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Air Pollution in the UK 2011

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A report prepared by AEA for Defra and the Devolved Administrations.

Title	Air Pollution in the UK 2011
Authors	AEA: Tony Bush, Sarah Choudrie, Beth Conlan, Stewart Eaton, Agnieszka Griffin, Andrew Kent, Rebecca King, Justin Lingard, Alison Loader, Carlos Martinez, Anne Misra, Neil Passant, John Stedman, Jaume Targa[a], Keith Vincent, Paul Willis. [a]4sfera Defra: Emily Connolly

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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 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 2011 submission on ambient air quality to the EU Commission, presenting air quality modelling data and measurements from national air pollution monitoring networks. This