

In June 2008, a new Directive came into force: the Council Directive on ambient air quality and cleaner air for Europe (2008/50/EC)[6], known as the "Air Quality Directive". This Directive consolidates the first three Daughter Directives, and was transposed into the Regulations in England, Scotland, Wales and Northern Ireland in June 2010. The 4th Daughter Directive remains in force.

The UK has statutory monitoring networks in place to meet the requirements of these Directives, with air quality modelling used to supplement the monitored data.

The results are submitted to the European Commission each year, in the form of a standard questionnaire which each Member State must complete. The UK's annual submission, together with those from previous years, can be found on the Commission website: http://cdr.eionet.europa.eu/gb/eu/annualair.

As well as reporting air quality data to the European Commission, the UK must also make the information available to the public. One way in which this is done is by the series of annual "Air Pollution in the UK" reports, prepared on behalf of Defra and the Devolved Administrations.

"Air Pollution in the UK 2009" continues this series, but follows a different structure to recent years' publications. This year, the report has been streamlined, and split into two editions:

- Edition A, published in September 2010 and available on the Air Quality Archive at http://www.airquality.co.uk/annualreport/index.php, provided a summary of the UK's 2009 annual report to the Commission, based upon measurements and modelling results. Its objective was to accompany the UK's 2009 data submission to the Commission, providing information to make it more understandable to the public. Edition A focused on the UK's *statutory* monitoring, and supplementary modelling.

- Edition B (this edition) is intended to provide information to a wider group of stakeholders and members of the public. This report incorporates the information on statutory monitoring, presented in Edition A, but also includes a more detailed analysis of air pollution in the UK and a wider range of information on air quality assessment. It also looks at other monitoring, which is undertaken for research purposes but is not required to be reported to the Commission.

This report (Edition B of Air Pollution in the UK 2009) will:

- Outline the legislative and policy framework within which the UK's monitoring is carried out *(Section 2).*
- Describe the monitoring and modelling carried out in the UK – the pollutants of concern and where and how air pollution is measured and modelled, both for the purpose of monitoring compliance with legislation, and for the purposes of research to help us better understand the pollution climate of the UK *(Section 3)*.
- Summarise the pollutants' sources and impacts *(Section 4).*
- Discuss 2009 data and trends, for each of the following pollutants: sulphur dioxide, oxides of nitrogen, particulate matter (as PM_{10} and $PM_{2.5}$), ozone, carbon monoxide, benzene, 1,3-butadiene, polycyclic aromatic hydrocarbons, and heavy metals (lead, arsenic, cadmium, nickel and mercury). This section also includes a summary of compliance with the Air Quality Directive and the 4th Daughter Directive (*Section 5).*
- Investigate the spatial distribution of the main pollutants of concern within the UK. *(Section 5)*.
- Investigate pollution events – "episodes" of high pollution – that occurred during 2009, and discuss their causes and effects (*Section 6*).
- Advise the reader on where to obtain more information (*Section 7*).

Links to the suite of EC Directives on ambient air quality are provided on Defra's web pages at http://www.defra.gov.uk/environment/quality/air/airquality/eu-int/eu-directives/airqual-directives/index.htm. The Air Quality Directive itself can also be found at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:152:0001:0044:EN:PDF

2 Legislative and Policy Framework

2.1 European background

European Directives place a duty on each EU Member State to institute policies to protect and improve its environment and the health of its citizens. European Community action is designed to:

- Protect the environment.
- Reduce exposure to air pollution.
- Ensure sustainable development.
- Promote better regulation.

The air quality policy adopted by the European Community has involved two complementary approaches – (i) controlling emissions at source, and (ii) the setting of long-term ambient air quality objectives. The main Directives currently involved in this are outlined below.

All Member States of the European Community must incorporate or - "transpose" - the provisions of EC Directives into their own national law by a specified date.

2.1.1 The Industrial Emissions Directive

In July 2010 the European Parliament endorsed the new Industrial Emissions Directive, which sets stricter limits on pollutant emissions to air, water and land from industrial installations. It limits atmospheric pollutants such as nitrogen oxides (NO_X), sulphur dioxide (SO_2) and particulates, all of which have health or environmental impacts. Installations will have until 2016 to comply with the stricter limits.

The new legislation combines seven existing air pollution directives, including the Large Combustion Plant Directive and the Integrated Pollution Prevention and Control (IPPC) Directive.

2.1.2 The Air Quality Directive and Fourth Daughter Directive

As summarised in section 1 (the Introduction), the Air Quality Directive (Directive 2008/50/EC of the European Parliament and of the Council of 21st May 2008, on ambient air quality and Cleaner Air for Europe), was adopted in June 2008. This directive substantially revised and merged four previous directives and one Decision:

- Directive 96/62/EC on Ambient Air Quality Assessment and Management (the Framework Directive), which established a framework under which the EU agreed air quality limit values for pollutants specified in a series of Daughter Directives.
- The First Daughter Directive (1999/30/EC), which set limit values for sulphur dioxide, oxides of nitrogen, particulate matter as PM_{10}, and lead.
- The Second Daughter Directive (2000/69/EC), which set limit values for carbon monoxide (CO) and benzene.
- The Third Daughter Directive (or EC Ozone Directive, 2002/3/EC), which set target values for the protection of human health and vegetation.
- Council Decision 97/101/EC[7], which established a reciprocal exchange of air quality monitoring information and data, between the Member States.

The Fourth Daughter Directive (2004/107/EC), which covers the four metallic elements cadmium, arsenic, nickel and mercury together with polycyclic aromatic hydrocarbons (PAH), is expected to be merged with the Air Quality Directive in the future.

The Air Quality Directive retained all the existing air quality standards, and also introduced limit values, average exposure indicators (AEI) and an exposure-reduction target for $PM_{2.5}$ particulate matter (a parameter which had not been covered by the previous legislation). The exposure reduction target aims to obtain maximum health benefits for most people by reducing pollutant levels across the whole urban area, rather that focussing action on "hot-spot" areas exceeding limit values.

The Directive provided greater clarity on a number of issues and provides guidance on:

- Setting up monitoring stations for $PM_{2.5}$.
- Quantification of contribution of natural sources.
- Dealing with the contribution from winter salting and sanding of roads.
- Characterisation of $PM_{2.5}$ at rural background locations.

The provisions of the EU ambient air quality directive 2008/50/EC and directive 2004/107/EC relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air were transposed into English legislation by the Air Quality Standards Regulations 2010[8]. The UK devolved administrations have introduced equivalent legislation.

2.2 The UK Perspective

Environmental legislation introduced over the past fifty years has provided a strong impetus to reduce the levels of harmful pollutants in the UK; as a result, current concentrations of many recognised pollutants are now at the lowest they have been since measurements began. However, although the lethal city smogs of the 1950s, caused by domestic and industrial coal burning, have now gone for good, air pollution remains a problem in the UK.

Medical evidence shows that many thousands of people still die prematurely every year because of the effects of air pollution. Air pollution from man-made particles and gaseous pollutants is currently estimated to reduce the life expectancy of every person in the UK by an average 7-8 months with estimated equivalent health costs of up to £20 billion each year[9]. Moreover, it is now firmly established that hospital admissions rise during periods of elevated air pollution levels.

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

2.2.1 **The UK Air Quality Strategy**

The Environment Act 1995 brought about the establishment of The Environment Agency and the Scottish Environment Protection Agency. It also ordered that a National Air Quality Strategy be published, containing policies for assessment and management of air quality. The Air Quality Strategy[10] for England, Scotland, Wales and Northern Ireland was first published in March 1997. The overall objectives of the Strategy are to:

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

The Strategy has established objectives for eight key air pollutants, based on the best available medical and scientific understanding of their effects on health, as well as taking into account relevant developments in Europe and the World Health Organisation. These Air Quality Objectives[11] are at least as stringent as the Limit Values of the relevant EC Directives – in some cases, more so.

The most recent review of the Strategy was carried out in 2007. All the previously existing Air Quality Strategy Objectives were retained, apart from the provisional PM_{10} objectives originally proposed for 2010 in England, Wales and Northern Ireland. The updated Strategy acknowledges the latest research for $PM_{2.5}$, indicating that the health impacts of particulate pollution are particularly associated with this very fine fraction.

There is now clear evidence that there is no 'safe' level for exposure to fine particles – in other words, no threshold below which no health impacts are expected to occur. There are therefore two aspects to the new Air Quality Strategy's exposure reduction approach for $PM_{2.5}$:

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

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

2.2.2 The air quality indicators for sustainable development

The UK Government's Sustainable Development Strategy, "Securing the Future"[12], was launched in March 2005. This strategy is designed to enable all people throughout the world to satisfy their basic needs and enjoy a better quality of life without compromising the quality of life of future generations. A suite of 68 national development indicators has been established to cover the following areas:

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

The suite contains two air quality indicators:

1) **Annual levels of particles and ozone**. These are the two types of air pollution believed to have the most significant impacts on public health (specifically, long-term exposure to PM_{10} and daily peak ozone levels).
2) **Number of days in the year when air pollution is moderate or higher**. This may relate to any of five key air pollutants (nitrogen dioxide, sulphur dioxide, ozone, carbon monoxide, PM_{10}) as defined by the banding system used by the Air Pollution Information Service[13].

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

A more in-depth analysis of the air quality indicator for 2009 is available from the Air Quality Archive, which is currently available at www.airquality.co.uk[14].

2.2.3 The Air Pollution Forecasting System

UK air pollution forecasts are prepared each day and cover five pollutants at present; ozone, nitrogen dioxide, sulphur dioxide, carbon monoxide and PM_{10} particles. For each of the UK's zones and agglomerations (these are explained in section 5), air pollution levels are predicted for rural areas, urban areas, as well as the roadside locations. The overall forecast for each area is a composite 'worst case' of all the pollutants and location types. The UK's Air Quality Objectives are simplified into an air quality banding system for media-based reporting of air quality and potential health effects to the public. This allows the public to see at a glance whether the air pollution is low, moderate or high (Table 2—1).

Table 2—1 Air Pollution Bandings and Index, and Health Impacts for People who are Sensitive to Air Pollution

Banding	Index	Health Descriptor
Low	**1, 2, or 3**	Effects are unlikely to be noticed even by individuals who know they are sensitive to air pollutants.
Moderate	**4, 5, or 6**	Mild effects, unlikely to require action, may be noticed amongst sensitive individuals.
High	**7, 8, or 9**	Significant effects may be noticed by sensitive individuals and action to avoid or reduce these effects may be needed (e.g. reducing exposure by spending less time in polluted areas outdoors). Asthmatics will find that their 'reliever' inhaler is likely to reverse the effects on the lung.
Very High	**10**	The effects on sensitive individuals described for 'High' levels of pollution may worsen.

Air pollution forecasts are compiled daily based on a portfolio of inputs including:

- A 48-hour air quality forecast produced using the Advanced Research – Weather Research and Forecasting model, to forecast the weather and the Community Multiscalar Air Quality model, to forecast the chemical transformations, transport and deposition of the pollutants.
- Other European air quality forecasting models.
- HYSPLIT trajectory models.
- Latest UK and European monitoring data.
- Weather forecasts from several sources.
- Satellite imagery.
- Expert judgment based on historical air pollution episodes.

An air pollution forecast for the following 24 hours is prepared each afternoon for the 16:00h air pollution bulletin, and a revised forecast is issued the following morning if the situation has changed. If the forecast or measurements indicate HIGH (index >=7) or conditions are changing rapidly, a new or revised forecast may be issued at any time. Anyone may subscribe to the air pollution bulletins (hourly, twice daily or daily) at:
http://www.airquality.co.uk/bulletin.php?type=Daily

The twice daily forecast is available from the Air Quality Archive and Scottish, Welsh and Northern Ireland air quality websites (see section 7), and is further disseminated via email and the Air Pollution Information Service, a free telephone service on 0800 556677. Latest forecasts are issued twice daily, at: http://www.airquality.co.uk/archive/uk_forecasting/apfuk_home.php

2.3 Local Authority Air Quality Management

Requirements for local air quality management are set out in Part IV of the Environment Act 1995, and the Environment (Northern Ireland) Order 2002[15]. The Central Government and the Devolved Administrations of Scotland, Wales and Northern Ireland are responsible for overall policy and legislation affecting the UK environment, including air quality. However, over recent years, the UK's Air Quality Strategy – discussed in the previous section – has progressively enabled and encouraged Local Government to take a central role in air quality management. Authorities are required to carry out regular "Review and Assessments" of air quality in their area and take action to improve air quality when the objectives set out in regulation cannot be met by the specified target dates.

Defra and the Devolved Administrations provide Local Authorities with Technical Guidance[16] and Policy Guidance[17] documents, to assist them in carrying out their Review and Assessment, and undertaking necessary activities such as assessment of emissions, modelling and monitoring. These are available via the Defra's Local Air Quality Management web pages.

Local Authorities in England, Scotland and Wales have completed their first, second and third rounds of reviews and assessments against the Strategy's objectives prescribed in the 2000 Air Quality Regulations[18], together with subsequent amendments[19,20,21,22]. The fourth round began in 2009. Under the Environment (Northern Ireland) Order 2002, Local Authorities in Northern Ireland are also required to carry out a Review and Assessment of their local air quality. Rounds 1 and 2 were undertaken on a different timescale to the rest of the UK, but Northern Ireland's Review and Assessment timetable is now running in parallel to that of the rest of the UK, with Round 4 having begun in April 2009.

When the Review and Assessment identifies an exceedence of an Air Quality Strategy objective, the Local Authority must declare an "Air Quality Management Area" (AQMA) and develop an Action Plan to tackle problems in the affected areas. Such a plan may include a variety of measures such as congestion charging, traffic management, planning and financial incentives. To date, 237 Local Authorities – roughly 59% of those in the UK – have established one or more AQMAs, and these are shown in Figure 2-1. Information on the UK's AQMAs is summarised in Table 2—2 below. Please note, some AQMAs are for more than one pollutant.

Table 2—2 Current UK-wide status of Air Quality Management Areas (AQMAs) and appraised Action Plans (as of May 2010)

Region	Total No. of Local Authorities	Number of LAs with AQMAs (May 2010)	Due to NO_2	Due to PM_{10}	Due to SO_2	Due to Benz-ene	Action plans sub-mitted (Sep 2010)	Action plans awaited (Sep 2010)
England (exclud-ing London)	292	173	166	38	7	1	140	42
London	33	33	33	28	-	-	32	2
Scotland	32	12	9	7	1	-	7	7
Wales	22	8	7	1	-	-	5	2
N. Ireland	26	11	7	5	1	-	7	4
TOTAL	**405**	237	222	79	9	1	**191**	**57**

Most of the Air Quality Management Areas that have been declared in the UK are in urban areas and result from traffic emissions of nitrogen dioxide or PM_{10}. Road traffic emissions are the main source in over 92% of the AQMAs; only a few have been designated as a result of other sources, such as industrial or domestic emissions. Figure 2-2 shows the percentages of AQMAs in the UK that have been declared as a result of various sources of pollutant emissions[23].

Figure 2-1 Air Quality Management Areas in the UK, 2009

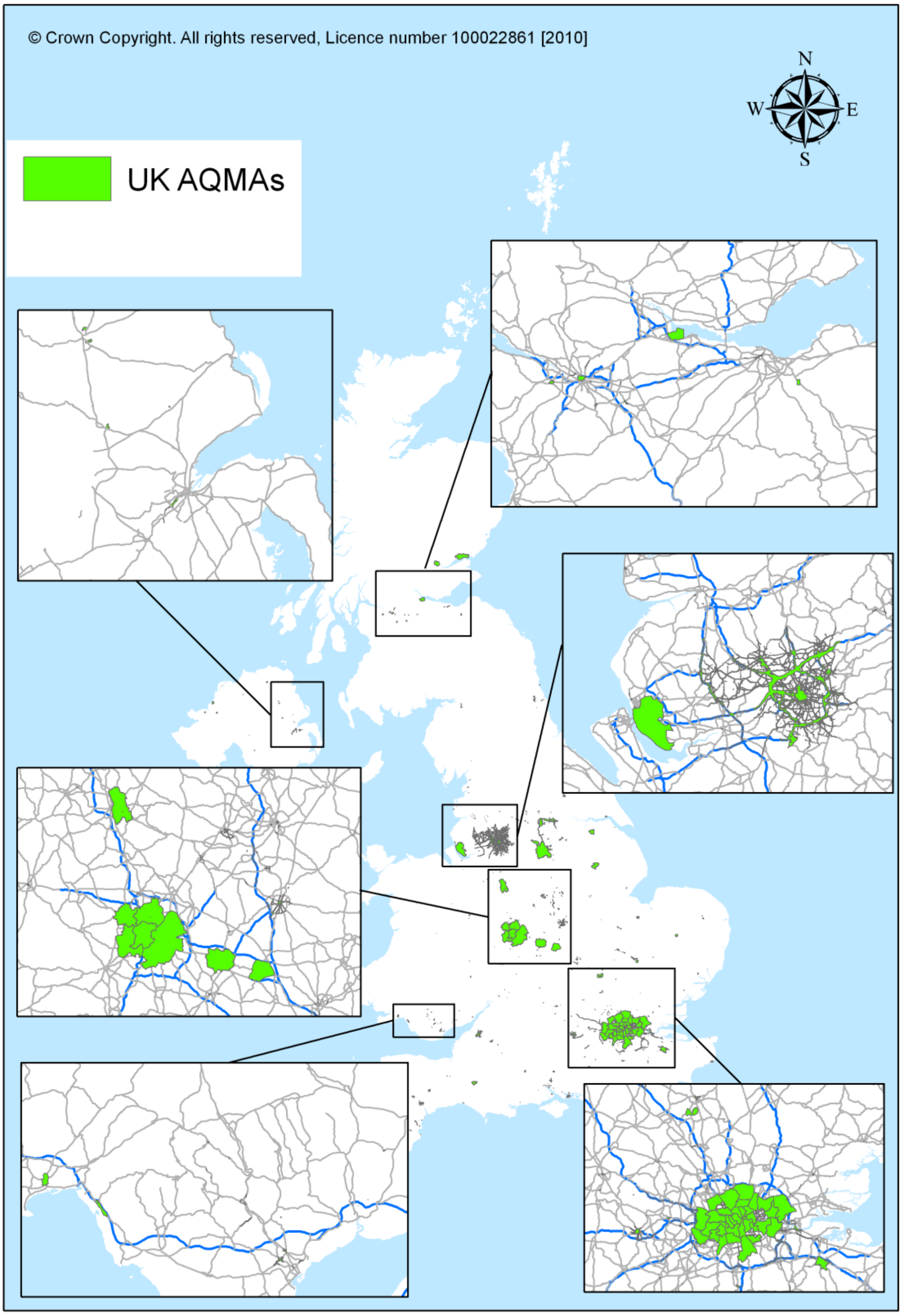
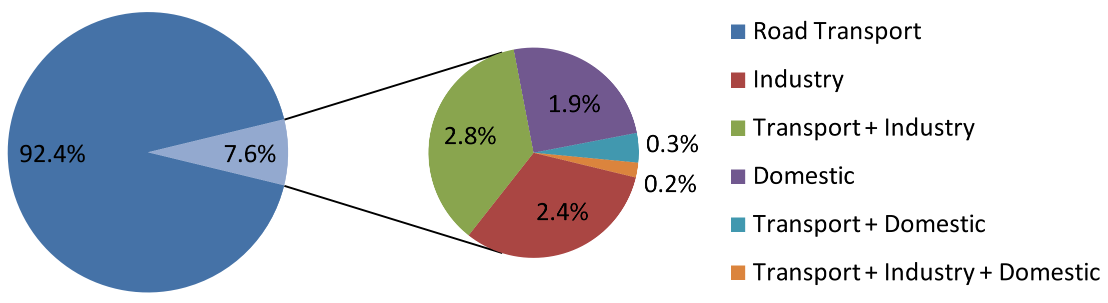


Figure 2-2 Proportion of the UK's current Air Quality Management Areas resulting from various sources (Source: University of the West of England).



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

Information on the UK's Air Quality Management Areas (AQMAs) is published on the Defra website. Information is provided on each one, together with a map of the AQMA, where available.

As shown in Table 2—2, a total of 248 authorities have now submitted action plans or are in the process of preparing them. These formally set out the measures they propose to take to work towards meeting the air quality objectives. Inevitably, the majority of the action plans focus on measures dealing with road traffic, such as:

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

Advice for Local Authorities on preparing an Action Plan is also available from the Defra website.

3 Air Quality Monitoring and Modelling in the UK

3.1 The Roles of Monitoring and Modelling

The evidence base for the annual assessment of compliance is based on a combination of information from the UK national monitoring networks and the results of modelling assessments. Considerably more monitoring sites would be required across the whole of the UK if monitoring data were to be used as the sole source of information. The use of models has the added benefits of enabling air quality to be assessed at locations without monitoring sites and providing additional information on source apportionment and projections required for the development and implementation of air quality plans.

Annex III of the Air Quality Directive provides information on where ambient air quality should be assessed and this applies to both measurements and modelling. The Annex is very prescriptive and identifies how many monitors are needed and where they should be located.

Modelling is undertaken using a national model known as the Pollution Climate Mapping (PCM) model. The PCM models have been designed to assess compliance with the limit values at locations defined within the directives. Local Air Quality Management (LAQM) modelling will usually output contour plots showing dispersion away from the source, on a fine resolution grid. National modelling focuses on concentrations at four metres away from selected road links. The level of detail and resolution of LAQM modelling is therefore much greater in order to focus on local exposure and hotspots. See Section 3.4 for more details on modelling.

3.2 Current UK Air Quality Monitoring

There are nearly 400 national air quality monitoring sites across the UK, each with different objectives, scope and coverage. This section provides a brief description of those used to monitor compliance with the Air Quality Directive and the 4th Daughter Directive. A summary of the UK national networks is provided in Table 3—1.

Table 3—1 The UK's Air Quality Monitoring Networks

Network	Statutory or Research	Pollutants	Number of Sites
The Automatic Urban and Rural Network (AURN)	Statutory	CO, NOx, SO_2, O_3, PM_{10}, $PM_{2.5}$.	132 (97 urban, 27 rural, 8 London)
UK Heavy Metals Monitoring	Statutory	Metals As, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Pt, V, Zn	24
Non-Automatic Hydrocarbon	Statutory	Benzene	36
Automatic Hydrocarbon	Statutory	Range of VOCs	4
Polycyclic Aromatic Hydrocarbons (PAH)	Statutory	PAH	31
UK Eutrophying and Acidifying Pollutants	Research	NO_2, gaseous nitric acid, SO_2, hydrochloric acid, aerosol nitrate, sulphate and chloride.	38
Particle concentrations and numbers	Research	Total particle number, concentration, size distribution, anions, EC/OC	4
Black Carbon	Research	Black Carbon	20
Acid Waters Monitoring	Research	Chemical and biological species in water	25
EMEP	Statutory and Research	Wide range of pollutants and other measurements	2
Heavy Metals Deposition Mapping	Research	As, Cd, Hg, Ni, Pb	15

3.2.1 The Automatic Urban and Rural Network (AURN)

The AURN is currently the largest automatic monitoring network in the UK and forms the bulk of the UK's statutory compliance monitoring evidence base. Data from the AURN are available on the Air Quality Archive.

The techniques used for monitoring within the AURN are the reference methods of measurement defined in the relevant EU Directives for the gaseous pollutants. For particulate matter the AURN uses methods which have demonstrated equivalence to the reference method, but which (unlike the reference method) allow continuous on-line monitoring. Details are provided in Table 3—2.

Table 3—2 AURN Measurement Techniques

Pollutant	CEN standard/ref method	Details
O_3	EN 14625:2005 "Ambient air quality – standard method for the measurement of the concentration of ozone by ultraviolet photometry"[24]	**UV absorption:** ozone absorbs UV light. The absorption of UV by sampled air is used to calculate the ozone concentration.
NO_2/NO_x	EN 14211:2005 "Ambient air quality - Standard method for the measurement of the concentration of nitrogen dioxide and nitrogen monoxide by Chemiluminescence"[25]	**Chemiluminescent:** this method measures the energy emitted when nitric oxide (NO) is reacted with ozone (O_3) in an evacuated chamber to form chemiluminescent nitrogen dioxide (NO_2).
SO_2	EN 14212:2005 "Ambient air quality – Standard method for the measurement of the concentration of sulphur dioxide by UV fluorescence"[26]	**UV fluorescence:** SO_2 molecules are excited to higher energy states by UV radiation. These excited molecules then release this energy as light (fluorescent radiation). The intensity of this can be used to calculate the concentration of SO_2 in sampled air.
CO	EN 14625:2005 "Ambient air quality - Standard method for the measurement of the concentration of carbon monoxide by infra red absorption"[27]	**IR absorption:** Carbon monoxide strongly absorbs infrared radiation of wavelength 4.5 to 4.9 μm. A reference detection system is used to alternately measure absorption due to CO in the sampled air stream and absorption by interfering species. An infrared detector gives a signal proportional to the CO concentration.
PM_{10} and $PM_{2.5}$	EN 12341:1999 "Air quality. Determination of the PM_{10} fraction of suspended particulate matter. Reference method and field test procedure to demonstrate reference equivalence of measurement methods."[28] EN 14907:2005 "Ambient air quality - Standard gravimetric measurement method for the determination of the $PM_{2.5}$ mass fraction of suspended particulate matter"[29]	The AURN uses three equivalent methods: the Filter Dynamic Measurement System (**FDMS**), which determines particulate concentration by continuously weighing particles deposited on a filter: the **beta-attenuation monitor** (BAM) which measures the attenuation of beta rays passing through a paper filter on which particulate matter from sampled air has been collected, and **Partisol –** an equivalent gravimetric sampler that collects daily samples onto a filter for subsequent weighing.

Between 2004 and 2006 a series of tests on ambient particulate analysers was undertaken by Bureau Veritas on behalf of Defra and the Devolved Administrations[30]. The purpose of the test programme was to test the overall performance of a number of 'candidate' particulate matter samplers with that of the EU reference methods for PM_{10} and $PM_{2.5}$ particulate fractions. The aims of these tests were to assess the achievement of criteria of the Data Quality Objectives in Annex 1 of the Ambient Air Quality Directive 2008/50/EC, and to provide the required information for the Competent Authority (Defra) to decide whether to declare the instruments equivalent to the reference method for use in the UK.

For those particulate matter monitoring instruments that are in the AURN, the previously reported 2006 equivalence trials data (as well as further data collected since) have now been reprocessed in accordance with the January 2010 version of The Guide to Demonstration of Equivalence (GDE)[31]. This GDE supersedes a version previously published in November 2005.

The reprocessing has shown that for the 8500 FDMSs, Partisol 2025s and PM_{10} Unheated BAM 1020s deployed in the original tests, the results and recommendations are still valid and therefore this justifies the UK's use of these instruments within the AURN.

3.2.2 Heavy Metals Network

The UK Heavy Metals Network forms the basis of the UK's compliance monitoring for:

- The Air Quality Directive (for lead).
- The 4th Daughter Directive (for arsenic, cadmium and nickel and mercury).

This network monitors a range of metallic elements at urban, industrial and rural sites, using a method equivalent to the CEN standard method[32]. In 2009, it comprised 24 sites, all of which monitored As, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Pt, V and Zn. Additionally, measurements of ambient vapour phase and particulate phase mercury concentrations are made at 13 sites.

3.2.3 Non-automatic Hydrocarbon Network

In this network of 36 sites, ambient concentrations of benzene are measured by the CEN standard method[33], which involves pumping air through an adsorption tube to trap the compound, which is later analysed in a laboratory. This network monitors compliance with the Air Quality Directive.

3.2.4 Automatic Hydrocarbon Network

Automatic hourly measurements of a range of hydrocarbon species are made using automated pumped sampling with in situ gas chromatography, which is an EU reference method[34], at five sites in the UK. These sites monitor benzene, which is covered by the Air Quality Directive. This network also provides data on ozone precursors (compounds that lead to the formation of ozone), which must also be reported to the European Commission.

Two monitoring sites, at Harwell in Oxfordshire and Auchencorth Moss in Lothian, are also part of the European EMEP programme, an international co-operative programme for monitoring and evaluation of the long-range transmissions of air pollutants in Europe.

3.2.5 PAH Monitoring Network

The PAH Network monitors compliance with the 4th Daughter Directive, which includes a target value of 1 ng m^{-3} for the annual mean concentration of benzo[a]pyrene as a representative PAH, to be achieved by 2012. This network uses the CEN reference method[35]. Ambient air is sampled through glass fibre filters and polyurethane foam pads, which capture the PAH compounds for later analysis in a laboratory. During 2009, there were 31 sites in this network.

3.2.6 UK Eutrophying and Acidifying Pollutants

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

The network currently comprises 38 sites in the UK, measuring wet bulk deposition on a fortnightly basis; 24 measuring NO_2 by diffusion tubes at rural sites. This network also includes the monitoring of gaseous nitric acid, sulphur dioxide, hydrochloric acid and aerosol nitrate, sulphate, chloride, plus base on a monthly basis at 30 locations.

3.2.7 Particle Concentrations and Numbers

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

- Total particle numbers per cubic centimeter of ambient air.
- Particle numbers in different particle size fractions.
- Nitrate, sulphate, and chloride.
- Organic and elemental carbon.
- Black carbon (Harwell only).

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

3.2.8 Black Carbon

Black Smoke measurements were some of the earliest systematic measurements of air pollution by particulate matter in the United Kingdom, with records dating back to the 1920s. Air was sampled through a filter and the darkness of the stain, measured by optical reflectance, was converted to a Black Smoke Index, given in units of $\mu g\ m^{-3}$.

In September 2006, the large and long-running national network measuring black smoke and SO_2 finally came to an end after over forty years of operation, and was replaced by a smaller programme measuring black smoke only, at 20 sites across the UK. In the earlier programme, black smoke was collected daily onto paper filters; the darkness of the resulting smoke stains on the filters was measured in a laboratory using an instrument known as a reflectometer, and this measurement was used to calculate a "black smoke index". Between October and December 2008, an automatic instrument called an aethalometer was deployed at each site; these now directly measure black carbon using a real-time optical transmission technique.

3.2.9 Acid Waters Monitoring

The UK Acid Waters Monitoring Network (AWMN) was set up in 1998 to assess the chemical and biological response of acidified lakes and streams in the UK to the planned reduction in emissions. It provides chemical and biological data on the extent and degree of surface water acidification in the UK uplands, in particular to underpin the science linking acid deposition to water quality and to monitor the response of aquatic ecosystems to reductions in air pollution. The sites making up the network were selected on the basis of acid deposition inputs being the only major sources of pollution, i.e. with no point sources of pollution or direct catchment disturbances other than traditional upland land use practices such as sheep grazing or forestry. There are 25 monitoring sites including 12 lakes and 11 streams across the UK, monitoring a range of parameters and life forms including sediment, water chemistry, fish, invertebrates, and aquatic organisms. More information on this network is available from the Defra website.

3.2.10 EMEP

EMEP (European Monitoring and Evaluation Programme) is a European programme set up by Member States to provide governments with qualified scientific information on air pollutants, under the Convention on Long-range Transboundary Air Pollution. In the UK there are two EMEP supersites, at Auchencorth Moss in Lothian (representing the north of the UK) and at Harwell in Oxfordshire (representing the south). A very wide range of measurements are taken at these sites, supplemented by data from other UK networks which are co-located. Monitoring includes:

- Hourly meteorological data.
- Soil and vegetation measurements.
- Heavy metals in PM_{10} and precipitation.
- Deposition of inorganic ions.
- Trace gases (ozone, NO_x and SO_2).
- Black carbon, organic and elemental carbon.
- Ammonia.
- Daily and hourly PM_{10} and $PM_{2.5}$ mass.
- Volatile Organic Compounds.

- Carbonyls.
- CH_4 and N_2O fluxes.

3.2.11 Heavy Metals Deposition Mapping

The heavy metals deposition network measures concentrations and deposition of heavy metals at 15 rural sites. Rainwater is collected and analysed for wet metals deposition at all sites, with cloud water also measured at two of the sites.

At ten locations airborne particulate matter is sampled and analysed for metals concentrations in PM_{10}. The metal concentration data are then combined with the local meteorological data (rainfall etc.) to calculate values for wet deposition (from rain and snow etc.), dry deposition (from dust settling etc.) and cloud deposition (condensation of cloud droplets).

This rural network complements the statutory heavy metals network (described in section 3.2.2), which predominantly monitors at industrial or urban locations.

3.3 Quality Assurance and Quality Control

Air quality monitoring in the UK is subject to rigorous procedures of validation and ratification. The well-established monitoring networks each have a robust and documented Quality Assurance and Control (QA/QC) programme designed to ensure that measurements meet the defined standards of quality with a stated level of confidence. Essentially, each programme serves to ensure that the data obtained are:

- Representative of ambient concentrations existing in the various areas under investigation.
- Sufficiently accurate and precise to meet specified monitoring objectives.
- Comparable and reproducible. Results must be internally consistent and comparable with international or other accepted standards, if these exist.
- Consistent with time. This is particularly important if long-term trend analysis of the data is to be undertaken.
- Representative over the period of measurement; for most purposes, a yearly data capture rate of not less than 90% is usually required for determining compliance with EC Limit Values where applicable.
- Consistent with Data Quality Objectives[36]. The uncertainty requirements of the EU Directives are specified as data quality objectives. In the UK, all air quality data meet the data quality requirements of the EU Directives.
- Consistent with methodology guidance defined in EC Directives for relevant pollutants and measurement techniques. The use of tested and approved analysers that conform to Standard Method (or equivalent) requirements and harmonised on-going QA/QC procedures allows a reliable and consistent quantification of the uncertainties associated with measurements of air pollution.

Most UK networks use a system of regular detailed audits of all monitoring equipment at every site. These audits supplement more regular calibrations and filter changes and test all critical parameters of the measuring equipment including, where appropriate, linearity, converter efficiency (oxides of nitrogen analysers) response time, flow rate etc.

Data ratification is a process to check and validate data as part of a final data ratification process. Data entered on the UK Air Quality website (www.airquality.co.uk) in near real time are provided as provisional data. All these data are then carefully screened and checked via the ratification process. The ratified data then overwrite the provisional data on the website. It should however be noted that there are occasionally circumstances where data which have been flagged as "Ratified" could be subject to further revision. This may be for example where:

- A QA/QC audit has detected a problem which affects data back into an earlier ratification period.
- Long-term analysis has detected an anomaly between expected and measured trends which requires further investigation and possible data correction. This was the case with 2000-2008 gravimetric particulate monitoring data in the UK national network.

- Further research comes to light which indicates that new or tighter QA/QC criteria are required to meet the data quality objectives. This may require review and revision of historical data by applying the new criteria.

Only ratified data are provided to the Commission in compliance with EU Directives.

Further details on the QA/QC procedures appropriate to each network can be obtained from the annual reports of the monitoring networks, and in the report 'QA/QC Procedures for the UK Automatic Urban and Rural Air Quality Monitoring Network (AURN)' available from Defra's air quality web pages.

3.4 Modelling

3.4.1 Why Do Modelling?

The UK's monitoring programmes are supplemented by air quality modelling. There are several benefits of using modelling to complement the monitoring data gathered across the UK national monitoring networks:

- The reduced need for fixed continuous monitoring – freeing up resources to be spent elsewhere such as on developing policy to improve air quality.

- Coverage of the whole UK rather than specific locations where there is a monitoring site. A monitoring site might not fully represent the wider region in which it is located due to local characteristics such as buildings affecting dispersion, localised or temporary sources.

- Provides a framework within which to assess different air quality scenarios – for example projecting concentrations forward to assess levels in future years, representing potential changes to emissions in order to assess the impact of policy initiatives on air quality.

3.4.2 How the Models Work

The modelling method varies between pollutants. Methodology is explained in separate reports[37],[38],[39] (the latest versions of these can be found on the Air Quality Archive[40]).

Air quality modelling in the UK consists of two aspects:

- Background concentrations – on a 1x1km resolution, representing ambient air quality concentrations at background locations.
- Roadside concentrations – concentrations at the roadside of urban major road links throughout the UK (i.e. motorways and major A-roads). There are approximately 9,000 of these road links.

Roadside concentrations are not modelled for SO_2, ozone, benzo[a]pyrene (BaP) and heavy metals which do not have significant roadside sources.

The models have been designed to assess compliance at locations defined by the Directives as relevant for air quality assessment.

3.4.3 Background Air Quality

The 1x1 km background maps are made up of several components which are modelled separately and then added together to make the final grid. These individual components (supplemented by some additional components for various pollutants) are:

- Large point sources (e.g. power stations, steel works, oil refineries).
- Small point sources (e.g. boilers in town halls, schools or hospitals, crematoria).
- Distant sources (characterised by the rural background concentration).
- Local area sources (e.g. road traffic, domestic and commercial combustion, agriculture).

In order to ensure that these ambient concentrations from area sources are representative of the real world situation, they are validated against measurements taken from the national networks (including the AURN). After the validation has been completed the large points, small points, distant sources and validated area source components are added together to provide the final background map.

3.4.4 Roadside Air Quality

Roadside concentrations are estimated by using a roadside increment model which attempts to estimate the contribution from road traffic sources and adds this on top of the modelled background concentrations discussed above.

For each of the road links that are modelled, there are emissions estimates from the National Atmospheric Emissions Inventory[41] (NAEI) for each pollutant and road traffic counts. A roadside increment is calculated for road links with a roadside monitoring station on them by taking the link's modelled background concentration (from the 1x1 km modelled maps) away from the relevant measured roadside concentration. The emission for the road link is scaled according to annual average daily traffic flow for that link and then this is compared against the roadside increment to establish a relationship. This relationship is then used to scale the link emission for different ranges of traffic flow and added to the modelled background concentration to calculate an estimated roadside concentration.

4 Pollutant Sources and Impacts

This section describes the sources and effects of the pollutants being assessed in relation to the Air Quality Directive and 4th Daughter Directive. This information has been taken from the UK Air Quality Strategy 2007 and data available on the UK Air Quality Archive.

4.1 Sulphur Dioxide

Sulphur dioxide (SO_2) is an acidic gas, formed by the oxidation of sulphur impurities in fuels during combustion processes. A very high proportion (approximately 85%) of UK SO_2 emissions originate from power stations and industrial sources, although these emissions are generally released at height by chimneys to achieve effective dispersion under normal conditions. Another important source of ground level SO_2 has historically been solid fuel use in domestic heating systems. As the use of coal and other solid fuels for domestic heating has decreased over the last 30-40 years with the penetration of natural gas into the UK's domestic central heating system stock, SO_2 emissions and atmospheric concentrations have decreased.

SO_2 is a respiratory irritant and can cause constriction of the airways of the lung. This effect is particularly likely to occur in people suffering from asthma and chronic lung disease. The effects of the gas on the lung's airways can occur very rapidly, making exposure to short-term peak concentrations important. Long-term exposure to lower levels has also been linked with adverse effects on lung function. Typical ambient short-term and longer-term concentrations within the UK towns and cities are generally below peak limit values set by the European Commission to protect human health. In 2009 the maximum hourly mean across all sites in the AURN (including traffic sites) was 271 µg m^{-3}, compared to the limit value of 350 µg m^{-3} (which may be exceeded up to 24 times in the calendar year). The annual average across all sites in the AURN (including traffic sites) was just 3 µg m^{-3}. Highest concentrations are likely to occur in residential areas with a high proportion of solid fuel use for domestic heating: also close to industry or large combustion plant under adverse weather conditions, which occasionally result in plume grounding.

SO_2 is also a precursor to secondary particulate matter (PM), and therefore contributes to the ill-health effects caused by PM_{10} and $PM_{2.5}$. The health effects of SO_2 and PM are closely linked, the individual effects of each pollutant only being quantifiable in the last 10 years or so. There is potential for damage to ecosystems at high levels, including degradation of chlorophyll, reduced photosynthesis, raised respiration rates and changes in protein metabolism. Deposition of pollution derived from SO_2 emissions can contribute to acidification of soils and waters and subsequent loss of biodiversity, often at locations far removed from the original emissions.

4.2 Nitrogen Oxides

In the context of air quality, nitrogen oxides refer to nitric oxide (NO) and nitrogen dioxide (NO_2), collectively known as NO_X. NO_X is emitted from many combustion processes, and the main sources in the UK include power generation and road transport. Motor vehicles make the largest contribution to long-term ground level concentrations in urban areas, and the highest NO_X levels in UK cities generally occur at kerbside locations in urban areas. In the presence of sunlight, nitrogen oxides can react with Volatile Organic Compounds (VOC) to produce photochemical pollutants including ozone. Nitrogen dioxide can be further oxidised in air to acid gases such as nitric acid, which contribute to the production of acid rain.

NO is not considered to be of concern with respect to human health. NO_2 is the more harmful species. At *very* high concentrations, such as may occur in certain industrial accidents, NO_2 can cause severe, sometimes fatal, lung damage. At ambient levels (which are very much lower) it acts as an irritant, causing inflammation of the airways. By affecting the immune cells in the lungs, it can also increase susceptibility to respiratory infections. It has been difficult to determine the direct, individual health effects of NO_2 at ambient concentrations because it is emitted from the same sources (notably traffic) as other pollutants such as PM. Ambient levels of NO_2 away from busy roads in the UK are typically below the Limit Values set by the European Union to protect human health. Occasionally the hourly mean Limit Value is breached, as explained in section 5. Close to busy roads, short and long-term average concentrations are higher particularly in locations with poor dispersion characteristics such as street canyons. Concentrations above the Air Quality

Directive Limit Values for human health have been observed in large cities in the UK, although this is not a problem specific to the UK and is common in many other European countries.

NO_2 is one of the five pollutants on which the Government's Air Quality Indicator (one of the 68 Government Indicators for sustainable development, see section 2.2.2) is based. The average number of days of 'Moderate' or higher air pollution, according to the banding system described in section 2.2.3 at urban sites is reported annually by Defra. The average number of such days due to NO_2 in 2009 was less than one per site[14].

High levels of NO_X can also have an adverse effect on vegetation, including leaf or needle damage and reduced growth. Deposition of pollutants derived from NO_X emissions contribute to acidification and/or eutrophication of sensitive habitats leading to loss of biodiversity, often at locations far removed from the original emissions. NO_X also contributes to the formation of secondary particles and ground level ozone, both of which are associated with ill-health effects. Ozone also damages vegetation.

4.3 Particulate Matter

Particulate matter (PM) is a complex mixture of organic and inorganic substances. Particles can be primary (emitted directly to the atmosphere) or secondary (formed by the chemical reaction of other pollutants in the air such as SO_2 or NO_2). Particles may arise from a wide variety of sources, man-made or natural. The main source of particles is combustion i.e. traffic and power stations. Other man-made sources include quarrying and mining activities, industrial processes, dust from construction work and particles from tyre and brake wear. Natural sources include wind-blown dust, sea salt, pollens, fungal spores and soil particles.

Particles found in ambient air range in size from a few nanometres (nm, or 10^{-9} m) to several hundred micrometres (µm, or 10^{-6} m) in diameter. Particle size is usually expressed in terms of its aerodynamic diameter. Two fine size fractions of particulate matter are measured in UK national monitoring networks: PM_{10} and $PM_{2.5}$. PM_{10} is the mass concentration (expressed in µg m^{-3}) of PM that is generally less than 10 millionths of a metre (10 µm) in diameter[i]. $PM_{2.5}$ refers to the mass concentration of particles less than 2.5 µm in diameter.

Fine particles are the main focus in air quality monitoring, as fine particulate matter can penetrate deep into the airways, carrying surface-absorbed harmful compounds into the lungs, increasing the risk of health effects. In most urban environments, both coarse ($>PM_{2.5}$) and fine particles ($<PM_{2.5}$) are present, but the proportion of particles in these two size ranges is likely to vary substantially between cities depending on local geography, meteorology and specific PM sources.

The range of health effects associated with PM is broad, but is predominantly related to the respiratory and cardiovascular systems. All population is affected, but susceptibility to the effects of PM may vary with health or age. The risk for various outcomes has been shown to increase with exposure, with both short-term and long-term exposure being important. There is little evidence to suggest a threshold below which no adverse health effects would be anticipated, but effects are unlikely to be noticed even by sensitive individuals below about 60 µg m^{-3} for PM_{10} (the bottom of the 'Moderate' band - see the Air Pollution bandings in Table 2-1). In 2009, the average number of days per site with PM_{10} concentrations in the 'Moderate' band or above was four (at urban sites)[14].

Annual mean PM_{10} concentrations for urban background and roadside sites are also reported annually as a Government Air Quality Indicator. At urban background sites, the annual mean PM_{10} concentration for 2009 was 19 µg m^{-3}; at roadside sites it was slightly higher at 22 µg m^{-3}.

Ambient levels of PM are below the long-term limit values for the protection of human health throughout the UK. In the UK, the short-term, daily mean limit value for the protection of human health is exceeded close to very busy roads in central London only.

4.4 Benzene

Benzene is an organic chemical compound. Ambient benzene concentrations arise primarily from road transport and the domestic combustion of wood and non-smokeless fuel. Benzene is naturally

[i] Mass per cubic metre of particles passing through the inlet of a size selective sampler with a transmission efficiency of 50% at an aerodynamic diameter of 10 micrometres.

broken down by chemical reactions in the atmosphere over a period up to several days; as a result outdoor benzene concentrations tend to correlate well with road networks and traffic density patterns, concentrations are now low due to the introduction of catalytic converters on car exhausts.

Benzene is a recognised human genotoxic carcinogen which attacks genetic material. As a result there is no absolutely safe threshold below which no adverse health effects are anticipated. Nevertheless, European Limit Values have been proposed below which, risks of health effects are exceedingly small, and the UK is compliant with these levels for benzene in all outdoor non-occupational locations.

4.5 Carbon Monoxide

Carbon monoxide (CO) is a colourless, odourless gas produced when gas and other fossil fuels (such as oil, coke and coal), wood and charcoal are burned without a sufficient supply of oxygen to fully oxidise the carbon present. Petrol engines used to emit significant amounts of CO but concentrations are now very low due to the introduction of catalytic converters on car exhausts. The UK is compliant with European Limit Values for CO in all outdoor non-occupational locations.

People are more likely to be exposed to dangerous concentrations of CO indoors. The main indoor sources are incorrectly installed, poorly maintained or poorly ventilated cooking and heating appliances such as gas fires, gas boilers and wood burning stoves. Cigarette smoke is also a major source of exposure.

4.6 Ozone

Ozone (O_3) is a secondary pollutant gas, formed by photochemical reactions in the lower atmosphere (the troposphere). In the stratosphere (part of the upper atmosphere) O_3 is formed by the action of ultraviolet light on oxygen molecules. This produces the ozone layer and at this level the gas has a beneficial effect by absorbing harmful ultraviolet radiation from the sun.

In the lower atmosphere however, O_3 is an air pollutant. It is produced by the photochemical effect of sunlight on oxides of nitrogen and volatile organic compounds produced by motor vehicles and industry. These reactions take place over periods of several hours or even days. Once formed, O_3 can travel long distances, accumulate and reach high concentrations often far away from the sources of the original pollutants. NO_X emitted in cities reduces local O_3 concentrations as NO reacts with O_3 to form NO_2. This means that O_3 precursors generated in countries with large traffic and industrial emissions may affect less polluted countries, and that levels of O_3 in the air are often higher in rural areas than urban areas. For example, it is often the case that when O_3 levels are elevated in the South East of England, much of the O_3 has originated in continental Europe. O_3 concentrations are greatest in the summer (usually on hot, sunny, windless days) and lowest in the winter months.

O_3 is an oxidising agent and acts as an irritant, producing inflammation of the respiratory tract. At high concentrations O_3 irritates the eyes, nose, and throat, causing coughing and discomfort whilst breathing. Exposure to elevated levels over several hours can lead to damage of the lining of the airways. This is followed by inflammation and narrowing of the airways and increased sensitivity to stimuli such as cold air and exercise. This is called "airway hyper-responsiveness". There is a wide variation in individuals' sensitivity to the effects of O_3. During pollution episodes, high levels of O_3 may exacerbate asthma or trigger asthma attacks. Some non-asthmatic individuals might also experience discomfort when breathing, particularly if they are exercising vigorously outdoors.

At urban sites, the average number of days in 2009 with 'Moderate' or worse air quality – at which sensitive individuals may notice effects – caused by ozone was just six[14]. However, at rural sites the average was 32 days per site in 2009[14] (the Indicators report does not provide a breakdown by pollutant but states that the 'vast majority' of rural air pollution is caused by ozone.) Since 1997, the average number of days per site with 'Moderate' or worse air quality has been greater at rural sites than at urban sites – and the majority of such days at rural sites are due to ozone[14].

Controls limiting the emissions of VOC from road transport and large scale industry have lead to a reduction in emissions of precursor species and the magnitude and frequency of ozone pollution episodes. However, under favourable conditions ozone pollution episodes and exceedences of the European Target Values for human health protection do occur in the UK, particularly when stable anticyclonic atmospheric conditions persist over the UK and northern Europe. Typically these conditions are only experienced a handful of times a year, most commonly over the summer months.

4.7 Lead

The majority of lead emissions arise from industry, in particular non-ferrous metal smelters. Exposure to high levels in air may result in toxic biochemical effects which have adverse effects on the kidneys, gastrointestinal tract, the joints, reproductive systems, and acute or chronic damage to the nervous system. There is evidence of impaired intellectual development in young children arising from long-term exposure to lead at elevated levels well in excess of the EU limit value of 0.5 μg m^{-3}.

4.8 Heavy Metals

Nickel is found in ambient air as a result of releases from oil and coal combustion, nickel metal refining, sewage sludge incineration, manufacturing facilities, and other sources. It may cause damage to the kidneys, inhibit reproductive ability, and result in respiratory problems.

Arsenic is emitted into the atmosphere as arsenic trioxide in the form of particulate matter. The primary source of arsenic emissions to the air in the UK is the combustion of coal and other fossil fuels, and also industrial processes which use arsenic. Exposure to arsenic dust causes respiratory irritation and it is believed to be a carcinogen.

Inhalation of cadmium present in airborne particulate matter results in a build-up of cadmium in the kidneys that can cause kidney disease. Exposure to cadmium is also likely to increase the risk of lung cancer in humans.

Mercury is released to the air by human activities, such as coal burning, use of mercury in industrial processes, and the release of mercury in dental fillings from crematoria. High levels of mercury in the bloodstream of unborn babies and infants may impede the development of the nervous system.

Health effects of these metals are only expected at elevated levels in excess of the European Values.

4.9 Benzo[a]pyrene

Benzo[a]pyrene (B[a]P) is used as a 'marker' for a group of chemical compounds known as polycyclic aromatic hydrocarbons (PAHs). Polycyclic aromatic hydrocarbons are a large group of persistent, bio-accumulative, organic compounds with toxic and carcinogenic effects; they are produced from a wide range of industrial, chemical and combustion processes.

The main sources of ambient B[a]P include road transport, domestic solid fuel use and activities at iron and steel plant. A major source of human exposure is also cigarette smoke. Studies of occupational exposure to PAHs have shown an increased incidence of tumours of the lung, skin and possibly bladder and other sites. Lung cancer is most obviously linked to exposure to PAHs through inhaled air. Individual PAHs vary in their ability to induce tumours in animals or humans.

5 Data and Trends

5.1 Definition of Zones

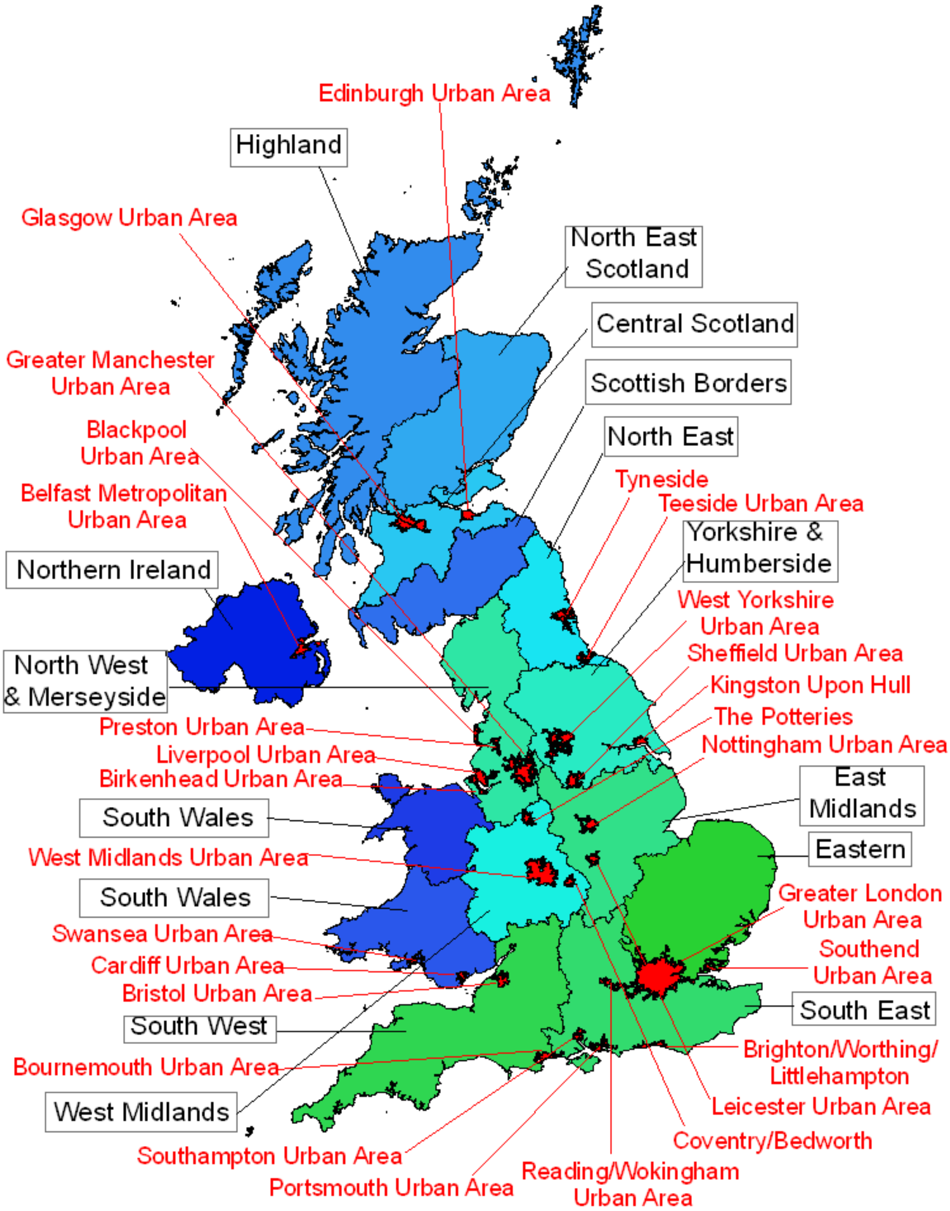
The UK has been divided into 43 zones for air quality assessment. There are 28 agglomeration zones (large urban areas) and 15 non-agglomeration zones. Form 2 of the EC Directive Air Quality Reporting Questionnaire ('the Questionnaire') contains details of these including type, area, and population (from the 2001 census). Each zone is assigned an identification code: these are listed in Table 5—1 and illustrated in Figure 5-1.

Table 5—1 UK zones and agglomerations for ambient air quality reporting 2009

Zone	Zone code	Ag or non-ag*
Greater London Urban Area	UK0001	Ag
West Midlands Urban Area	UK0002	Ag
Greater Manchester Urban Area	UK0003	Ag
West Yorkshire Urban Area	UK0004	Ag
Tyneside	UK0005	Ag
Liverpool Urban Area	UK0006	Ag
Sheffield Urban Area	UK0007	Ag
Nottingham Urban Area	UK0008	Ag
Bristol Urban Area	UK0009	Ag
Brighton/Worthing/Littlehampton	UK0010	Ag
Leicester Urban Area	UK0011	Ag
Portsmouth Urban Area	UK0012	Ag
Teesside Urban Area	UK0013	Ag
The Potteries	UK0014	Ag
Bournemouth Urban Area	UK0015	Ag
Reading/Wokingham Urban Area	UK0016	Ag
Coventry/Bedworth	UK0017	Ag
Kingston upon Hull	UK0018	Ag
Southampton Urban Area	UK0019	Ag
Birkenhead Urban Area	UK0020	Ag
Southend Urban Area	UK0021	Ag
Blackpool Urban Area	UK0022	Ag
Preston Urban Area	UK0023	Ag
Glasgow Urban Area	UK0024	Ag
Edinburgh Urban Area	UK0025	ag
Cardiff Urban Area	UK0026	ag
Swansea Urban Area	UK0027	ag
Belfast Metropolitan Urban Area	UK0028	ag
Eastern	UK0029	non-ag
South West	UK0030	non-ag
South East	UK0031	non-ag
East Midlands	UK0032	non-ag
North West & Merseyside	UK0033	non-ag
Yorkshire & Humberside	UK0034	non-ag
West Midlands	UK0035	non-ag
North East	UK0036	non-ag
Central Scotland	UK0037	non-ag
North East Scotland	UK0038	non-ag
Highland	UK0039	non-ag
Scottish Borders	UK0040	non-ag
South Wales	UK0041	non-ag
North Wales	UK0042	non-ag
Northern Ireland	UK0043	non-ag

ag = agglomeration zone, non-ag = non-agglomeration zone

Figure 5-1 UK zones and agglomerations for ambient air quality reporting 2009



Agglomeration zones (red)
Non-agglomeration zones (blue/green)

5.2 Air Quality Assessment for 2009

As explained in section 2, the air quality assessment for each pollutant is derived from a combination of measured and modelled concentrations. Where both measurements and model results are available the assessment of compliance for each zone is based on the higher concentration of the two.

The results of the air quality assessment submitted to the European Commission are summarised in table format, in sections 5.3 to 5.12 below. The tables have been completed as follows:

- Where all measurements were within the relevant limit values, (or limit values with margins of tolerance where applicable) in 2009, the table shows this as 'OK'.
- Where compliance was determined by modelling, this is shown as 'OK (m)'.
- Where locations were identified as exceeding a limit value, or a limit value plus margin of tolerance where applicable, this is identified as '>MOT' or '>LV' as applicable.
- Where an exceedence was determined by modelling, this is indicated by (m), as above.

Zones that complied with the relevant limit values, targets or long-term objectives are shaded blue, while those that did not are shaded red.

A similar approach has also been used to compare concentrations with target values (TV) and long term objectives (LTO). 'n/a' means that an assessment is not relevant for this zone, such as for the vegetation limit value in agglomeration zones.

5.3 Sulphur Dioxide

5.3.1 SO_2: Compliance with Directive

Sulphur dioxide (SO_2) is covered by the Air Quality Directive. The results of the UK's air quality assessment for sulphur dioxide are presented in Form 8a of the Questionnaire.

In 2009, all zones and agglomerations within the UK complied with the limit values for 1-hour mean and 24-hour mean SO_2 concentrations, set for protection of human health. All non-agglomeration zones within the UK also complied with the limit values for annual mean and winter mean SO_2 concentrations, set for protection of ecosystems. (These are not applicable to built-up areas as Directive 2008/50/EC[36] states that sampling points targeted at the protection of vegetation and natural ecosystems *"shall be sited more than 20 kilometres away from agglomerations or 5 kilometres away from other built up areas, industrial installations or motorways"*).

5.3.2 SO_2: Spatial Distribution in the UK

Figure 5-2 shows the 99.73th percentile of hourly mean sulphur dioxide concentration varied across the UK during 2009. This statistic corresponds approximately to the 25th highest annual mean (in the case of a full year's data); if greater than the hourly mean Limit Value it indicates that the Limit Value was exceeded on more than the 24 permitted occasions. There were no areas in which this statistic exceeded the Limit Value of 350 µg m^{-3}.

Figure 5-3 shows the 99.18th percentile of 24-hour mean (which corresponds to the 4th highest day in a full year). If greater than the 24-hourly mean Limit Value of 125 µg m^{-3}, this indicates that there were more than the permitted three exceedences in the year.

Figure 5-2 99.73th percentile of 1-hour mean SO_2 concentration, 2009 (μg m^{-3})

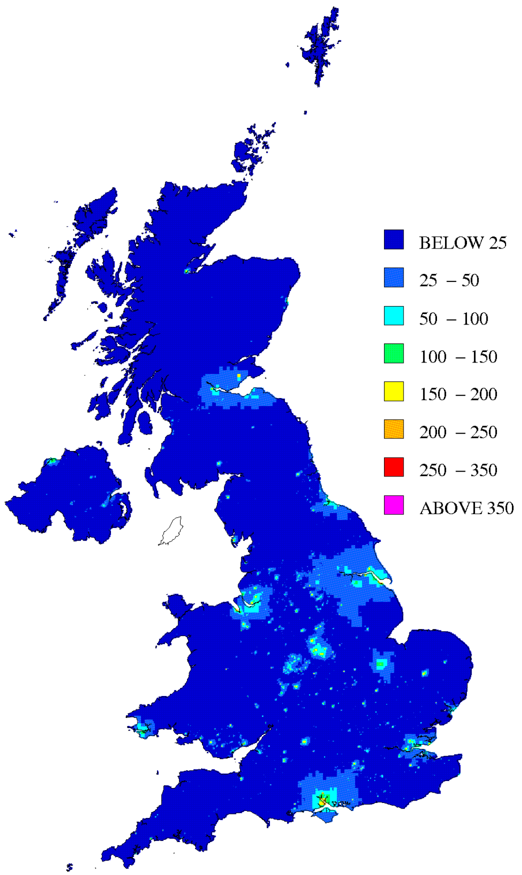
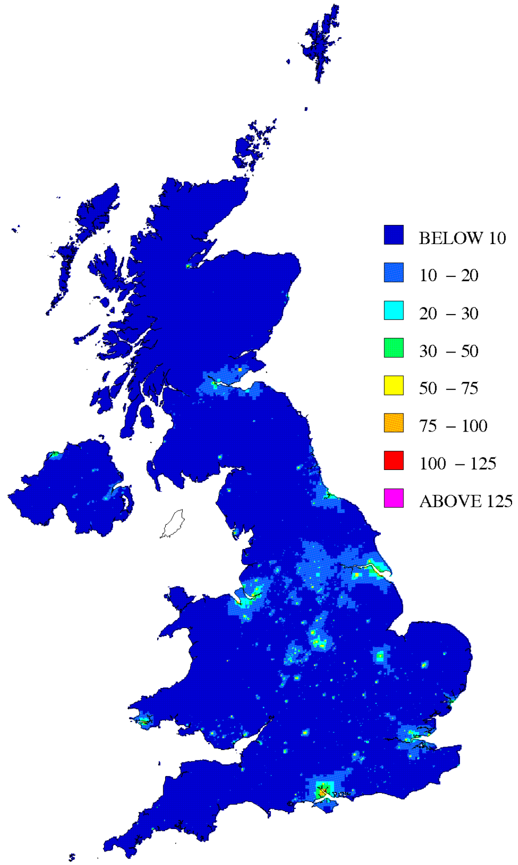


Figure 5-3 99.18th percentile of 24-hour mean SO_2 concentration, 2009 (μg m^{-3})



5.3.3 SO_2: Trends

Figure 5-4 shows a time series chart of annual mean sulphur dioxide concentrations from 1990 onwards, based on the average of all background urban sites (i.e. urban centre, urban background, suburban and urban industrial). Ambient concentrations decreased sharply during the 1990s, and this downward trend continued in the following decade.

Figure 5-4 Average Annual Mean SO_2 Concentration: All Background Urban AURN Sites

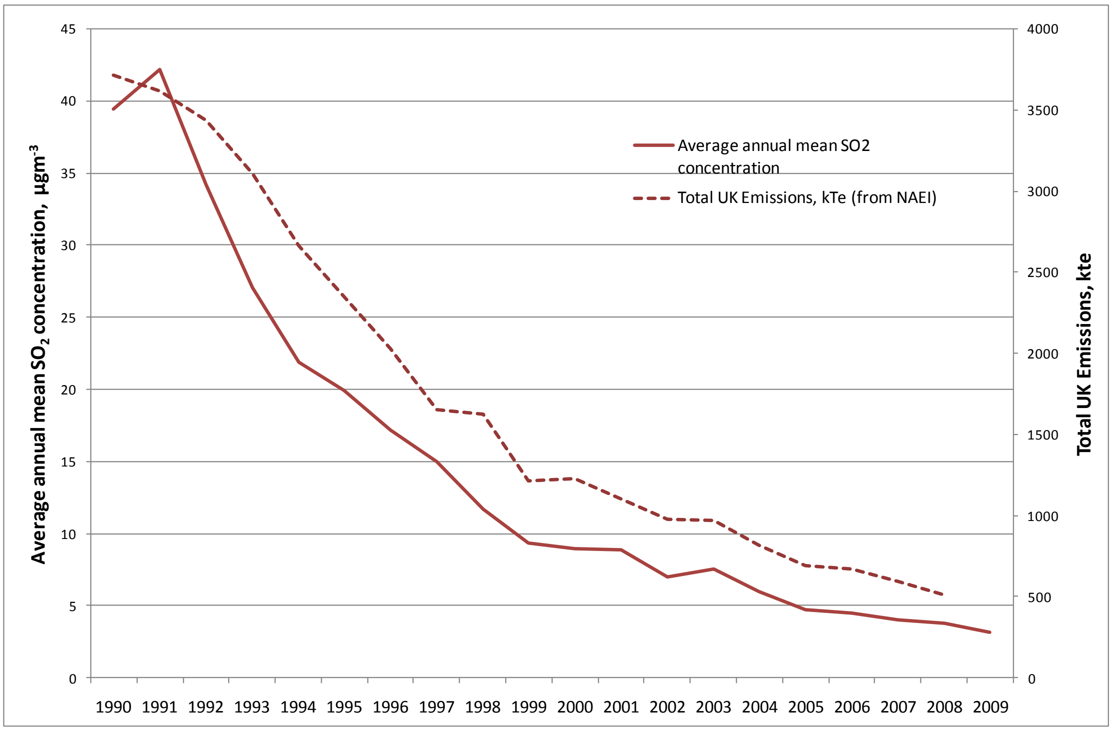


Figure 5-4 also shows how the UK's estimated total emissions of sulphur dioxide have decreased since 1990 (data from the National Atmospheric Emissions Inventory (NAEI), available at www.naei.org.uk and shown in the graph as a dotted line). The main source of this pollutant is fossil fuel combustion. SO_2 emissions in the UK have decreased substantially since 1990, due to reductions in the use of coal, gas and oil, and also to reductions in the sulphur content of fuel oils and DERV (diesel fuel used for road vehicles). The fall in emissions is reflected in a corresponding fall in ambient concentration. It should be noted that the decreasing trend in emissions shown here is the continuation of an ongoing trend observed by the NAEI throughout the 1970s and 1980s, partly due to the decline of the UK's heavy industry.

5.4 Nitrogen Dioxide

5.4.1 NO_2: Compliance with Directive

Oxides of nitrogen are covered by the Air Quality Directive. The results of the air quality assessment for nitrogen dioxide for each zone are presented in Form 8b of the Questionnaire, and summarised here in Table 5—2, Table 5—3 and Table 5—4.

Two agglomeration zones - **Greater London Urban Area (UK0001)** and **Glasgow Urban Area (UK0024)** had locations which exceeded the 1-hour limit value plus margin of tolerance (220 µg m^{-3}) on more than the permitted number of occasions during 2009.

The majority of zones and agglomerations in the UK had locations with measured or modelled annual mean NO_2 concentrations higher than the annual mean limit value plus margin of tolerance (42 µg m^{-3}). This was the case in 40 zones of the 43 zones. Only the following three zones ***met*** the annual mean limit value in 2009:

- Blackpool Urban Area (UK0022)
- Highland (UK0039)
- Scottish Borders (UK0040)

  - **all others exceeded the annual mean limit value.**

All non-agglomeration zones within the UK also complied with the limit value for annual mean NO_2 concentration, set for protection of vegetation.

5.4.2 NO_2: Spatial Distribution in the UK

Figure 5–5 shows the annual mean NO_2 concentrations for 2009, at *urban roadside* locations only. Although not every road link is clearly visible, it can be seen that many roadside locations had annual mean NO_2 concentrations in excess of the limit value of 40 µg m^{-3} (shaded yellow, orange and red). These locations are widespread throughout most of the UK.

Figure 5-6 shows the annual mean *background* NO_2 concentrations for 2009. The major urban areas, and principal road links, are clearly visible. Although most background locations were compliant with the limit value, there were some city centre locations that were not – for example in central London.

Table 5—2 Results of air quality assessment for nitrogen dioxide in 2009

Zone	Zone code	NO_2 LV for health (1hr mean)	NO_2 LV for health (annual mean)	NOx LV for vegetation (annual mean)
Greater London Urban Area	UK0001	> MOT	> MOT	n/a
West Midlands Urban Area	UK0002	OK	> MOT	n/a
Greater Manchester Urban Area	UK0003	OK	> MOT	n/a
West Yorkshire Urban Area	UK0004	OK	> MOT	n/a
Tyneside	UK0005	OK	> MOT (m)	n/a
Liverpool Urban Area	UK0006	OK	> MOT (m)	n/a
Sheffield Urban Area	UK0007	OK	> MOT (m)	n/a
Nottingham Urban Area	UK0008	OK	> MOT (m)	n/a
Bristol Urban Area	UK0009	OK	> MOT	n/a
Brighton/Worthing/Littlehampton	UK0010	OK	> MOT (m)	n/a
Leicester Urban Area	UK0011	OK	> MOT (m)	n/a
Portsmouth Urban Area	UK0012	OK	> MOT (m)	n/a
Teesside Urban Area	UK0013	OK	> MOT (m)	n/a
The Potteries	UK0014	OK	> MOT (m)	n/a
Bournemouth Urban Area	UK0015	OK	> MOT (m)	n/a
Reading/Wokingham Urban Area	UK0016	OK (m)	> MOT (m)	n/a
Coventry/Bedworth	UK0017	OK	> MOT (m)	n/a
Kingston upon Hull	UK0018	OK	> MOT (m)	n/a
Southampton Urban Area	UK0019	OK	> MOT (m)	n/a
Birkenhead Urban Area	UK0020	OK	> MOT (m)	n/a
Southend Urban Area	UK0021	OK (m)	> MOT (m)	n/a
Blackpool Urban Area	UK0022	OK (m)	OK (m)	n/a
Preston Urban Area	UK0023	OK	> MOT (m)	n/a
Glasgow Urban Area	UK0024	> MOT	> MOT	n/a
Edinburgh Urban Area	UK0025	OK	> MOT (m)	n/a
Cardiff Urban Area	UK0026	OK	> MOT (m)	n/a
Swansea Urban Area	UK0027	OK	> MOT (m)	n/a
Belfast Urban Area	UK0028	OK	> MOT (m)	n/a
Eastern	UK0029	OK	> MOT	OK
South West	UK0030	OK	> MOT	OK
South East	UK0031	OK	> MOT	OK
East Midlands	UK0032	OK	> MOT (m)	OK
North West & Merseyside	UK0033	OK	> MOT (m)	OK (m)
Yorkshire & Humberside	UK0034	OK	> MOT (m)	OK (m)
West Midlands	UK0035	OK	> MOT (m)	OK (m)
North East	UK0036	OK	> MOT (m)	OK (m)
Central Scotland	UK0037	OK	> MOT (m)	OK
North East Scotland	UK0038	OK	> MOT (m)	OK (m)
Highland	UK0039	OK	OK	OK (m)
Scottish Borders	UK0040	OK	OK	OK
South Wales	UK0041	OK	> MOT (m)	OK
North Wales	UK0042	OK	> MOT (m)	OK
Northern Ireland	UK0043	OK	> MOT (m)	OK (m)

Table 5—3 Exceedences of the NO_2 limit value plus MOT for health (1 hour mean)

Site name	Zone code	Number of 1-hour exceedences of MOT	Number of 1-hour exceedences of LV	Maximum 1-hour concentration ($\mu g\ m^{-3}$)
Glasgow Centre	UK0024	43	48	701
Glasgow Kerbside	UK0024	32	57	384
London Marylebone Road	UK0001	312	486	332

Table 5—4 Exceedences of the NO_2 limit value plus MOT for health (annual mean)

Site name	Zone code	Annual mean concentration ($\mu g\ m^{-3}$)
Bath Roadside	UK0030	65
Birmingham Tyburn Roadside	UK0002	47
Bristol Old Market	UK0009	63
Bury Roadside	UK0003	72
Glasgow City Chambers	UK0024	46
Glasgow Kerbside	UK0024	78
Haringey Roadside	UK0001	43
Leeds Headingley Kerbside	UK0004	48
London Bloomsbury	UK0001	54
London Cromwell Road 2	UK0001	72
London Hillingdon	UK0001	54
London Marylebone Road	UK0001	107
London Westminster	UK0001	44
Oxford Centre Roadside	UK0031	50
Sandy Roadside	UK0029	46
Tower Hamlets Roadside	UK0001	61

Figure 5-5 Urban major roads, annual mean roadside NO_2 concentration, 2009 ($\mu g\ m^{-3}$)

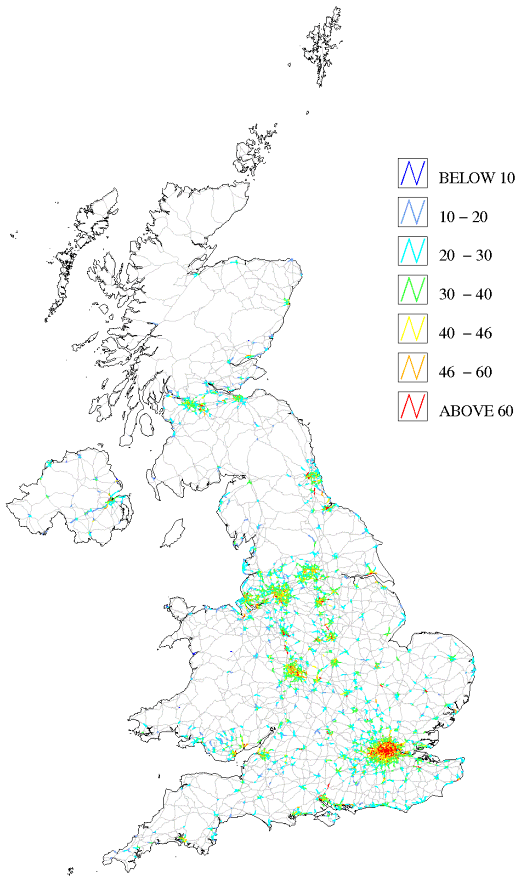
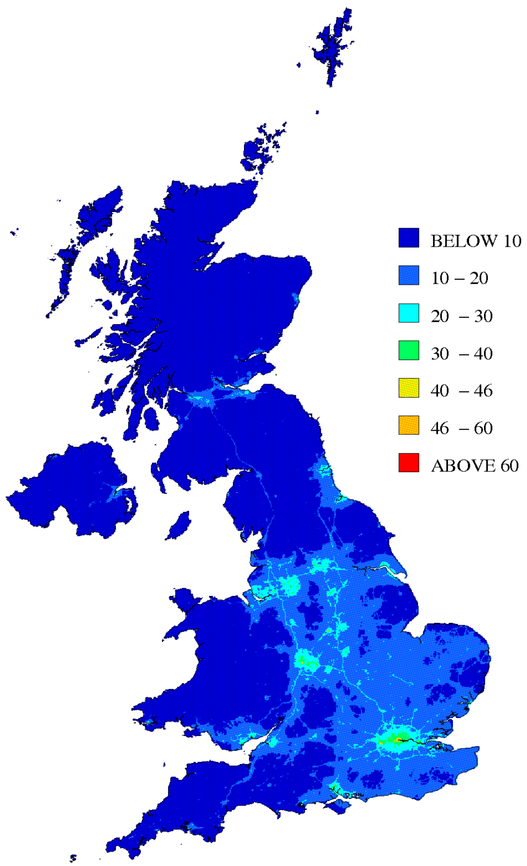


Figure 5-6 Annual mean background NO_2 concentration, 2009 ($\mu g\ m^{-3}$)



5.4.3 NO_2: Trends

Figure 5-7 shows how ambient concentrations of nitrogen dioxide (averaged over all sites in the AURN) have decreased since 1990. Time series of annual mean NO_2 concentrations are shown for the following groups of sites:

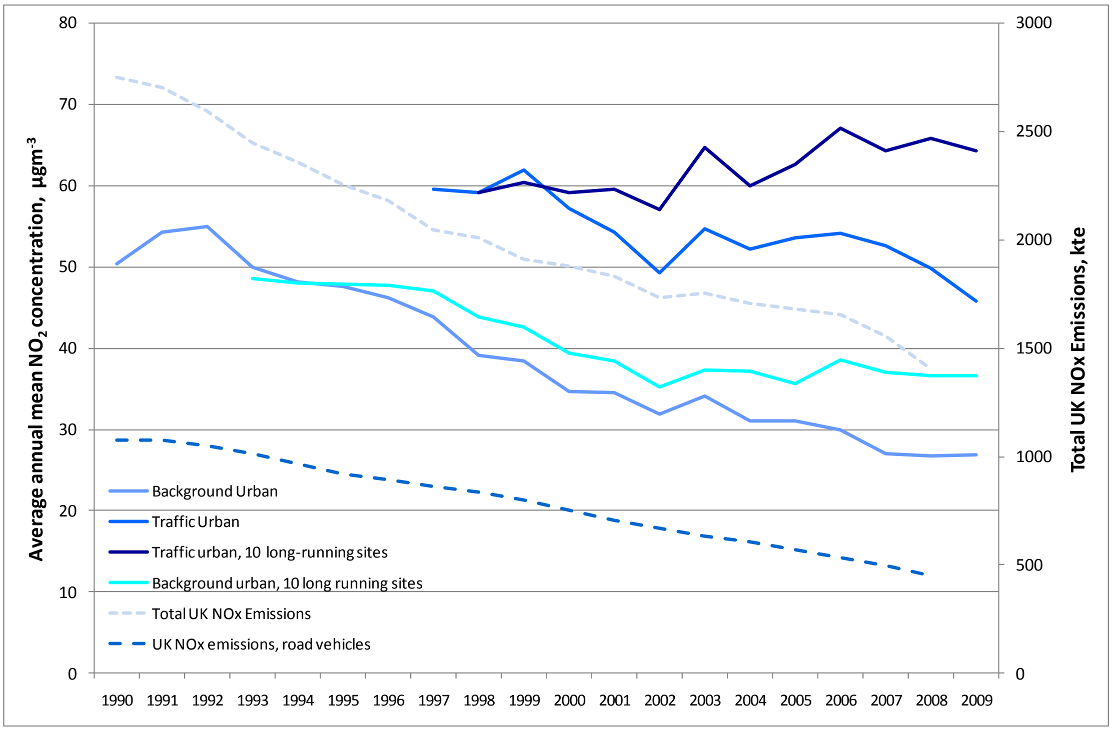
- All background urban sites (comprising AURN urban non-roadside sites, i.e. urban centre, urban background, urban industrial and suburban sites).
- All traffic-related urban monitoring sites, mostly less than five metres from the kerb of a major road (classified within the AURN as kerbside or roadside). This statistic is shown from 1997 only, as before then only one such site was in operation.
- From 1998 onwards, a set of ten long-running traffic urban sites which have been consistently in operation from that time until 2009 (Bath Roadside, Bristol Roadside, Bury Roadside, Camden Roadside, Glasgow Kerbside, Exeter Roadside, Haringey Roadside, London Marylebone Road, Oxford Centre Roadside, and Tower Hamlets Roadside). This is intended to show trends without any effects due to changes in the number and distribution of sites.

Also shown (as dotted lines, axis on the right) are the estimated total annual emission of oxides of nitrogen, and the estimated total emission of NOx from road vehicles (data from the NAEI).

The annual mean NO_2 concentration averaged for all background urban sites in the AURN shows a steady decrease, generally consistent with the downward trend in the amount of total NO_X emitted. The annual mean NO_2 concentration averaged for all traffic urban AURN sites is higher, but shows a similar (though less consistent) downward trend. However, the annual mean averaged over just the ten long-running traffic urban sites shows a different pattern: in contrast to the downward trend shown by the average for all sites, the average for long-running sites shows a slight *increase* in recent years.

This is broadly consistent with the findings of a recent study by King's College London and the University of Leeds, which investigated the relationship between pollutant emissions and ambient concentrations, for central London and outer London[42]. This study found that between 2003 and 2008, ambient concentrations of oxides of nitrogen (also particulate matter) at traffic-influenced sites had decreased much less than would be predicted on the basis of emissions estimates. There was also a difference between outer and central London sites: in the case of central London sites, ambient concentrations at traffic-influenced monitoring sites had actually increased.

Figure 5-7 Average Annual Mean NO_2 Concentration: Background Urban and Traffic Urban AURN Sites



5.5 PM_{10} Particulate Matter

5.5.1 PM_{10}: Compliance with Directive

Both PM_{10} and $PM_{2.5}$ are covered by the Air Quality Directive. The results of the air quality assessment for PM_{10} for each zone are presented in Form 8c of the Questionnaire (with $PM_{2.5}$ in Form 9c), and summarised in Table 5—5.

Three zones had locations where measured or modelled PM_{10} concentrations exceeded the 24-hour mean limit value of 50 µg m^{-3} on more than the permitted 35 days:

- Greater London Urban Area (UK0001)
- Southampton Urban Area (UK0019)
- Eastern (zone) (UK0029)

The Directive requires Member States to quantify the contribution to PM_{10} from natural sources, and subtract this. After subtraction of the contribution from natural sources, one modelled exceedence of the 24-hour limit value remained in one zone **(Greater London Urban Area, UK0001)**

All zones and agglomerations complied with the annual mean limit value of 40 µg m^{-3} for PM_{10}.

5.5.2 PM_{10}: Spatial Distribution

Figure 5-8 shows annual mean urban roadside PM_{10} concentrations in 2009. No roadside locations are shaded pink, i.e. annual mean concentration is not greater than 40 µg m^{-3}.

Figure 5-9 shows annual mean background PM_{10} concentrations in 2009. Levels are higher in the southern and eastern parts of the country, because these regions receive a larger contribution of transboundary particulate pollution from mainland Europe. The elevated levels of PM_{10} associated with urban areas and major roads can also be seen.

Some of the concentration bands used in Figure 5-8 and Figure 5-9 may seem strange: the range 30-40 µg m^{-3} is subdivided into 30-31.5 µg m^{-3}, and 31.5-40 µg m^{-3}. The significance of this division is that where the annual mean PM_{10} concentration exceeds 31.5 µg m^{-3} it is likely also that the 24-hour mean has exceeded the daily mean Limit Value of 50 µg m^{-3} on more than the permitted 35 occasions. Red shaded road links may be visible in London, Southampton on the south coast, and in the Eastern region – the zones where the 24-hour mean was reported to be exceeded.

Table 5—5 Results of air quality assessment for PM_{10} and $PM_{2.5}$ in 2009 prior to subtraction of natural sources.

Zone	Zone code	PM_{10} LV (24hr mean)	PM_{10} LV (annual mean)	$PM_{2.5}$ Target value (annual mean)
Greater London Urban Area	UK0001	> LV	OK	OK
West Midlands Urban Area	UK0002	OK	OK	OK
Greater Manchester Urban Area	UK0003	OK	OK	OK
West Yorkshire Urban Area	UK0004	OK	OK	OK
Tyneside	UK0005	OK	OK	OK
Liverpool Urban Area	UK0006	OK	OK	OK
Sheffield Urban Area	UK0007	OK (m)	OK (m)	OK
Nottingham Urban Area	UK0008	OK (m)	OK (m)	OK
Bristol Urban Area	UK0009	OK	OK	OK
Brighton/Worthing/Littlehampton	UK0010	OK (m)	OK (m)	OK
Leicester Urban Area	UK0011	OK	OK	OK (m)
Portsmouth Urban Area	UK0012	OK (m)	OK (m)	OK
Teesside Urban Area	UK0013	OK (m)	OK (m)	OK (m)
The Potteries	UK0014	OK	OK	OK
Bournemouth Urban Area	UK0015	OK (m)	OK (m)	OK
Reading/Wokingham Urban Area	UK0016	OK	OK	OK
Coventry/Bedworth	UK0017	OK (m)	OK (m)	OK
Kingston upon Hull	UK0018	OK	OK	OK
Southampton Urban Area	UK0019	> LV (m)	OK	OK
Birkenhead Urban Area	UK0020	OK (m)	OK (m)	OK
Southend Urban Area	UK0021	OK (m)	OK (m)	OK
Blackpool Urban Area	UK0022	OK (m)	OK (m)	OK
Preston Urban Area	UK0023	OK (m)	OK (m)	OK
Glasgow Urban Area	UK0024	OK	OK	OK
Edinburgh Urban Area	UK0025	OK (m)	OK (m)	OK
Cardiff Urban Area	UK0026	OK	OK	OK
Swansea Urban Area	UK0027	OK	OK	OK
Belfast Urban Area	UK0028	OK	OK	OK
Eastern	UK0029	> LV (m)	OK	OK
South West	UK0030	OK	OK	OK (m)
South East	UK0031	OK	OK	OK
East Midlands	UK0032	OK	OK	OK
North West & Merseyside	UK0033	OK	OK	OK
Yorkshire & Humberside	UK0034	OK	OK	OK
West Midlands	UK0035	OK	OK	OK
North East	UK0036	OK	OK	OK
Central Scotland	UK0037	OK	OK	OK
North East Scotland	UK0038	OK	OK	OK (m)
Highland	UK0039	OK	OK	OK
Scottish Borders	UK0040	OK (m)	OK (m)	OK (m)
South Wales	UK0041	OK	OK	OK
North Wales	UK0042	OK	OK	OK (m)
Northern Ireland	UK0043	OK	OK	OK (m)

Note: Following subtraction of natural sources, only UK001, Greater London Urban Area remained non-compliant with the 24 hour mean limit value for PM_{10}.

Table 5—6 Exceedences of the PM_{10} limit value (24 hour mean)

Site name	Zone code	Number of 24-hour exceedences of LV	Maximum 24-hour concentration ($\mu g\ m^{-3}$)
London Marylebone Road PARTISOL	UK0001	36	88

Note: Number of exceedences reduced to 25 after subtraction of the contribution from natural sources but a modelled exceedence of the 24 hour mean limit value remains in this zone after subtraction of the contribution from natural sources.

Figure 5-8 Urban major roads, annual mean roadside PM_{10} concentration, 2009 ($\mu g\ m^{-3}$, gravimetric)

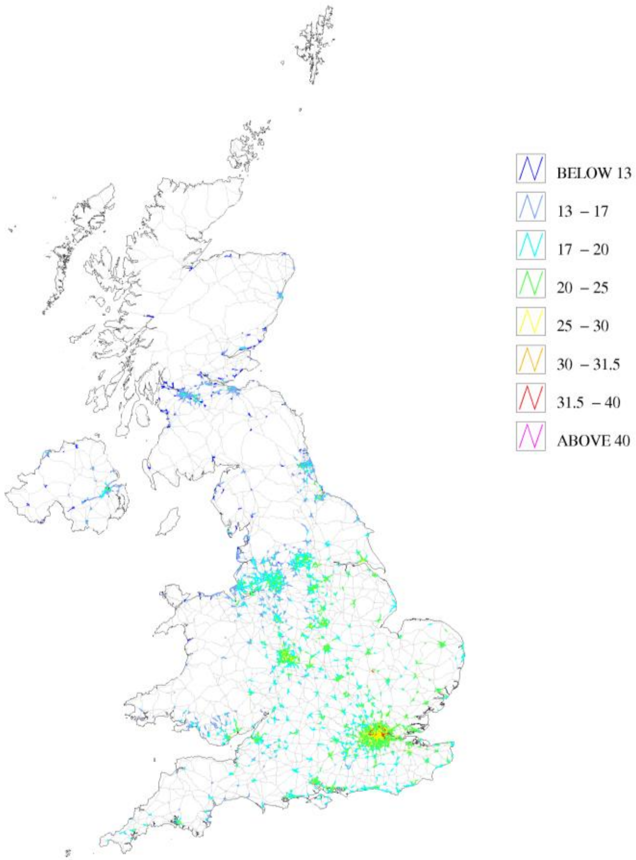
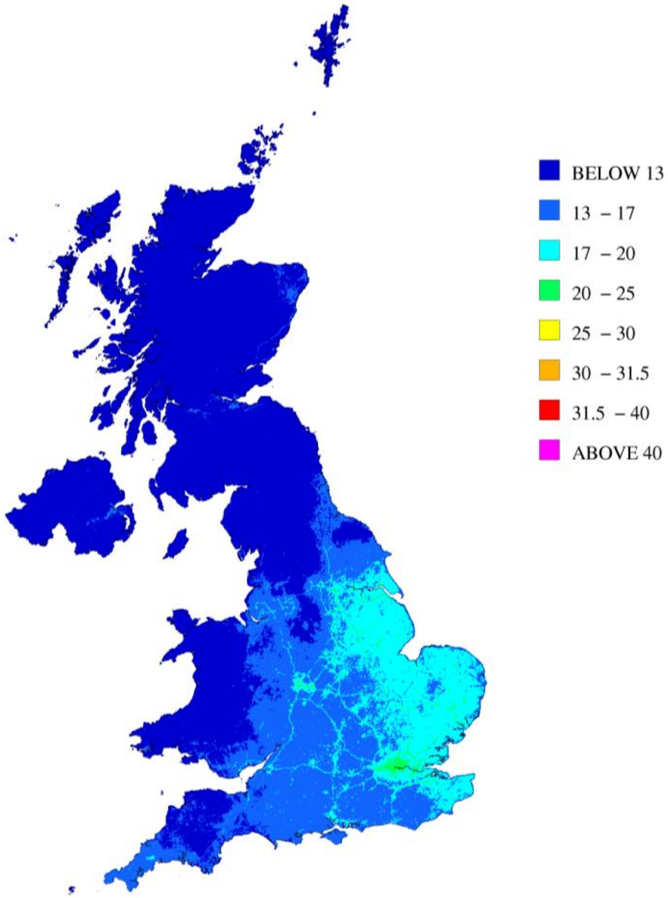


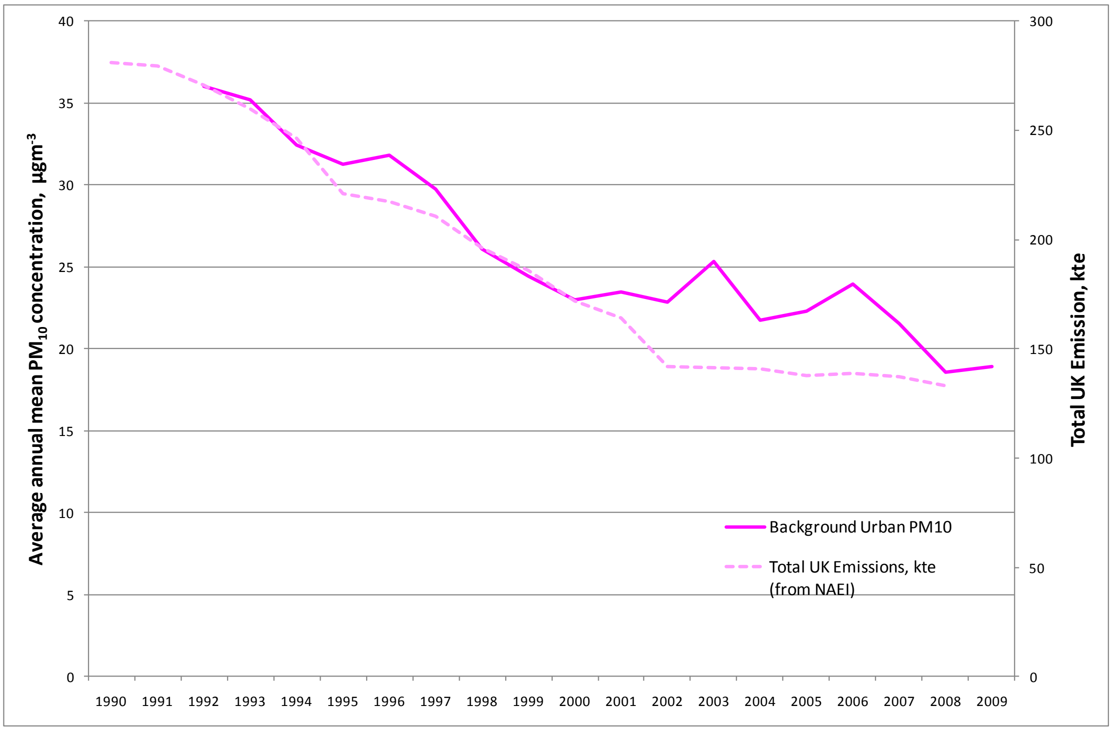
Figure 5-9 Annual mean background PM_{10} concentration, 2009 ($\mu g\ m^{-3}$, gravimetric)



5.5.3 PM_{10} Trends

Figure 5-10 shows a time series graph of annual mean ambient PM_{10} concentration, averaged over all background urban sites in the AURN. The earliest data are from 1992. Ambient concentrations decreased steadily throughout the 1990s. The decreasing trend appears to have levelled off in the early 2000s, although the graph indicates that it may have resumed around 2007.

Figure 5-10 Annual mean ambient PM_{10} concentration, and total annual emissions.



Also shown (by the dotted line) is the total UK annual emission of particulate matter (as PM_{10}), as estimated in the NAEI. Throughout the past two decades, the observed trend in ambient PM_{10} concentration appears to reflect estimated reductions in emissions, including the 'flattening off' in the early 2000s.

5.6 $PM_{2.5}$ Particulate Matter

5.6.1 $PM_{2.5}$: Compliance with Directive

$PM_{2.5}$ is covered by the Air Quality Directive. The results of the air quality assessment for $PM_{2.5}$ for each zone are presented in Form 9c of the Questionnaire (PM_{10} is in Form 8c), and summarised (together with PM_{10}) in Table 5—5 of this report (above). Annual mean concentrations of $PM_{2.5}$ were below the target value in all zones and agglomerations.

5.6.2 $PM_{2.5}$: Spatial Distribution

Figure 5-11 shows the annual mean urban roadside $PM_{2.5}$ concentrations in 2009. No roadside locations have annual means greater than the target value of 25 µg m^{-3}. Figure 5-12 shows annual mean background $PM_{2.5}$ concentrations in 2009. The pattern shows some similarities to that observed for PM_{10}, in that levels are higher in the southern and eastern areas, due to the contribution of particulate matter from mainland Europe. Also, the map shows elevated levels of $PM_{2.5}$ around major urban areas and alongside major routes.

Figure 5-11 Urban major roads, annual mean roadside $PM_{2.5}$ concentration, 2009 ($\mu g\ m^{-3}$, gravimetric)

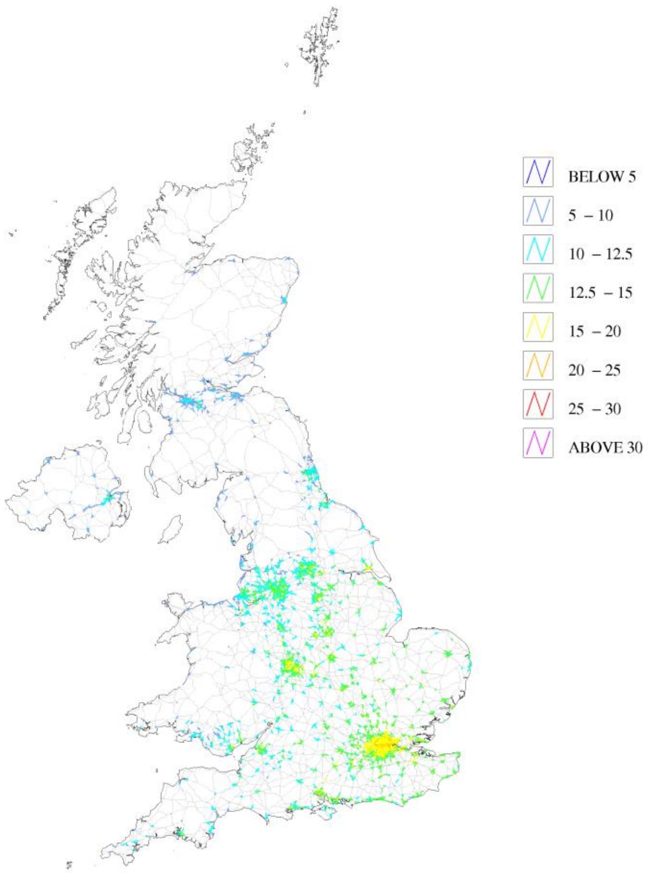
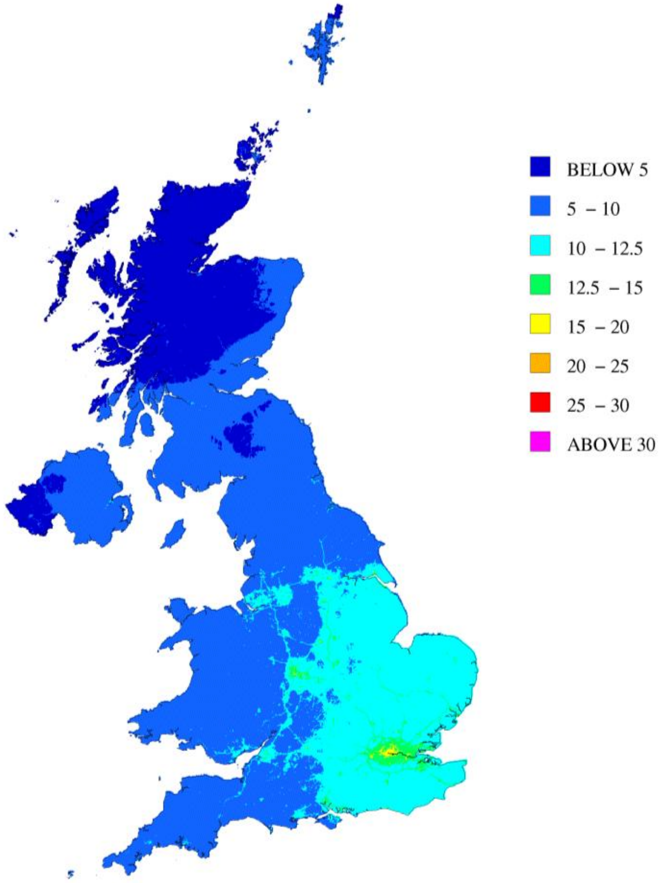


Figure 5-12 Annual mean background $PM_{2.5}$ concentration, 2009 ($\mu g\ m^{-3}$, gravimetric)

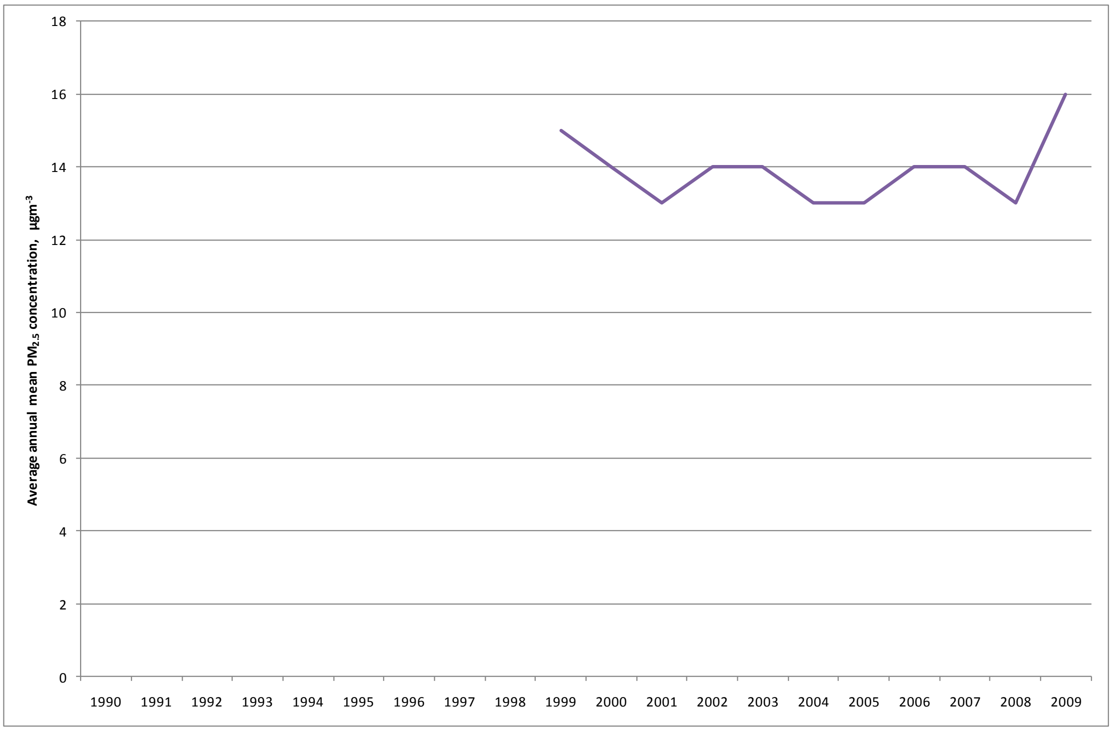


5.6.3 $PM_{2.5}$: Trends

Until 2008, routine monitoring of $PM_{2.5}$ was only carried out at one urban background AURN site (London Bloomsbury). Therefore, only this site has sufficient data to show long-term trends.

Figure 5-13 shows the annual mean $PM_{2.5}$ concentration at this site, and how it has varied since the site commenced operation in 1999. No clear trends are apparent. Although there is no indication of an increasing trend, the annual mean for 2009 was the highest recorded at the site so far.

Figure 5-13 Annual mean ambient $PM_{2.5}$ concentration at London Bloomsbury.



Emissions of the $PM_{2.5}$ fraction are not currently included in the NAEI, so it is not possible to examine the relationship between estimated emissions and measured ambient concentrations for this particulate fraction.

5.7 Benzene

5.7.1 Benzene: Compliance with Directive

The results of the air quality assessment for benzene are presented in Form 8e of the Questionnaire. All zones or agglomerations were compliant with the limit value for benzene in 2009.

5.7.2 Benzene: Spatial Distribution

Benzene is found in petrol and in vehicle emissions, therefore elevated levels may be expected at roadside locations.

Figure 5-14 shows annual mean benzene concentrations at roadside locations in 2009. Figure 5-15 shows the modelled annual mean background concentrations of benzene in 2009.

5.7.3 **Benzene: Trends**

Figure 5-16 shows a time series of annual mean benzene concentrations, based upon the mean value for four long-running sites in the Automatic Hydrocarbon Network – Glasgow Kerbside, Harwell, London Eltham and London Marylebone Road. The average for these four sites shows a steady downward trend from 2000 to 2006 (this continues the downward trend observed by previous sites in this network). The 'dip' in 2007 is likely to be due to the annual mean for London Marylebone Road being excluded due to insufficient data capture; this traffic-related site gives consistently higher benzene concentrations than the other three, due to its location near a busy city centre road.

Figure 5-14 Urban major roads, annual mean roadside benzene concentration, 2009 (μg m^{-3})

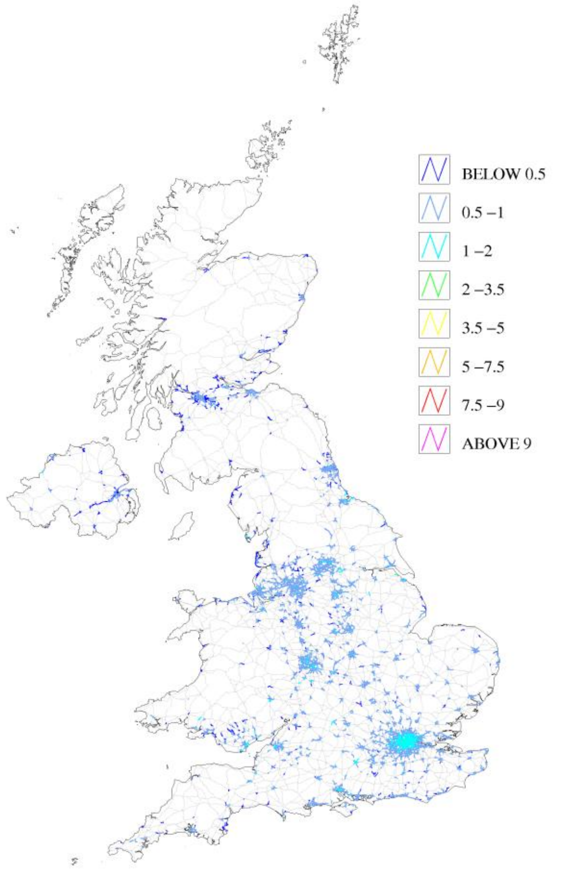


Figure 5-15 Annual mean background benzene concentration, 2009 (μg m^{-3})

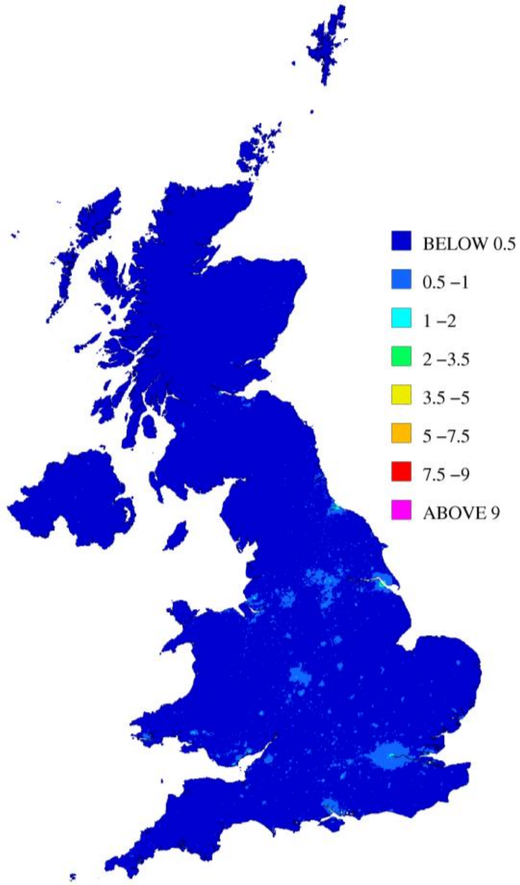
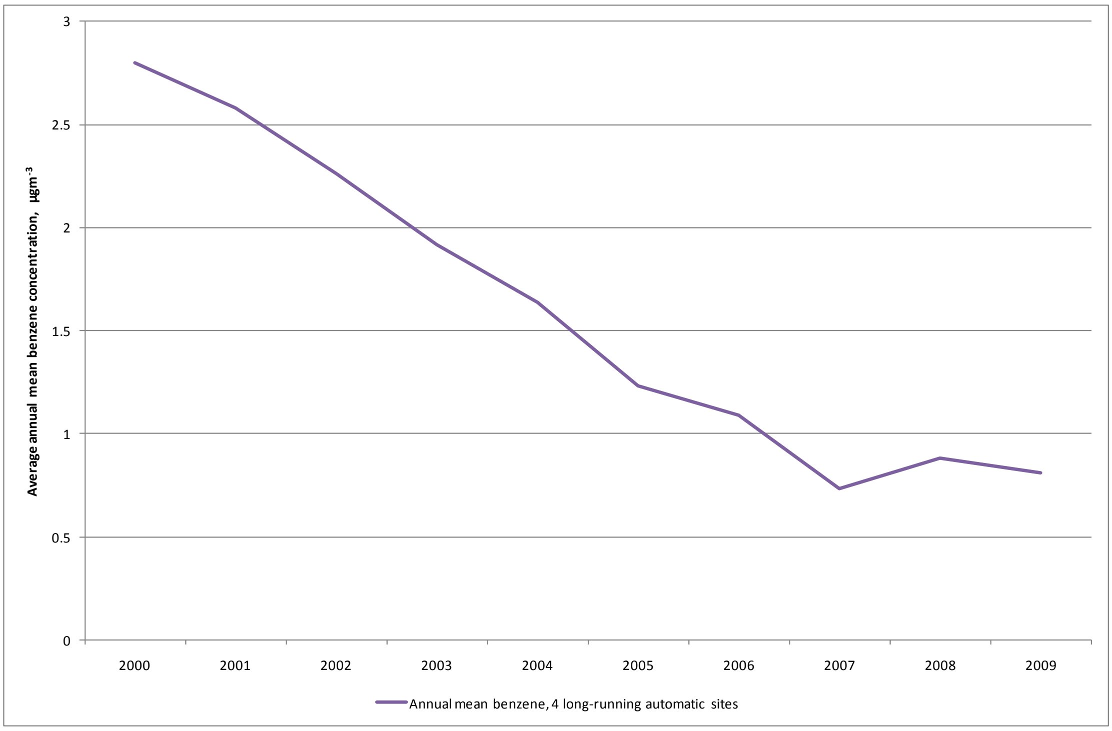


Figure 5-16 Annual mean benzene concentration, mean of four long-running automatic sites



5.8 1,3-Butadiene

5.8.1 1,3-Butadiene: Compliance with AQS Objective

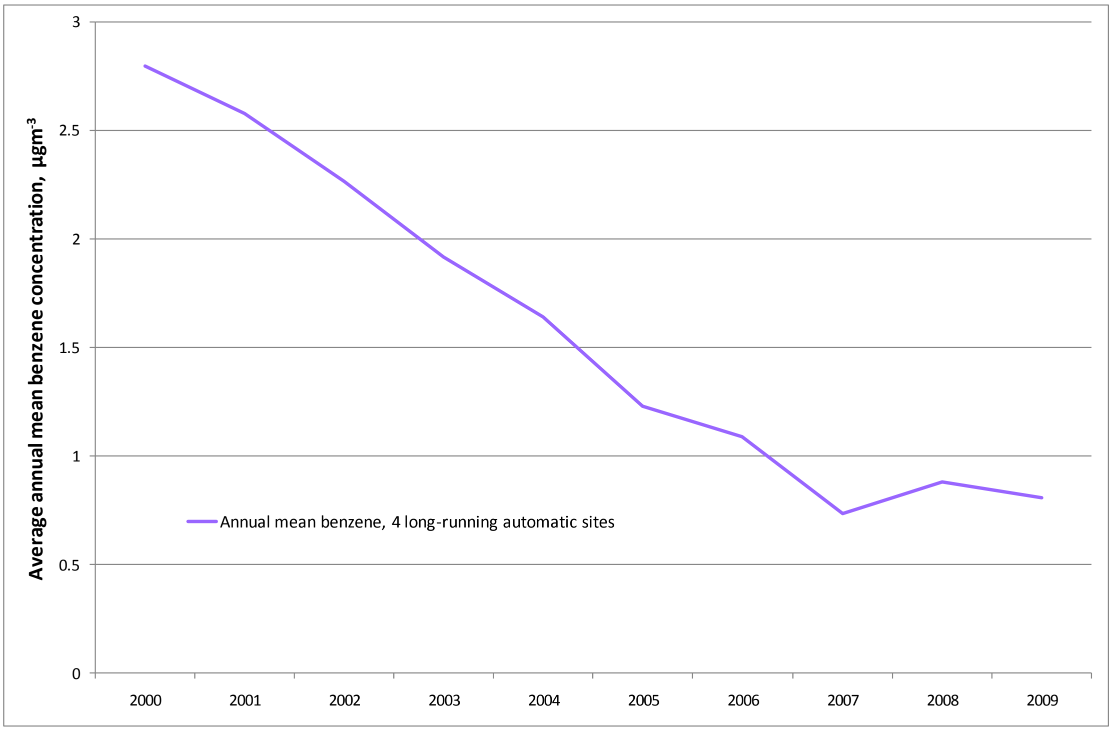
The ambient concentration of 1,3-butadiene is not currently covered by any EC Directives. However, it is within the scope of the UK Air Quality Strategy. Within the UK, there is an Air Quality Strategy Objective of 2.25 µg m^{-3} as a maximum running annual mean, to have been achieved by 31st December 2003. This objective was met throughout the UK by the due date.

1,3-butadiene is one of the suite of hydrocarbons measured at the five sites comprising the Automatic Hydrocarbon Network. The running annual means at all five sites were within the Air Quality Strategy Objective in 2009.

5.8.2 1,3 Butadiene: Trends

Figure 5-17 shows the annual mean 1,3-butadiene concentration measured from 2003 by four long-running sites in the Automatic Hydrocarbon Network (Glasgow Kerbside, Harwell, London Eltham and London Marylebone). From 2003 to 2007 the average concentration at the four sites shows a decrease: slightly higher values were measured in 2008 and 2009. It remains to be seen whether the increase will continue in future years. However, annual mean concentrations remain well below the AQS Objective.

Figure 5-17 Annual mean 1,3-butadiene concentration averaged over four Automatic Hydrocarbon Network sites



5.9 Carbon Monoxide

5.9.1 CO: Compliance with Directive

The results of the air quality assessment for CO are presented in Form 8f of the Questionnaire. All zones and agglomerations were compliant with the limit value for this pollutant in 2009.

5.9.2 CO: Spatial Distribution

Figure 5-18 shows the annual maximum 8-hour mean CO concentration, alongside major urban roads. Figure 5-19 shows the same statistic for background locations. Concentrations were well within the limit value throughout the UK, although a pattern of slightly higher concentrations around urban areas and main routes is clearly visible.

5.9.3 CO: Trends

Figure 5-20 shows a time series chart of the average maximum 8-hour running mean CO concentration, for all AURN sites 1990 - 2009. There is a clear decreasing trend.

Figure 5-20 also shows total annual UK emissions of CO for the same period. The downward trend in ambient concentrations reflects declining emissions over the last two decades. UK emissions of this pollutant have decreased by 71% between 1970 and 2008 (most of this occurring between 1990 and 2008). The NAEI attributes this decrease to *"significant reductions in emissions from road transport, agricultural field burning and the domestic sector"*.[43]

Figure 5-18 Urban major roads, maximum 8-hour mean roadside CO concentration, 2009 (mg m^{-3})

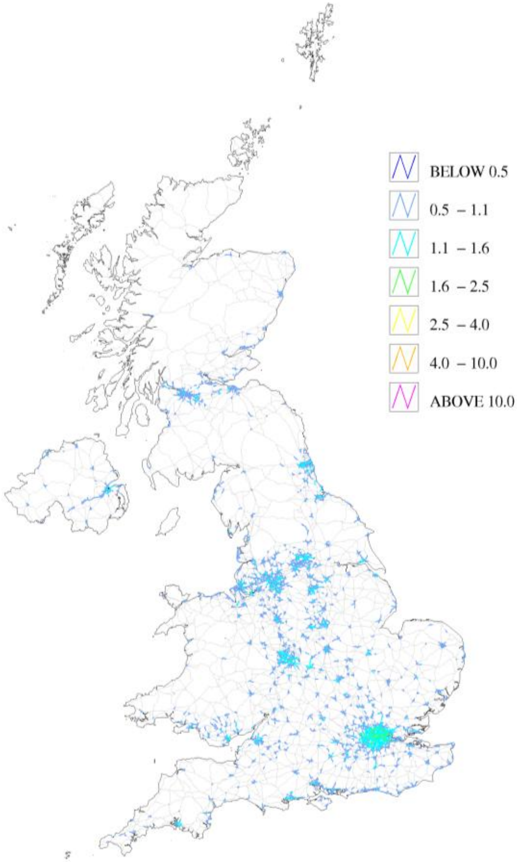


Figure 5-19 Maximum 8-hour mean background CO concentration, 2009 (mg m^{-3})

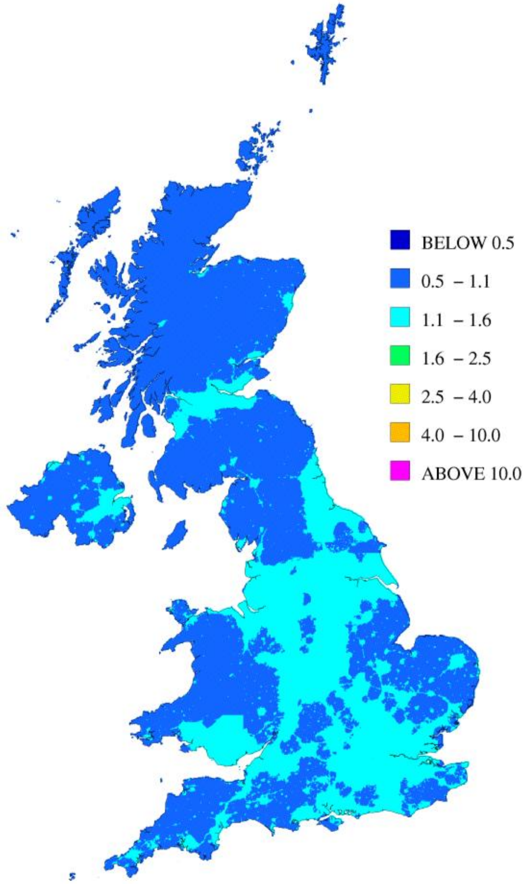
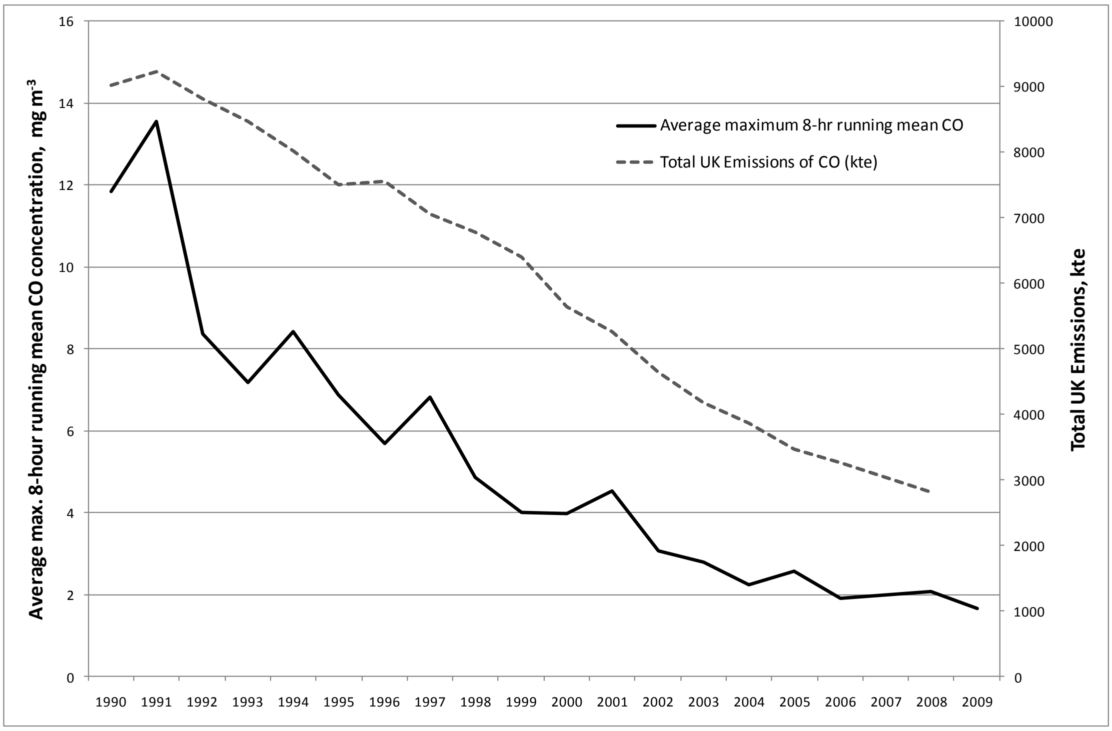


Figure 5-20 Trends in average maximum 8-hour running mean CO concentration, all AURN sites.



5.10 Ozone

5.10.1 O_3: Compliance with Directive

The results of the air quality assessment for ozone for each zone are presented in Form 9a of the Questionnaire. All zones and agglomerations were compliant with the two target values, which are based on the maximum daily 8-hour mean and on the AOT40 statistic[1]. There are also two long-term objectives, one for human health, and one (only applicable in the non-agglomeration zones) for vegetation. 39 zones and agglomerations were above the long-term objective (LTO) for health, and 10 of the 15 non-agglomeration zones were above the long-term objective for vegetation. This is illustrated in Table 5—7 below with compliant zones shaded blue and non-compliant zones shaded red.

Table 5—7 Summary of Air quality assessment for ozone in 2009

Zone	Zone code	O_3 TV and LTO for health (8hr mean)	O_3 TV and LTO for vegetation (AOT40)
Greater London Urban Area	UK0001	Meets TV, >LTO	OK
West Midlands Urban Area	UK0002	Meets TV, >LTO	OK
Greater Manchester Urban Area	UK0003	Meets TV, >LTO (m)	OK
West Yorkshire Urban Area	UK0004	Meets TV, >LTO (m)	OK
Tyneside	UK0005	Meets TV, >LTO (m)	OK
Liverpool Urban Area	UK0006	Meets TV, >LTO	OK
Sheffield Urban Area	UK0007	Meets TV, >LTO (m)	OK
Nottingham Urban Area	UK0008	Meets TV, >LTO (m)	OK
Bristol Urban Area	UK0009	Meets TV, >LTO	OK
Brighton/Worthing/Littlehampton	UK0010	Meets TV, >LTO	Meets TV, >LTO
Leicester Urban Area	UK0011	Meets TV, >LTO	OK
Portsmouth Urban Area	UK0012	Meets TV, >LTO	OK
Teesside Urban Area	UK0013	Meets TV, >LTO (m)	OK
The Potteries	UK0014	Meets TV, >LTO	OK
Bournemouth Urban Area	UK0015	Meets TV, >LTO	OK
Reading/Wokingham Urban Area	UK0016	Meets TV, >LTO	Meets TV, >LTO
Coventry/Bedworth	UK0017	Meets TV, >LTO	OK
Kingston upon Hull	UK0018	Meets TV, >LTO (m)	OK
Southampton Urban Area	UK0019	Meets TV, >LTO (m)	OK
Birkenhead Urban Area	UK0020	Meets TV, >LTO	OK
Southend Urban Area	UK0021	Meets TV, >LTO	Meets TV, >LTO
Blackpool Urban Area	UK0022	Meets TV, >LTO	OK
Preston Urban Area	UK0023	Meets TV, >LTO	OK
Glasgow Urban Area	UK0024	OK	OK
Edinburgh Urban Area	UK0025	OK	OK
Cardiff Urban Area	UK0026	Meets TV, >LTO	OK
Swansea Urban Area	UK0027	Meets TV, >LTO	OK
Belfast Urban Area	UK0028	OK	OK
Eastern	UK0029	Meets TV, >LTO	Meets TV, >LTO
South West	UK0030	Meets TV, >LTO	Meets TV, >LTO
South East	UK0031	Meets TV, >LTO	Meets TV, >LTO (m)
East Midlands	UK0032	Meets TV, >LTO	Meets TV, >LTO
North West & Merseyside	UK0033	Meets TV, >LTO	OK
Yorkshire & Humberside	UK0034	Meets TV, >LTO (m)	OK
West Midlands	UK0035	Meets TV, >LTO	Meets TV, >LTO (m)
North East	UK0036	Meets TV, >LTO (m)	OK (m)
Central Scotland	UK0037	Meets TV, >LTO (m)	OK
North East Scotland	UK0038	Meets TV, >LTO (m)	OK
Highland	UK0039	OK	OK
Scottish Borders	UK0040	Meets TV, >LTO (m)	OK
South Wales	UK0041	Meets TV, >LTO	Meets TV, >LTO
North Wales	UK0042	Meets TV, >LTO	Meets TV, >LTO
Northern Ireland	UK0043	Meets TV, >LTO (m)	OK

Four monitoring sites (in three zones) recorded ozone concentrations above the ozone information threshold in 2009, and one of these also exceeded the ozone alert threshold value. These are shown in Table 5—8 and Table 5—9 respectively.

Table 5—8 Exceedences of the ozone information threshold value

Site name	Zone code	Number of 1-hour exceedences of alert threshold	Maximum 1-hour concentration (µg m^{-3})
Brighton Preston Park	UK0010	1	184
Sibton	UK0029	3	200
Southend-on-Sea	UK0021	2	210
St Osyth	UK0029	5	258

Table 5—9 Exceedences of the ozone alert threshold value

Site name	Zone code	Number of 1-hour exceedences of information threshold	Maximum 1-hour concentration (µg m^{-3})
St Osyth	UK0029	2	258

Table 5—10 Exceedences of the ozone long term objective for health protection

Site name	Zone code	Number of days with exceedences	Maximum 8-hour concentration (µg m^{-3})
Aston Hill	UK0042	5	136
Birmingham Tyburn	UK0002	2	150
Birmingham Tyburn Roadside	UK0002	1	132
Blackpool Marton	UK0022	1	137
Bottesford	UK0032	1	121
Bournemouth	UK0015	3	131
Brighton Preston Park	UK0010	2	171
Bristol St Paul's	UK0009	5	128
Cardiff Centre	UK0026	2	125
Charlton Mackrell	UK0030	3	122
Coventry Memorial Park	UK0017	3	150
Cwmbran	UK0041	6	131
Glazebury	UK0033	1	124
Harwell	UK0031	3	157
Ladybower	UK0032	2	128
Leamington Spa	UK0035	2	148
Leicester Centre	UK0011	1	138
Leominster	UK0035	2	131
Liverpool Speke	UK0006	1	125
London Haringey	UK0001	1	151
London Harlington	UK0001	1	136
London N. Kensington	UK0001	1	128
London Teddington	UK0001	3	154
Lullington Heath	UK0031	2	145
Market Harborough	UK0032	1	128
Narberth	UK0041	4	134
Northampton	UK0032	5	163
Port Talbot Margam	UK0027	1	125
Portsmouth	UK0012	2	161
Preston	UK0023	1	124
Reading New Town	UK0016	5	164
Rochester Stoke	UK0031	1	124
Sandwell West Bromwich	UK0002	4	157
Sibton	UK0029	2	170
Southend-on-Sea	UK0021	2	152
St Osyth	UK0029	2	188
Stoke-on-Trent Centre	UK0014	1	122
Thurrock	UK0029	1	134
Weybourne	UK0029	12	144

Site name	Zone code	Number of days with exceedences	Maximum 8-hour concentration (µg m^{-3})
Wicken Fen	UK0029	3	147
Wigan Centre	UK0033	1	124
Wirral Tranmere	UK0020	1	133
Yarner Wood	UK0030	6	133

5.10.2 O_3: Spatial Distribution

Figure 5-21 shows the average number of days per year with ozone concentration > 120 µg m^{-3}, over the three years 2007-2009. Some coastal areas of East Anglia averaged more than 10 such days (light blue on the map).

Figure 5-22 shows the same statistic, for 2009 only (i.e. not averaged over three years). Ozone concentrations for 2009 were lower than the three-year average, and only a small area of Norfolk had more than 10 days above the target value.

Figure 5-23 shows the AOT40 statistic, averaged over the past five complete years.

Figure 5-24 shows the same statistic, for 2009 only.

Figure 5-21 Average number of days with ozone concentration > 120 μg m^{-3} 2007-2009

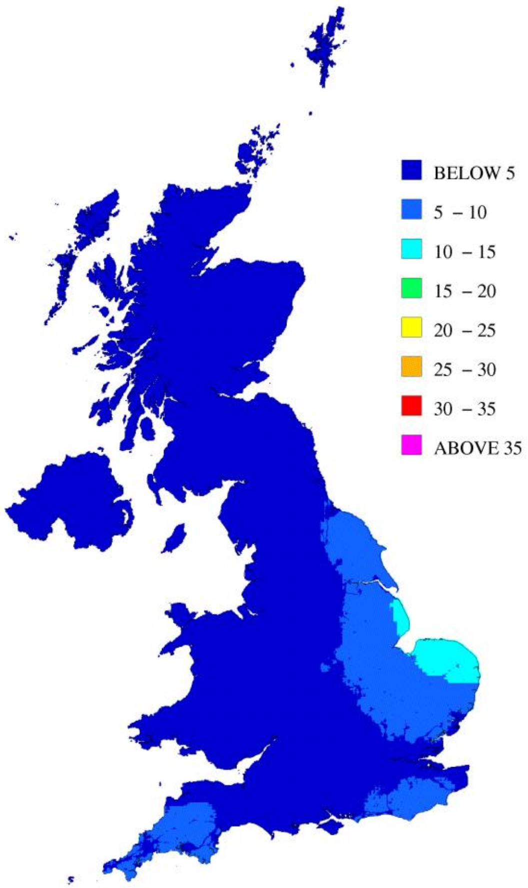


Figure 5-22 Number of days with ozone concentration > 120 μg m^{-3} 2009

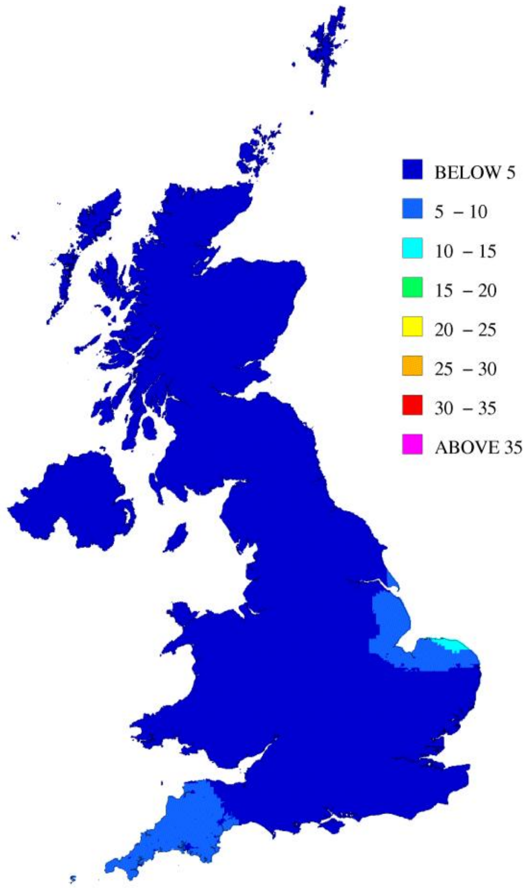


Figure 5-23 Average AOT40 wheat crops, 2005-2009 ($\mu g\ m^{-3}$.hours)

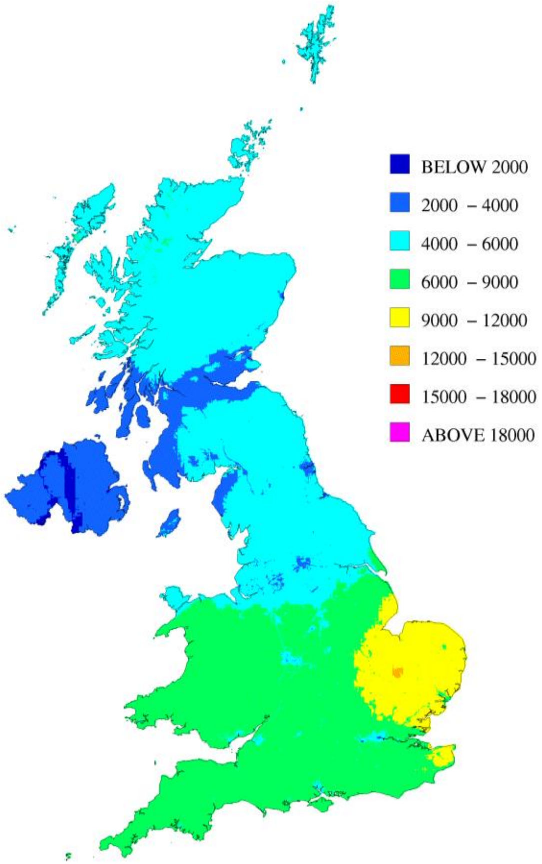
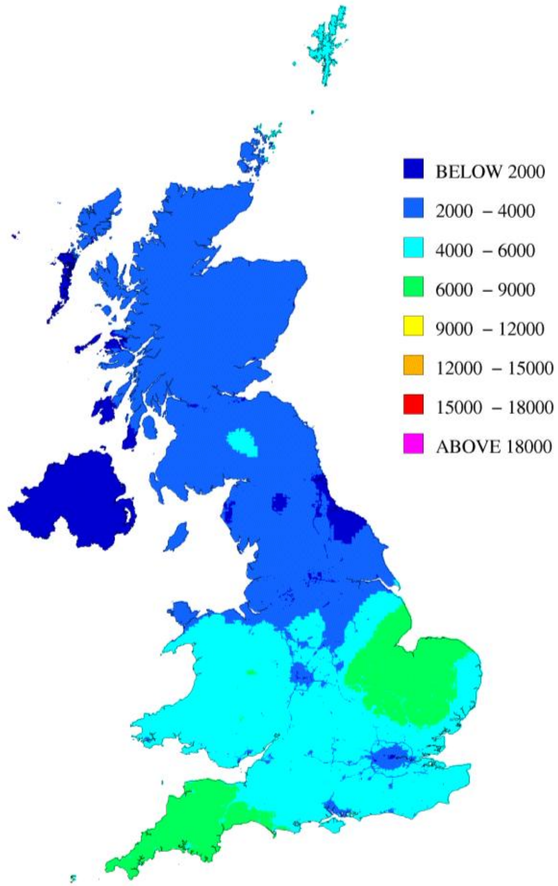


Figure 5-24 Average AOT40 wheat crops, 2009 ($\mu g\ m^{-3}$.hours)

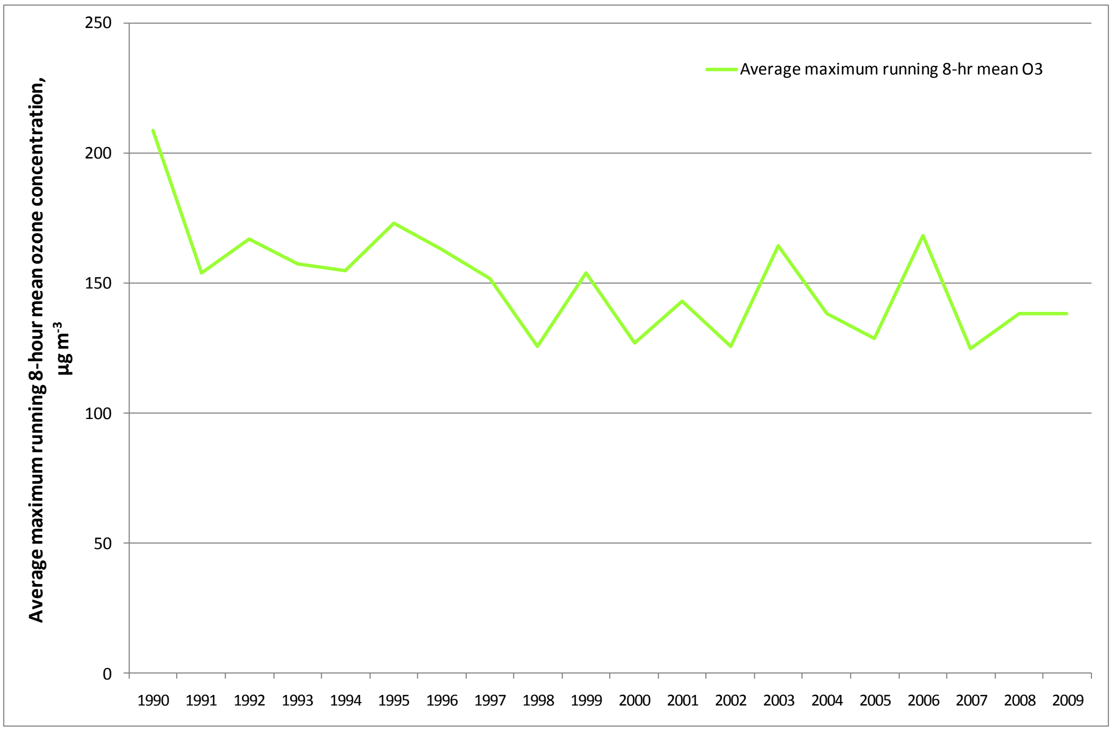


5.10.3 O_3: Trends

Figure 5-25 shows trends in the annual maximum 8-hour running mean ozone concentration. Although there is some year-to-year variation in this measurement of peak ozone concentrations, there is no clear upward or downward trend. The implication of this is that areas currently at risk of exceeding Limit Values are likely to remain at risk of exceeding in the near future.

No emissions trend data are included; ozone is not emitted in significant quantities directly from any source in the UK (instead, it is formed from reactions involving other pollutants). Therefore ozone is not included in the NAEI.

Figure 5-25 Trends in annual maximum 8-hour running mean, all AURN sites.



5.11 Heavy Metals

5.11.1 Heavy Metals: Compliance with Directive

Lead (Pb) is covered by the Air Quality Directive, while arsenic (As), cadmium (Cd) and nickel (Ni), are covered by the Fourth Daughter Directive. The results of the air quality assessment for lead are presented in Form 8d of the Questionnaire, and those for As, Cd and Ni are presented in Form 9b of the Questionnaire.

All zones or agglomerations were compliant with the limit value for lead, and the target values for arsenic and cadmium. However, two zones exceeded the target value for Ni, illustrated in Table 5—11.

Table 5—11 Results of air quality assessment for As, Cd, Ni and benzo(a)pyrene in 2009

Zone	Zone code	As TV	Cd TV	Ni TV	B[a]P TV
Greater London Urban Area	UK0001	OK	OK	OK	OK (m)
West Midlands Urban Area	UK0002	OK	OK	OK	OK
Greater Manchester Urban Area	UK0003	OK	OK	OK	OK
West Yorkshire Urban Area	UK0004	OK (m)	OK (m)	OK (m)	OK
Tyneside	UK0005	OK (m)	OK (m)	OK (m)	OK
Liverpool Urban Area	UK0006	OK (m)	OK (m)	OK (m)	OK
Sheffield Urban Area	UK0007	OK	OK	OK	OK (m)
Nottingham Urban Area	UK0008	OK (m)	OK (m)	OK (m)	OK (m)
Bristol Urban Area	UK0009	OK	OK	OK	OK (m)
Brighton/Worthing/Littlehampton	UK0010	OK (m)	OK (m)	OK (m)	OK
Leicester Urban Area	UK0011	OK (m)	OK (m)	OK (m)	OK (m)
Portsmouth Urban Area	UK0012	OK (m)	OK (m)	OK (m)	OK (m)
Teesside Urban Area	UK0013	OK	OK	OK	> TV (m)
The Potteries	UK0014	OK (m)	OK (m)	OK (m)	OK (m)
Bournemouth Urban Area	UK0015	OK (m)	OK (m)	OK (m)	OK (m)
Reading/Wokingham Urban Area	UK0016	OK (m)	OK (m)	OK (m)	OK (m)
Coventry/Bedworth	UK0017	OK (m)	OK (m)	OK (m)	OK (m)
Kingston upon Hull	UK0018	OK (m)	OK (m)	OK (m)	OK (m)
Southampton Urban Area	UK0019	OK (m)	OK (m)	OK (m)	OK (m)
Birkenhead Urban Area	UK0020	OK (m)	OK (m)	OK (m)	OK (m)
Southend Urban Area	UK0021	OK (m)	OK (m)	OK (m)	OK (m)
Blackpool Urban Area	UK0022	OK (m)	OK (m)	OK (m)	OK (m)
Preston Urban Area	UK0023	OK (m)	OK (m)	OK (m)	OK (m)
Glasgow Urban Area	UK0024	OK	OK	OK	OK
Edinburgh Urban Area	UK0025	OK (m)	OK (m)	OK (m)	OK
Cardiff Urban Area	UK0026	OK	OK	OK	OK
Swansea Urban Area	UK0027	OK	OK	> TV (m)	> TV (m)
Belfast Urban Area	UK0028	OK	OK	OK	OK
Eastern	UK0029	OK	OK	OK	OK
South West	UK0030	OK	OK	OK	OK (m)
South East	UK0031	OK	OK	OK	OK
East Midlands	UK0032	OK	OK	OK	OK
North West & Merseyside	UK0033	OK	OK	OK	OK
Yorkshire & Humberside	UK0034	OK	OK	OK	> TV
West Midlands	UK0035	OK (m)	OK (m)	OK (m)	OK (m)
North East	UK0036	OK	OK	OK	> TV (m)
Central Scotland	UK0037	OK	OK	OK	OK
North East Scotland	UK0038	OK	OK	OK	OK (m)
Highland	UK0039	OK (m)	OK (m)	OK (m)	OK
Scottish Borders	UK0040	OK	OK	OK	OK (m)
South Wales	UK0041	OK	OK	> TV (m)	> TV (m)
North Wales	UK0042	OK (m)	OK (m)	OK (m)	OK (m)
Northern Ireland	UK0043	OK (m)	OK (m)	OK (m)	> TV

5.11.2 **Heavy Metals: Spatial Distribution**

Figures 5-26, 5-27, 5-28 and 5-29 show modelled annual mean concentrations of Pb, As, Cd and Ni respectively in 2009. The spatial distribution patterns are discussed below.

Pb: background concentrations were less than 10 ng m^{-3} over most of the UK. Higher levels are in urban areas (particularly industrial areas). Higher concentrations are also clearly visible along major routes: this is not caused by vehicle emissions (leaded petrol having been banned within the EU from January 2000), but by re-suspended road dust.

As: background concentrations were less than 0.6 ng m^{-3} over most of the UK. However, higher concentrations occurred in some areas – particularly the north eastern part of England including the north east, Yorkshire and Humberside. This pattern reflects the natural sources of airborne arsenic, particularly wind-blown dust. Modelled concentrations are therefore highest in areas where agricultural practices give rise to wind blown dust (such as parts of eastern England) and where the natural arsenic content of the soil is relatively high (such as parts of Cornwall).

Cd: background concentrations were less than 0.5 ng m^{-3} over almost all of the UK. The only locations with higher concentrations were small spots relating to specific point sources.

Ni: Outside of urban areas, background concentrations of Ni were less than 1.0 ng m^{-3}. Some major road routes are visible: like lead, nickel is found in suspended road dust.

Figure 5-26 Annual mean background Lead concentration, 2009 (ng m^{-3})

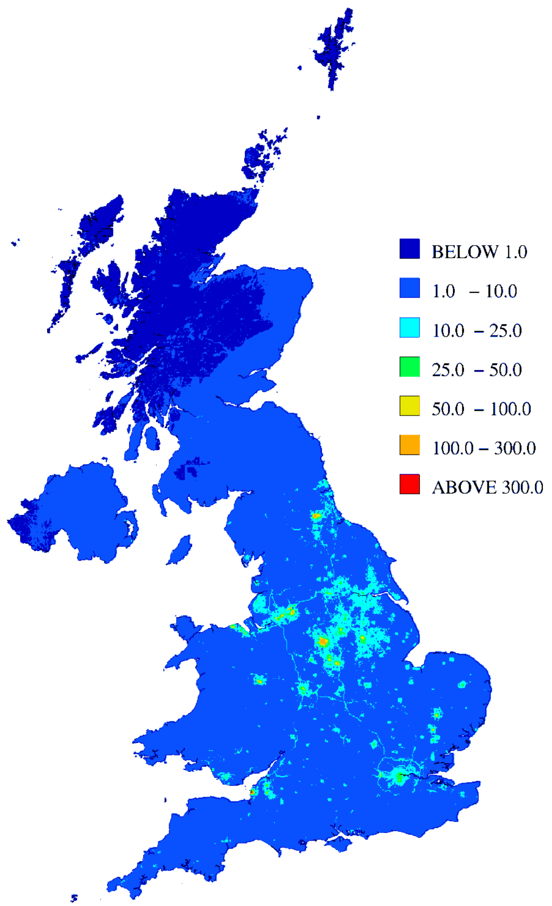


Figure 5-27 Annual mean background Arsenic concentration, 2009 (ng m^{-3})

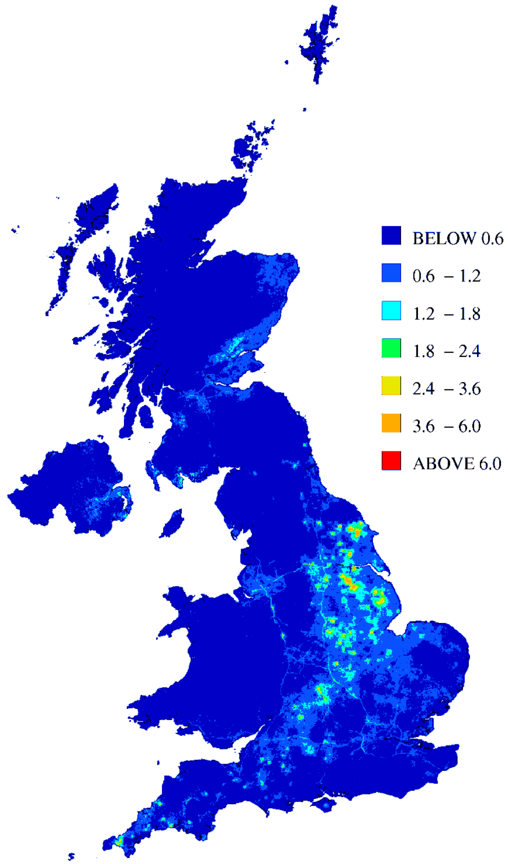


Figure 5-28 Annual mean background Cadmium concentration, 2009 (ng m^{-3})

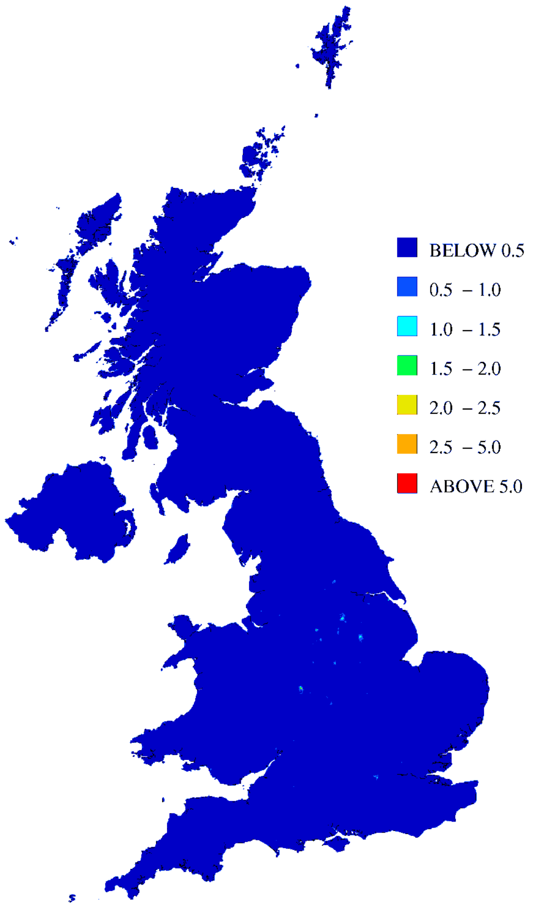
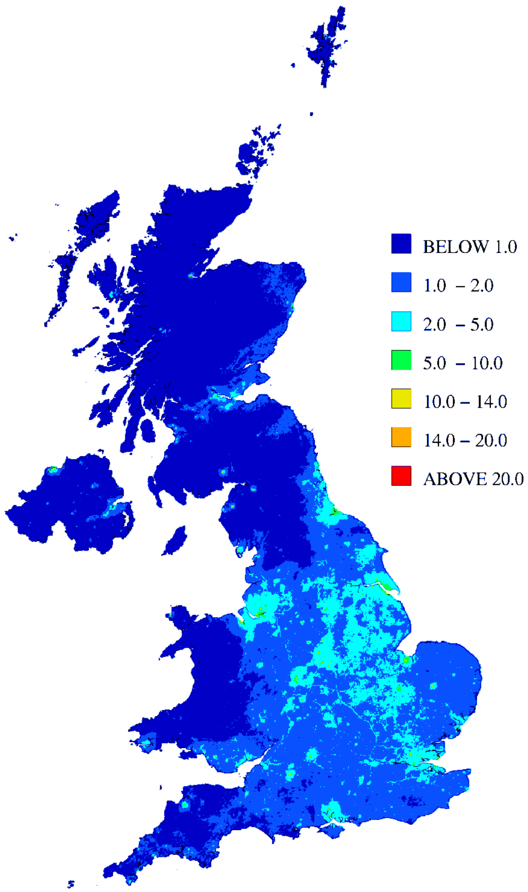


Figure 5-29 Annual mean background Nickel concentration, 2009 (ng m^{-3})



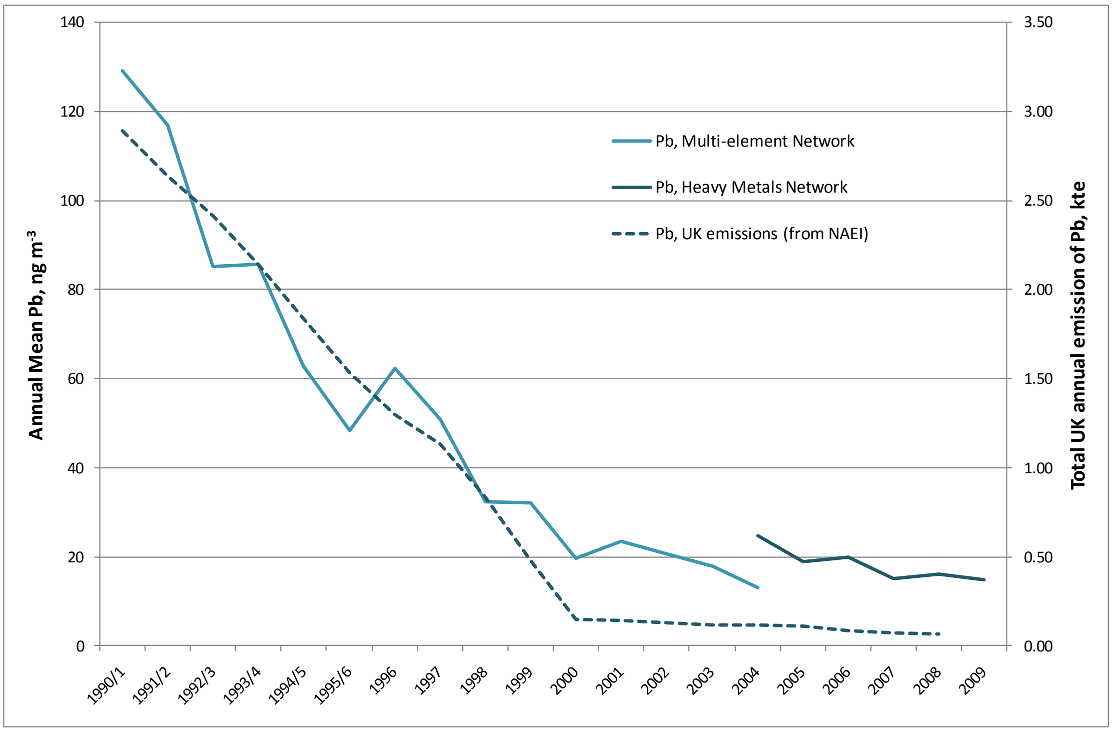
5.11.3 Lead: Trends

Figure 5-30 shows a time series of annual mean concentration of Pb in the particulate phase. For years prior to 2004, the graph shows the annual mean concentration of Pb in the particulate phase, as measured by the six sites comprising the former Multi-Element Network. This used a sampling method that was not size-selective.

From 2004 onwards, Pb was monitored in the PM_{10} fraction by the Heavy Metals Network, described in section 3.2.2 above. The annual mean of all 24 sites is shown. The mean for all sites is well below the Air Quality Directive limit value for annual mean Pb, of 500 ng m^{-3}.

Figure 5-30 also shows estimated total annual UK emissions of this metal. Measured ambient concentrations follow the same pattern, with a steep downward trend throughout the 1990s, levelling off after 2000.

Figure 5-30 Ambient Concentrations of Particulate-phase Pb, and Total UK Emissions



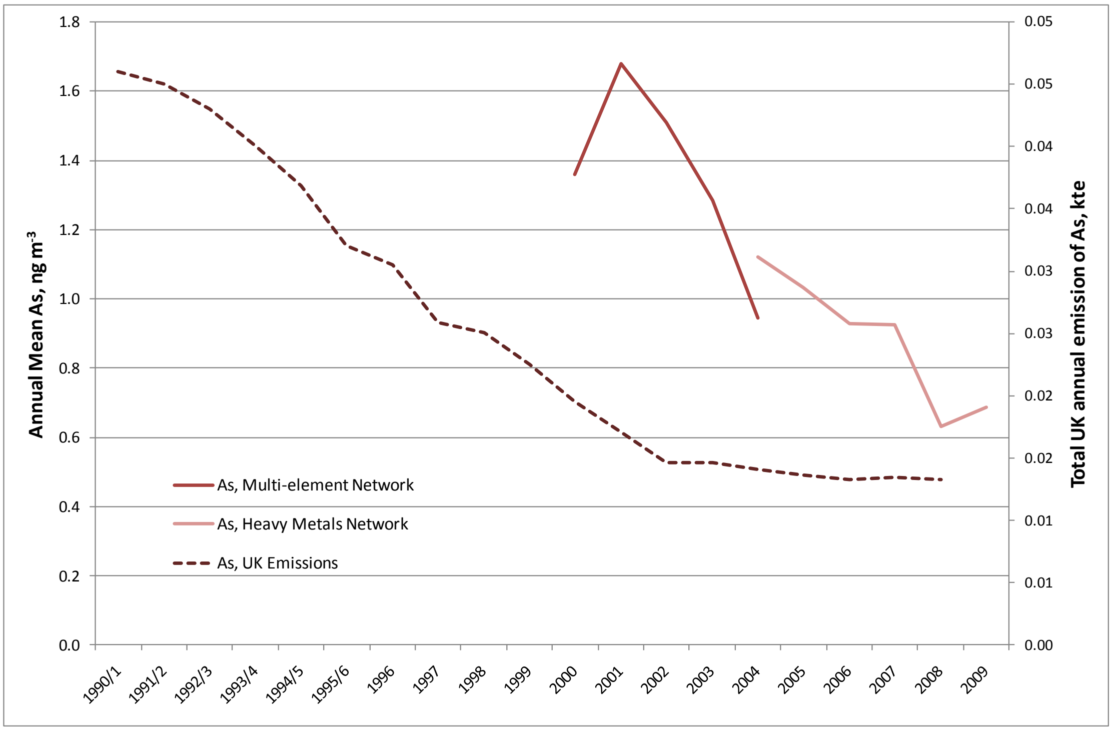
5.11.4 Arsenic: Trends

Figure 5-31 shows a time series of annual mean concentrations of As in the particulate phase. Arsenic monitoring began in 2000, at just two of the sites in the former Multi-Element Network. The other four sites began sampling As in 2003.

From 2004 onwards, As was monitored in the PM_{10} fraction by the Heavy Metals Network, described in section 3.2.2 above. The annual mean of all sites is shown. This parameter is well within the Fourth Daughter Directive target value of 6 ng m^{-3}.

Also shown is the UK's estimated total annual emission of As. The decrease in emissions is generally reflected in the decrease in measured ambient concentrations.

Figure 5-31 Ambient Concentrations of Particulate-phase As, and Total UK Emissions



5.11.5 Cadmium: Trends

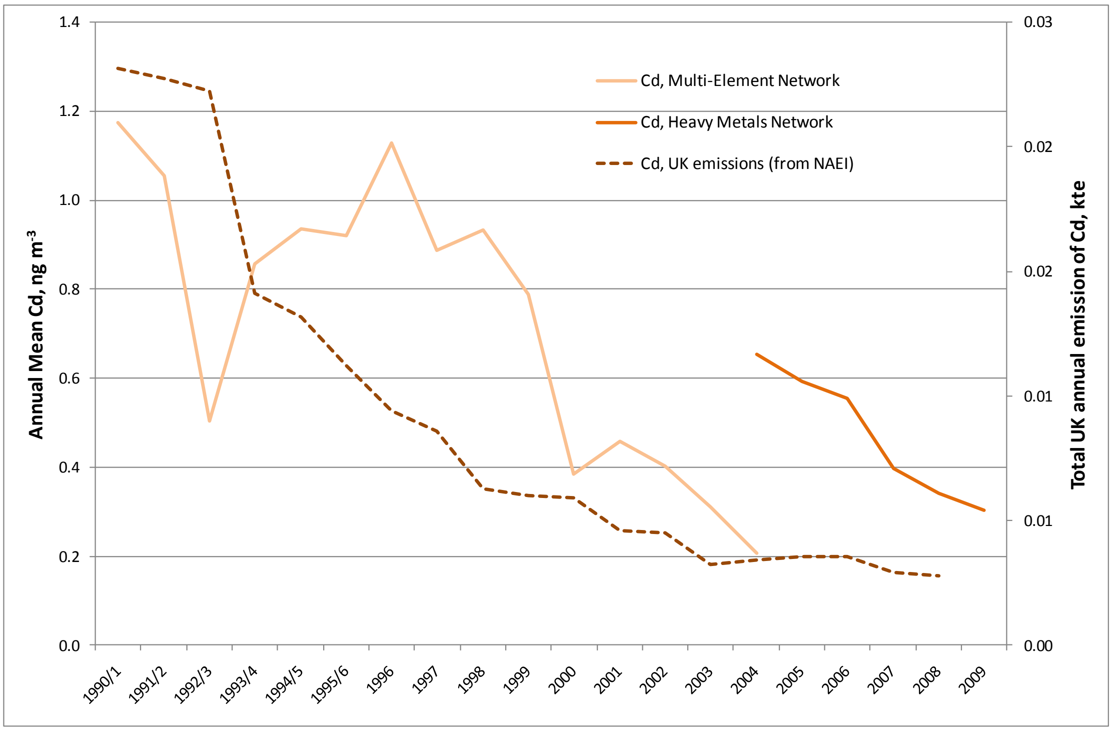
Figure 5-32 shows a time series of annual mean concentration of Cd in the particulate phase. Cd was monitored at five of the six sites in the former Multi-Element Network, until 2000 when monitoring also began at the rural Eskdalemuir site.

From 2004 onwards, Cd was monitored in the PM_{10} fraction by the Heavy Metals Network, described in section 3.2.2 above. The annual mean of all sites is shown. There is a small discontinuity between the averages measured by the two networks in 2004, probably caused by the increase in the number of sites from six to 17.

This parameter is well within the Fourth Daughter Directive target value of 5 ng m^{-3}.

Also shown is the UK's estimated total annual emission of Cd. The decrease in emissions is generally reflected in the decrease in measured ambient concentrations.

Figure 5-32 Ambient Concentrations of Particulate-phase Cd, and Total UK Emissions

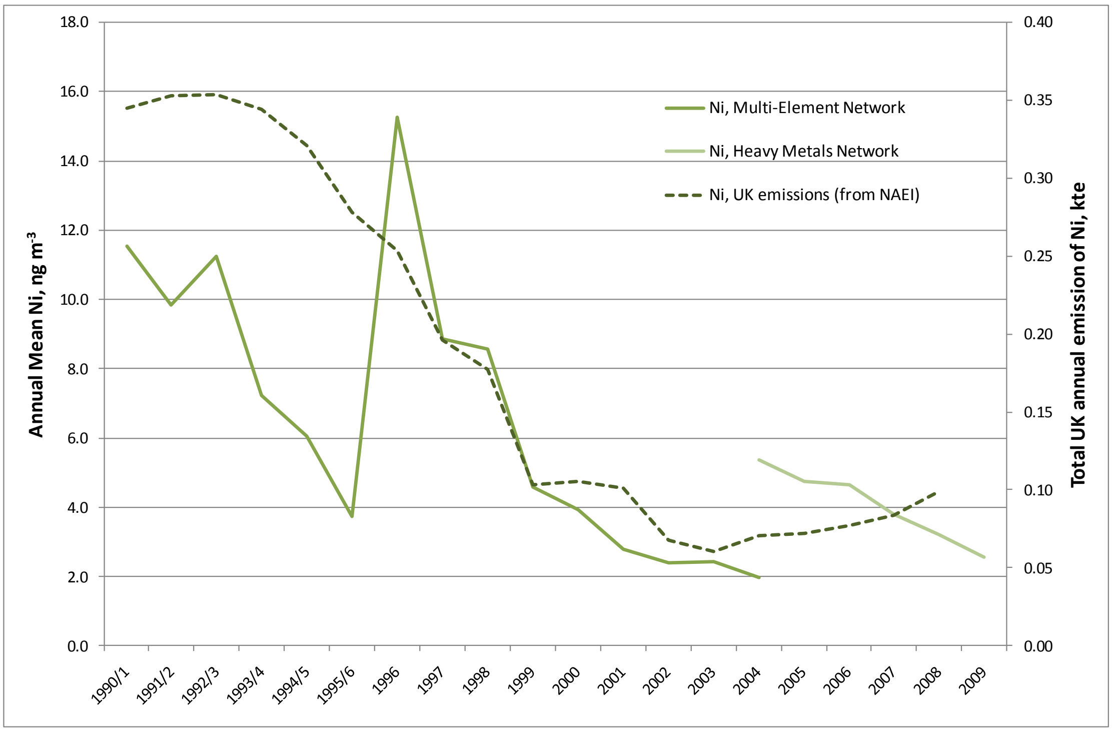


5.11.6 Nickel: Trends

Figure 5-33 shows a time series of annual mean concentrations of Ni in the particulate phase. Measurements up to 2004 are from the six sites in the former Multi-Element Network, measurements from 2004 onwards are from the Heavy Metals Network. The mean for all sites is well within the Fourth Daughter Directive target value of 20 ng m^{-3}, and there were no measured exceedences in 2009. However, as highlighted in section 5.11.1 above, there were *modelled* exceedences in some parts of South Wales in 2009.

Figure 5-33 also shows total estimated annual UK emissions of Ni. During the late 1990s and up to 2004, the NAEI data show a decrease in the UK's total emissions of Ni. This is generally reflected in the average ambient concentrations measured by the Multi-Element Network. However, in the past five years, the NAEI data indicate that the UK's Ni emissions have begun to increase again. This upturn in emissions is not reflected in the results of the Heavy Metals Network for 2004 onwards, which appear to indicate that ambient concentrations are still decreasing.

Figure 5-33 Ambient Concentrations of Particulate-phase Ni, and Total UK Emissions

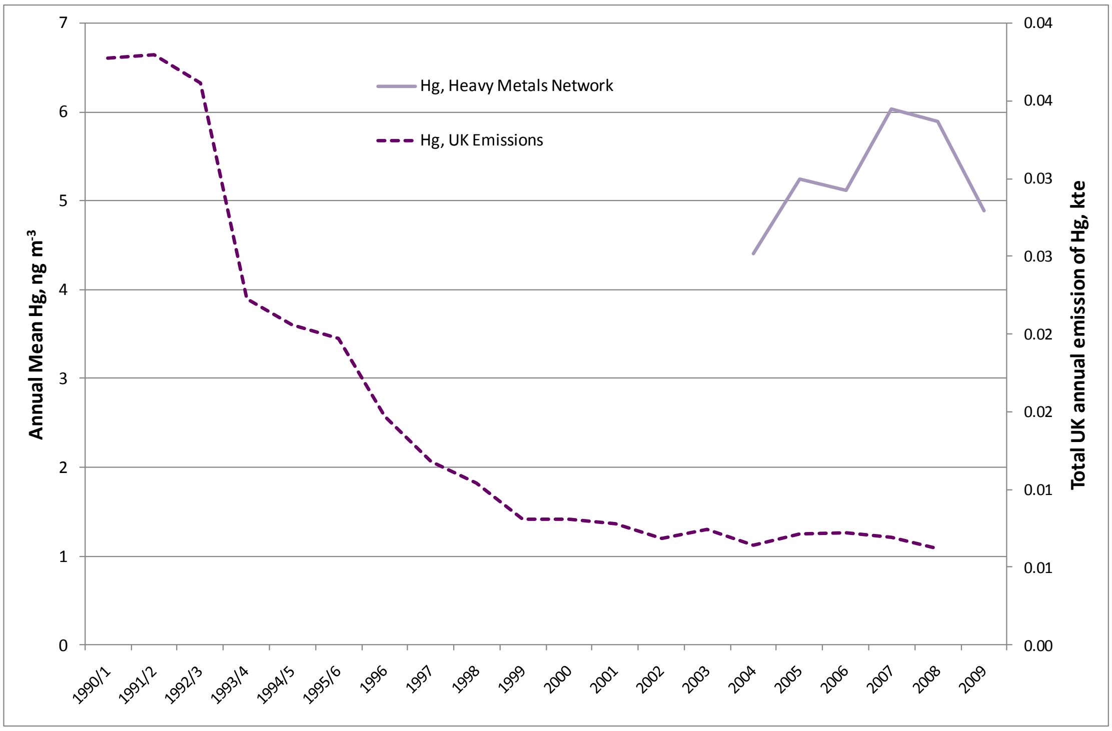


5.11.7 Mercury: Trends

Figure 5-34 shows a time series of total annual mean concentrations of Hg, as measured by the Heavy Metals Network from 2004. The graph shows the sum of the vapour phase and particulate phase components: the majority of ambient Hg is in the vapour phase. Although the former Multi-Element Network did start measuring mercury in 2000, only particulate phase measurements are available, so these are not shown here. The five years of available data from the Heavy Metals Network do not appear to show a clear trend in ambient mercury concentrations.

Figure 5-34 also shows total annual UK emissions of this metal (from the NAEI). Although emissions decreased substantially throughout the 1990s, they have levelled off from the early 2000s, and there is no clear trend in emissions in the past five years. The ambient concentration measurements from the Heavy Metals Network appear consistent with this.

Figure 5-34 Ambient Concentrations of Particulate and Vapour phase Hg, and Total UK Emissions



5.12 Benzo [a] Pyrene

5.12.1 B[a]P: Compliance with Directive

The compound benzo[a]pyrene is used as a marker for the group of hydrocarbon pollutants known as polycyclic aromatic hydrocarbons (PAH). Benzo[a]pyrene (B[a]P) is covered by the Fourth Daughter Directive. Concentrations of B[a]P were above the target value in six zones and below in all remaining zones. This is shown in Table 5—11 above. The six zones with exceedences were:

- Teesside Urban Area
- Swansea Urban Area
- Yorkshire and Humberside
- North East
- South Wales
- Northern Ireland.

5.12.2 B[a]P: Spatial Distribution

Figure 5-35 below shows the modelled annual mean background concentration of B[a]P. The areas of highest concentration reflect the distribution of industrial sources, and also areas where there is widespread domestic use of oil and solid fuels for heating. These include parts of Yorkshire and Humberside, South Wales and the Belfast area.

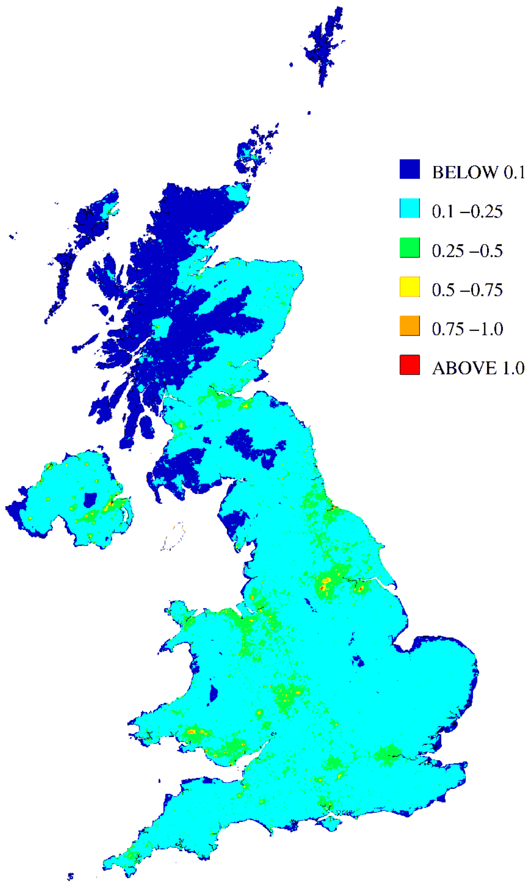
5.12.1 B[a]P: Trends

The PAH monitoring network began operation in 1991, comprising a small number of sites, and was increased to over 20 in the late 1990s. However, during the years 2007-2008, the network underwent a further major expansion and re-organisation. The measurement method was changed, bringing the Network into compliance with the requirements of the Fourth Daughter Directive.

The newer sampling technique used at most sites from 2008 onwards has been found to give higher results than the older method. The reason for this is likely to be due to a number of factors, predominantly the fact that the new samplers have a shorter collection period. The shorter collection period is likely to decrease the degradation of the PAHs by ozone or other oxidative species[44].

Because of these changes in the composition of the network, and in particular the techniques used, trends in data from the PAH network have not been analysed in this report. It is intended that this will be investigated in future reports, when there are sufficient data using the new technique.

Figure 5-35 Annual mean background B[a]P concentration, 2009 (ng m^{-3})



5.13 Comparison with Previous Years

Table 5—12 to Table 5—17 summarise the results of the air quality assessment for 2009 and provide a comparison with the results of the assessments carried out in previous years.

Table 5—12 Exceedences of limit values plus margins of tolerance for Air Quality Directive (1st and 2nd Daughter Directives)

Pollutant	Averaging time	2009	2008	2007	2006	2005	2004	2003	2002	2001
SO_2	1-hour	n/a	n/a	n/a	n/a	n/a	1 zone modelled (Eastern)	1 zone modelled (Eastern)	none	none
SO_2	24-hour[1]	n/a	n/a	n/a	n/a	n/a	none	1 zone modelled (Eastern)	none	1 zone measured (Belfast Urban Area)
SO_2	annual[2]	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SO_2	winter[2]	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
NO_2	1-hour[3]	2 zones measured (London, Glasgow)	2 zones measured (London, Glasgow)	1 zone measured (Greater London Urban Area)	1 zone measured (Greater London Urban Area)	1 zone measured (Greater London Urban Area)	1 zone measured (Greater London Urban Area)	1 zone measured (Greater London Urban Area)	none	none
NO_2	annual	40 zones (9 measured + 31 modelled)	40 zones (7 measured + 33 modelled)	39 zones (6 measured + 33 modelled)	38 zones (6 measured + 32 modelled)	35 zones (6 measured + 29 modelled)	34 zones (6 measured + 28 modelled)	35 zones (5 measured + 30 modelled)	19 Zones (5 measured + 14 modelled)	21 Zones (4 measured + 17 modelled)
NO_x	annual[2]	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
PM_{10}	24-hour[4] (Stage 1)	n/a	n/a	n/a	n/a	n/a	19 zones (1 measured + 18 modelled)	18 zones (2 measured + 16 modelled)	1 zone modelled (Greater London Urban Area)	1 zone modelled (Greater London Urban Area)

Pollutant	Averaging time	2009	2008	2007	2006	2005	2004	2003	2002	2001
PM_{10}	annual (Stage 1)	n/a	n/a	n/a	n/a	n/a	1 zone modelled (Greater London Urban Area)	10 zones (1 measured + 9 modelled)	1 zone modelled (Greater London Urban Area)	1 zone modelled (Greater London Urban Area)
Lead	annual	n/a	n/a	n/a	n/a	n/a	none	none	none	none
Benzene	annual	none	none	none	none	none	none	none	not assessed	not assessed
CO	8-hour	n/a	n/a	n/a	n/a	n/a	none	none	not assessed	not assessed

[1] No MOT defined, LV + MOT = LV
[2] Applies to vegetation and ecosystem areas only. No MOT defined, LVs are already in force
[3] No modelling for 1-hour LV

Table 5—13 Exceedences of limit values for Air Quality Directive (1st and 2nd Daughter Directives)

Pollut-ant	Averag-ing time	2009	2008	2007	2006	2005	2004	2003	2002	2001
SO_2	1-hour	none	none	none	1 zone modelled (Eastern)	1 zone modelled (Eastern)	1 zone modelled (Eastern)	1 zone modelled (Eastern)	none	none
SO_2	24-hour[1]	none	none	none	1 zone modelled (Eastern)	1 zone modelled (Eastern)	none	1 zone modelled (Eastern)	none	1 Zone measured (Belfast Urban Area)
SO_2	Annual[2]	none	none	none	none	none	none	none	none	none
SO_2	Winter[2]	none	none	none	none	none	none	none	none	not assessed
NO_2	1-hour[3]	2 zones measured (London, Glasgow)	3 zones measured (London, Glasgow, NE Scotland)	2 zones measured (London, Glasgow)	1 zone measured (Greater London Urban Area)	2 zones measured (London, Bristol)	1 zone measured (Greater London Urban Area)	3 zones measured (London, Glasgow, South East)	1 zone measured (Glasgow Urban Area)	4 zones measured

Pollut-ant	Averag-ing time	2009	2008	2007	2006	2005	2004	2003	2002	2001
NO_2	Annual	40 zones (9 measured + 31 modelled)	40 zones (10 measured + 30 modelled)	41 zones (8 measured + 33 modelled)	39 zones (7 measured + 32 modelled)	38 zones (8 measured + 30 modelled)	39 zones (9 measured + 30 modelled)	42 zones (10 measured + 32 modelled)	36 zones (6 measured + 30 modelled)	38 zones (6 measured + 32 modelled)
NO_x	Annual[2]	none	none	none	none	none	none	none	none	None
PM_{10}	24-hour (Stage 1)	3 zones (1 measured + 2 modelled) *1 zone modelled after subtraction of natural contribution*	2 zones (1 measured + 1 modelled) *1 zone measured after subtraction of natural contribution*	6 zones (3 measured + 3 modelled)	30 zones (5 measured + 25 modelled)	29 zones (3 measured + 26 modelled)	27 zones (2 measured + 25 modelled)	33 zones (10 measured + 23 modelled)	18 zones (1 measured + 17 modelled)	26 zones (5 measured + 21 modelled)
PM_{10}	annual (Stage 1)	none	none	1 zone measured (Greater London Urban Area)	2 zones (1 measured + 1 modelled)	4 zones (1 measured + 3 modelled)	2 zones (1 measured, London + 1 modelled, West Midlands Urban Area)	15 zones (1 measured + 14 modelled)	2 zones (Greater London Urban Area measured, Eastern modelled)	2 zones (London measured, Manchester modelled)
Lead	Annual	none	none	none	none	none	none	none	none	None
Benzene	Annual	none	none	none	1 zone modelled (Yorkshire & Humberside)	2 zones modelled (Yorkshire & Humberside, Central Scotland)	none	1 zone modelled (Greater London Urban Area)	not assessed	not assessed
CO	8-hour	none	none	none	none	none	none	none	not assessed	not assessed

[1] No MOT defined, LV + MOT = LV
[2] Applies to vegetation and ecosystem areas only. No MOT defined, LVs are already in force
[3] No modelling for 1-hour LV

Table 5—14 Quality Directive (3rd Daughter Directive) Target Values

Pollutant	Averaging time	2009	2008	2007	2006	2005	2004
O_3	8-hour	none	1 zone measured (Eastern)	none	none	none	none
O_3	AOT40	none	none	none	none	none	none

Table 5—15 Air Quality Directive (3rd Daughter Directive) Long Term Objectives

Pollutant	Averaging time	2009	2008	2007	2006	2005	2004
O_3	8-hour	39 zones (25 measured + 14 modelled)	43 zones (35 measured + 8 modelled)	41 zones (24 measured + 17 modelled)	43 zones (41 measured + 2 modelled)	37 zones (22 measured + 15 modelled)	43 zones (36 measured + 7 modelled)
O_3	AOT40	10 zones (8 measured + 2 modelled)	41 zones (25 measured + 16 modelled)	3 zones (1 measured + 2 modelled)	41 zones (32 measured + 9 modelled)	16 zones (9 measured + 7 modelled)	7 zones (5 measured + 2 modelled)

Table 5—16 4th Daughter Directive Target Values

Pollutant	Averaging time	2009	2008	2007
As	Annual	none	none	none
Cd	Annual	none	none	none
Ni	Annual	2 zones modelled (Swansea, S Wales)	2 zones modelled (Swansea, S Wales, measured at non-network site, so reported as m)	1 zone (Swansea Urban area, measured but low data capture, so reported as m)
BaP	Annual	6 zones, (2 zones measured Yorkshire & Humberside, N Ireland + 4 zones modelled Teesside, Swansea, North East, S Wales)	6 zones, (3 zones measured Yorkshire & Humberside, Teeside, N Ireland + 3 zones modelled Swansea, S Wales, Belfast)	1 zone measured (Yorkshire & Humberside)

Table 5—17 Air Quality Directive Target Value

Pollutant	Averaging time	2009
$PM_{2.5}$	Annual	none

6 Pollution Events in 2009

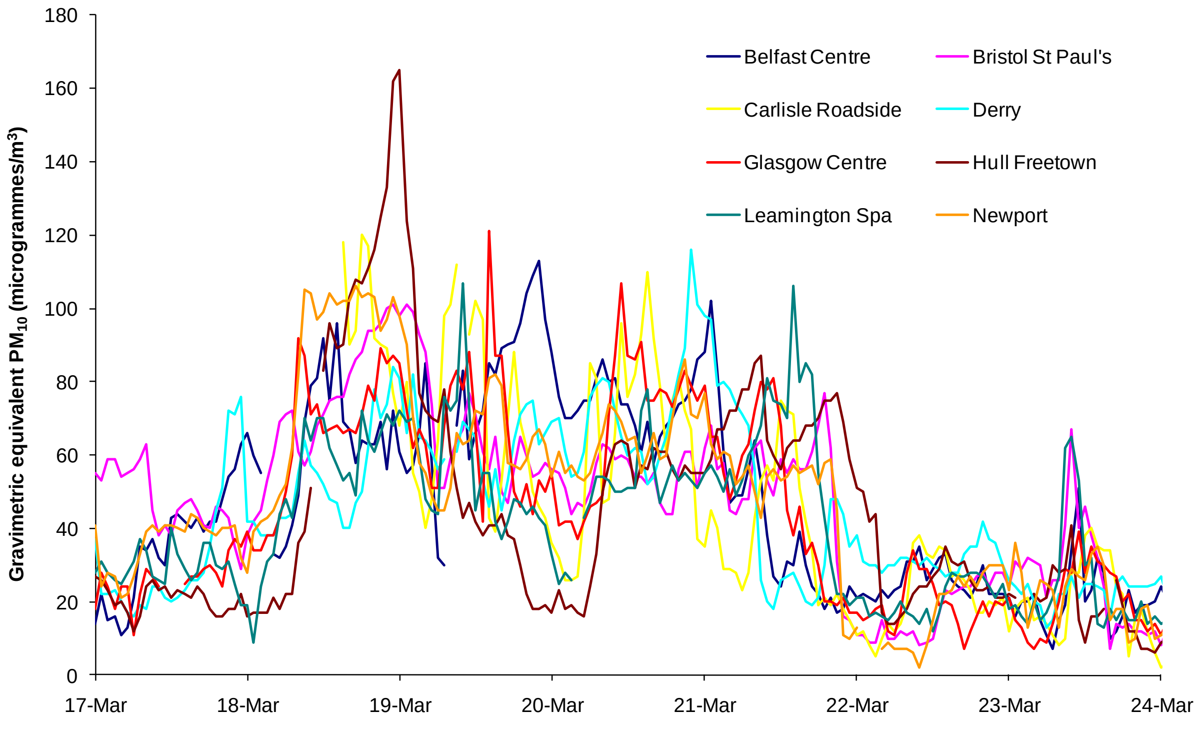
6.1 Pollution Episode in March

The first particulate episode of the year occurred between 18th March and 22nd March 2009, when the UK experienced an episode of increased PM_{10} and $PM_{2.5}$ concentrations[45] (Figure 6-1 shows this episode, for selected sites).

London Marylebone Road and Sandy Roadside (in Bedfordshire) both reached air pollution index 5 on 17th March (a full day before other sites recorded air pollution indices above 3). For the remainder of the episode both sites did not exceed air pollution index 3. Although these two sites also recorded elevated levels, it was concluded that these were *not* connected to the episode.

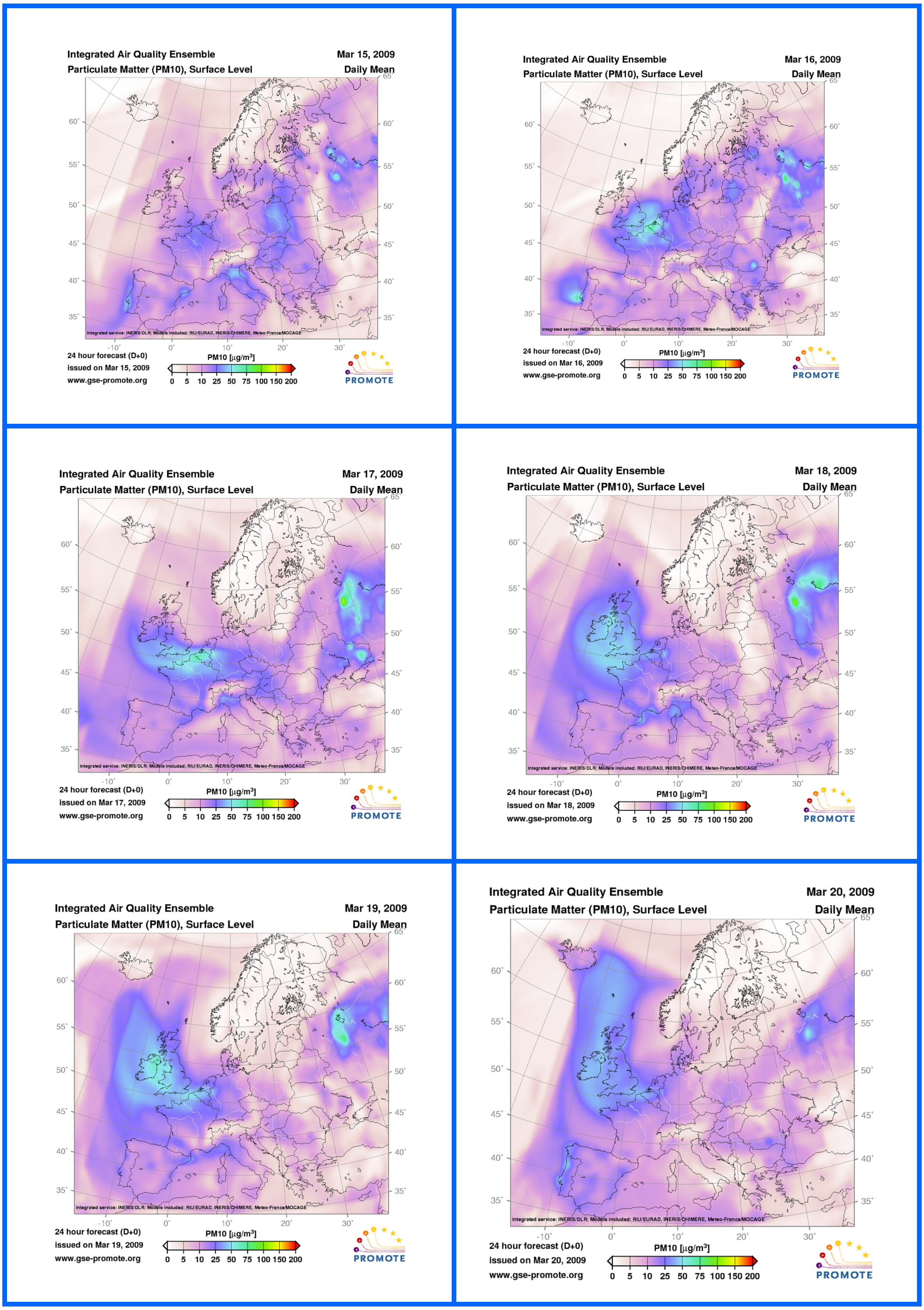
From Wednesday 18th to Sunday 22nd March, 29 sites reached the 'Moderate' band or higher. 19 of these were located in England, two in Northern Ireland, three in Scotland and five in Wales. Only one site, Hull Freetown, measured levels of PM_{10} particulate matter at air pollution index 7 ('High').

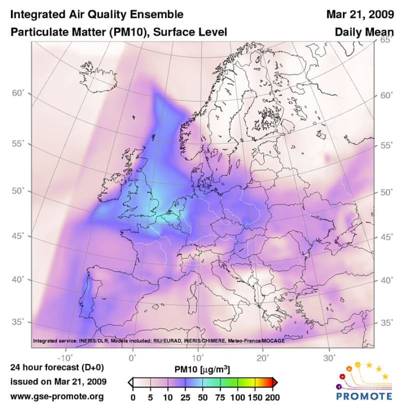
Figure 6-1 Hourly mean PM_{10} measurements at selected sites across the UK, March 17th to 24th 2009

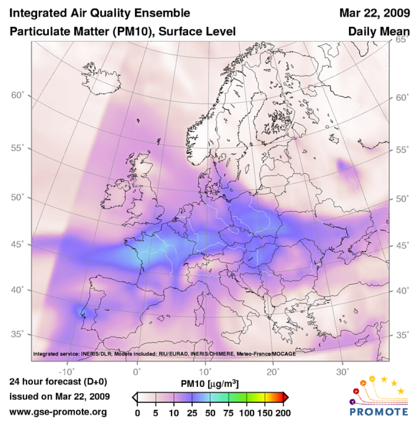


Air mass back-trajectory plots revealed that the cause of this particulate episode was long range transport of particulate matter building up over the Benelux (Belgium, Netherlands and Luxemburg) region during the 16th and 17th March as shown in the PROMOTE[46] forecasts in Figure 6-2. The air masses arriving over the UK on 18th March 2009 had picked up particulate matter building up over the area during the 16th and 17th March. During the 19th to 21st March air masses started to re-circulate over the UK, prolonging the elevated levels.

Figure 6-2 PROMOTE model output showing daily mean PM_{10} concentrations for March 15th -22nd 2009.







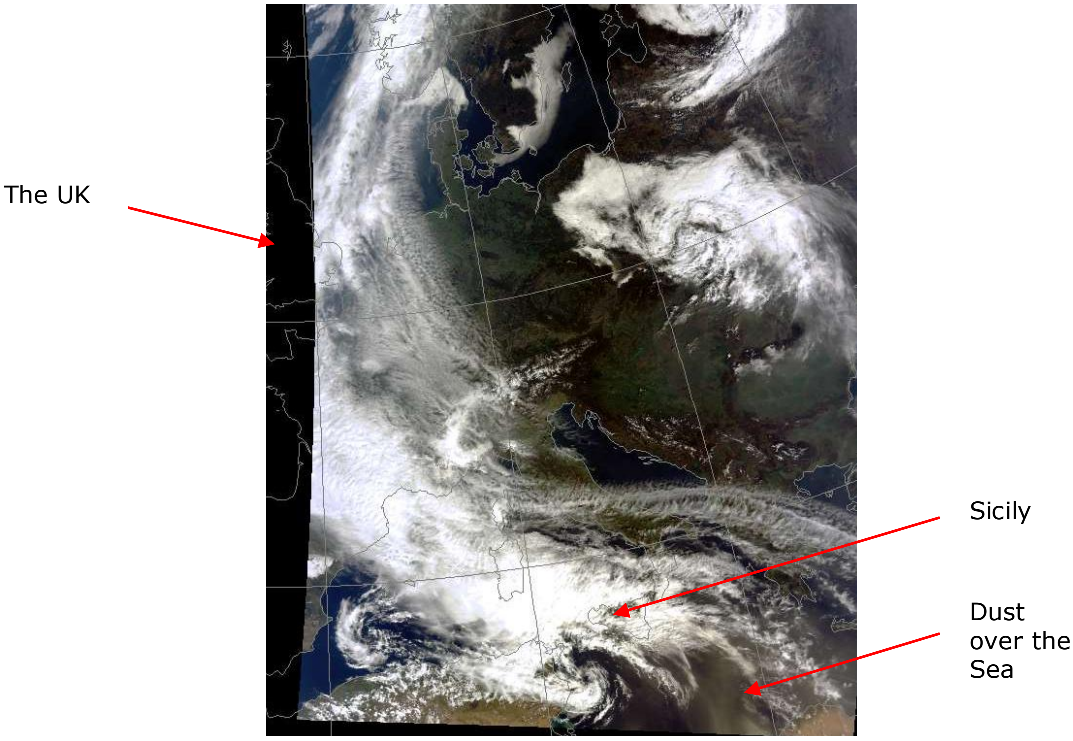
The sequence of maps in Figure 6-2 shows that on the 15th March the UK was enjoying relatively clean air, however an increase in PM_{10} particulate matter concentrations can be observed over the Benelux area. As the PROMOTE forecast progresses through to 18th to 21st March a build up of PM_{10} can be seen over the UK. The last map in Figure 6-2 shows that on the 22nd March the modelled particulate concentrations over the UK decreased. The PROMOTE output shows good agreement with the PM_{10} concentrations as measured by monitoring stations in the AURN.

6.2 Pollution Episode in April

During the second episode, Wednesday 15th and Thursday 16th April 2009, 31 sites in the AURN measured particulate PM_{10} concentrations in the 'Moderate' band[47]. Four of the sites went on to measure in the 'High' band. The elevated levels of particulates had been primarily caused by long range transport of particulates from mainland Europe and the east, arriving in the UK on the 15th April, combined with localised pollution levels at the sites. All the sites measuring an exceedence were located in England and Wales. Four of the 'Moderate' band sites were located in South Wales and the remainder were geographically widespread across England. Eight of the sites measuring an exceedence were situated near a busy road, twenty were in an urban area and three were described as urban industrial. Two of the 'High' sites were located in London and two in East Anglia. In the south of England most of the elevated measurements occurred on the 15th April and had cleared by the following day. However, in the north of England the elevated levels continued onto the 16th April and slowly dispersed throughout that day. Sites in Wales had measured a dramatic and sustained decrease in particulate levels on the morning of the 16th.

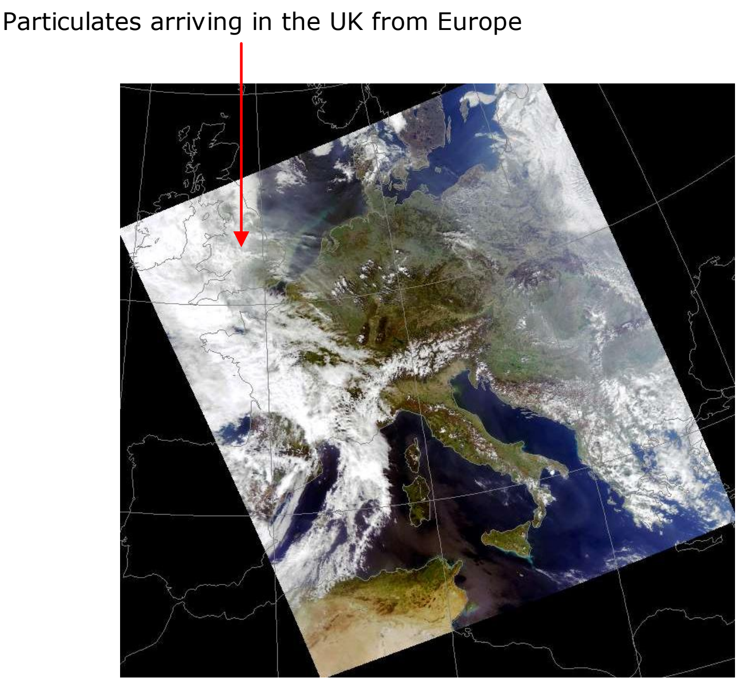
Three days prior to the particulate episode in England and Wales, dust from sandstorms in North Africa were seen travelling north-westwards across the Mediterranean Sea, towards Italy and Sicily. Figure 6-3 shows satellite imagery of the event, taken on the same day.

Figure 6-3 Global view of the dust travelling away from North Africa on 12th April[48].



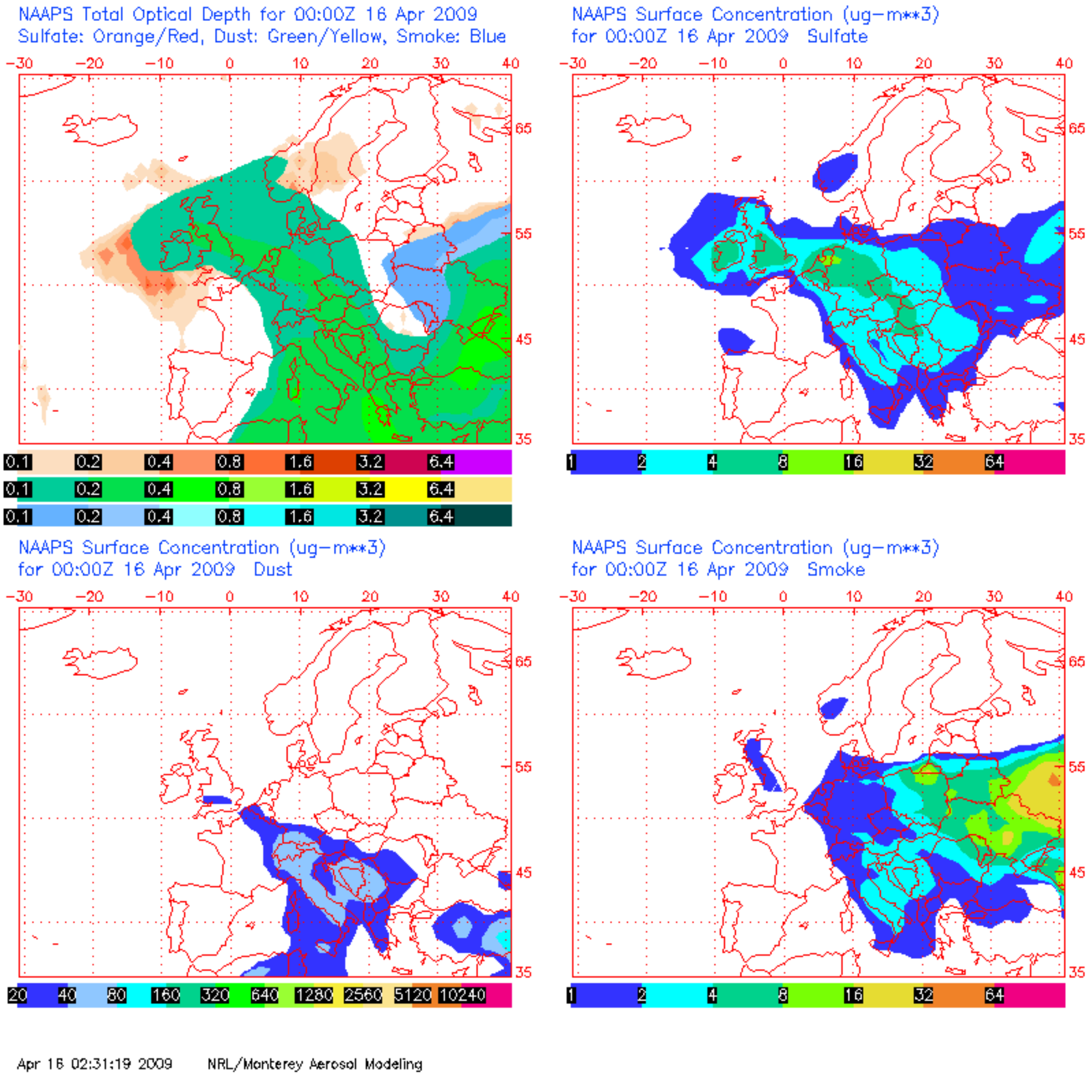
European particulate forecasting models suggested that the elevated levels were due to long range transport of a combination of secondary pollution from Europe, smoke from agricultural fires in western Russia, and dust from sandstorms over northern Africa. The relative contributions from the three sources were modelled to be approximately in these proportions: 80% from dust storms in North Africa, 4% from eastern sources (such as the fires in Russia), and 16% contribution from European pollution sources. The satellite image shown in Figure 6-4 shows the position of some of the particulates at midday on 15th April. The majority of Europe and the Mediterranean Sea appear to have cleared of particulates.

Figure 6-4 Satellite image taken on midday on the 15th April[49].



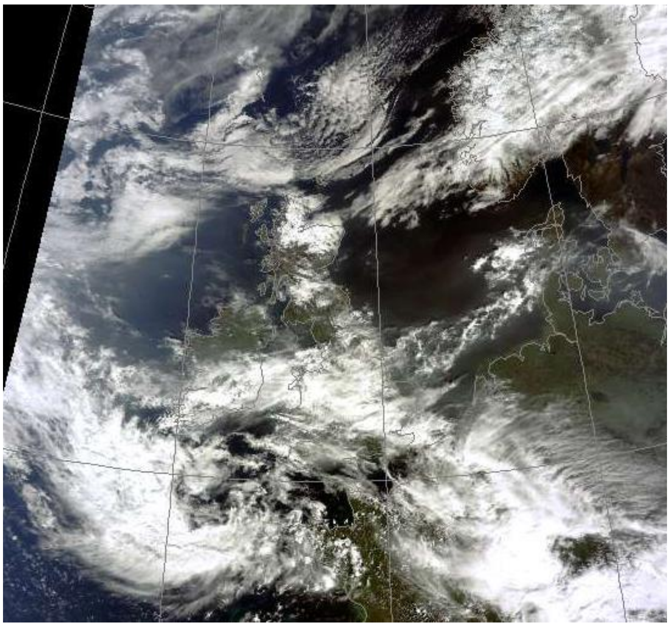
By midnight on the 16th some of the dust from North Africa was modelled to have spread over parts of the south of England and South Wales, as shown in the Navy Aerosol Analysis and Prediction System (NAAPS) model in Figure 6-5.

Figure 6-5 The NAAPS model[50] dust forecast for the 16th April at 00:00



The North African dust was shown to have cleared from the UK by 06:00 that morning, however European pollution remained in the south and smoke remained in the north. This was reflected in data from the monitoring networks and from the satellite image in Figure 6-6, taken late in the morning of the 16th and showing the particulates slowly clearing from the UK over the Atlantic.

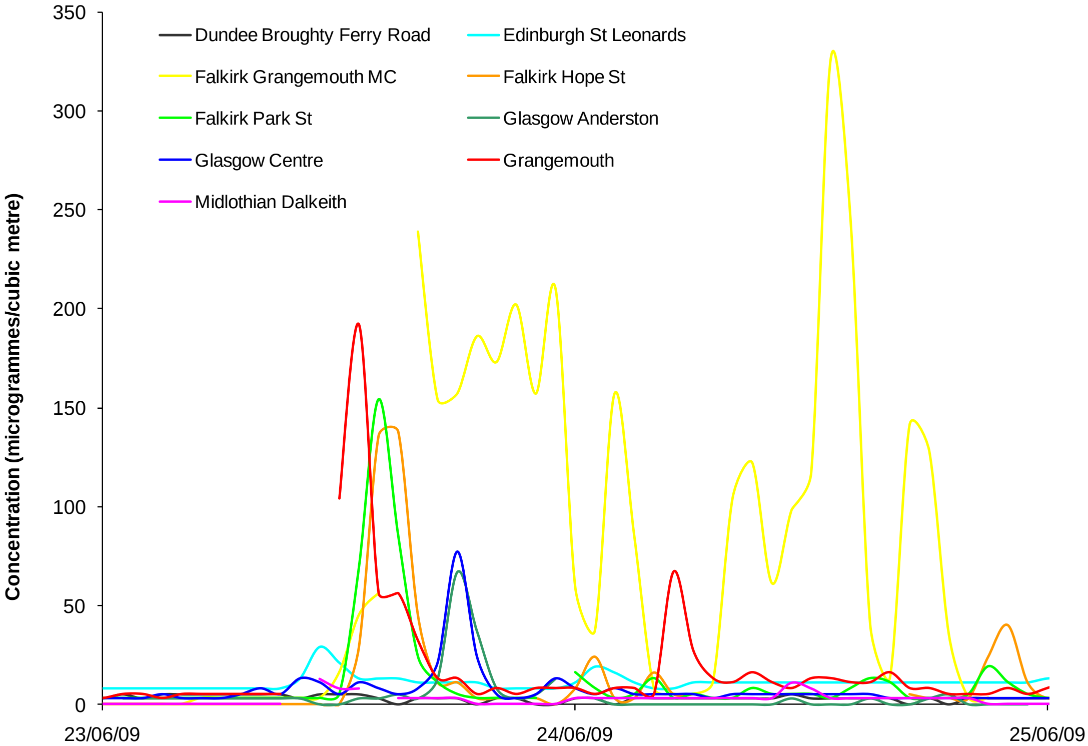
Figure 6-6 Satellite image taken at 11:00 on the 16th April[51].



6.3 Possible UK Impact of the SO_2 plume from Sarychev Peak Eruption

Unusual short-term increases in SO_2 concentrations were observed across a wide range of the Scottish air quality monitoring network sites towards the end of June 2009, as seen in Figure 6-7. Upon further investigation similar peaks were observed at monitoring stations in London, Port Talbot, Hull, and at other stations in the UK and across Norway[52].

Figure 6-7 SO_2 concentrations at Scottish air quality monitoring network sites

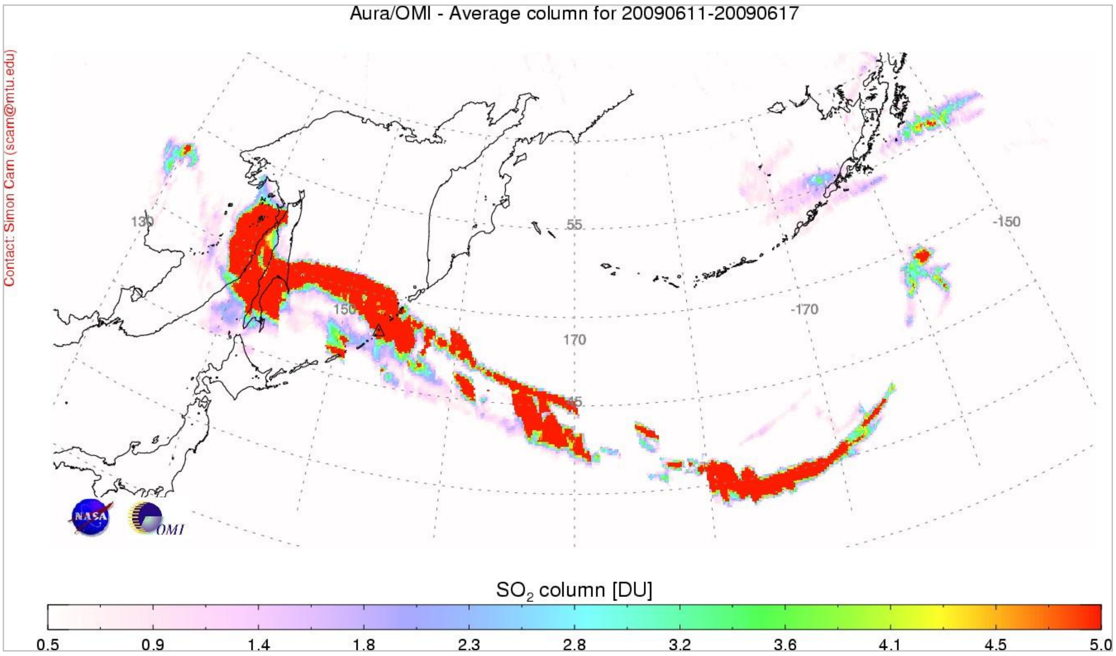


Whilst increases at some sites could be explained by meteorology and local emissions, it was more difficult to understand the increases at locations away from any industrial sources. One possible explanation is the impact of the SO_2 plume from the spectacular eruption of the Sarychev Peak volcano in the Kuril Islands, Russia, on June 12th 2009. An image of the eruption taken from the International Space Station can be seen in Figure 6-8.

Figure 6-8 The SO_2 plume from the spectacular eruption of the Sarychev Peak volcano[53]

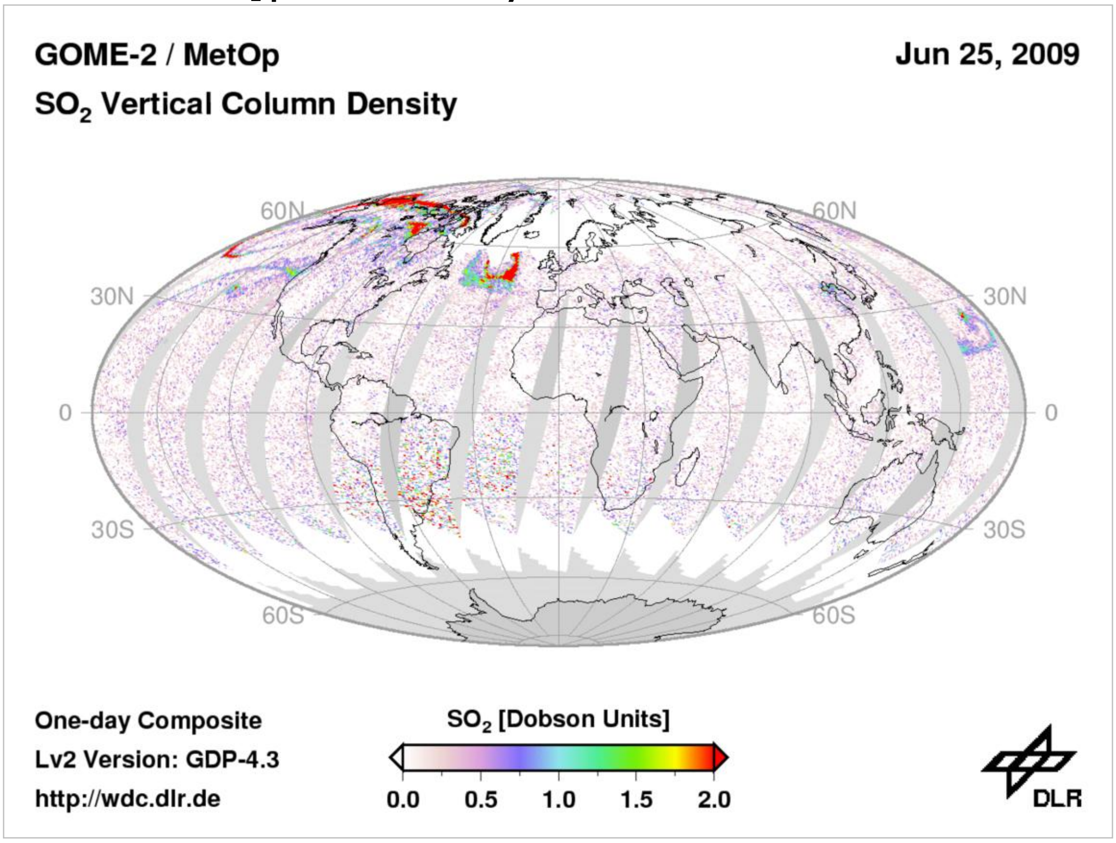
An image of the initial SO_2 plume released can be seen in Figure 6-9.

Figure 6-9 The SO_2 plume recorded by Ozone Monitoring Instrument (OMI) on NASA's Aura satellite[54]



Tracking of the plume by the GOME satellite shows that it travelled across North America and the North Atlantic and was possibly over the UK at the time of the monitored peaks in SO_2. Further evidence is also provided by increases in the total column SO_2 over the UK from June 18th to 21st. This was picked up by ground-based Brewer spectrophotometers operated in Manchester and Reading as part of the UK Column Ozone and Spectral UV Radiation monitoring programme.

Figure 6-10 The SO_2 plume recorded by the GOME satellite[55]



7 Where to find more information

This section provides details of sources of further information on the UK's air quality, including media and web-based resources.

The Defra air quality information web resource at http://www.defra.gov.uk/environment/airquality/index.htm contains details of what the UK is doing to tackle air pollution, and the science and research programmes in place.

As shown in previous sections, the UK's air monitoring programmes produce very large amounts of data. The UK's **Air Quality Archive** at www.airquality.co.uk enables wide access and use of air quality information in the UK. The main functions are:

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

The Air Quality Archive is also the national repository for historical ambient air quality measurements and emissions data. It contains measurements from automatic measurement programmes dating back to 1972, together with non-automatic 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.

Similar national archives have also been developed for Scotland, Wales and Northern Ireland:

- The Welsh Air Quality Archive at www.welshairquality.org.uk
- The Scottish Air quality Archive at www.scottishairquality.co.uk
- The Northern Ireland Archive at www.airqualityni.co.uk

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

The UK Air Quality Archive also provides a twice-daily air quality forecast, which is further disseminated via email and the **Air Pollution Information Service**, a free telephone service on 0800 556677. Latest forecasts are issued twice daily, at http://www.airquality.co.uk/archive/uk_forecasting/apfuk_home.php

Detailed pollutant emission data for the UK are available from the National Atmospheric Emissions Inventory (NAEI) at www.naei.org.uk.

Additional information from the Devolved Administrations can be found at:

- The Scottish Government Air Quality pages on http://www.scotland.gov.uk/Topics/Environment/Pollution/16215/4561

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

- The Northern Ireland DoE Environmental Policy Division website at http://www.doeni.gov.uk/epd

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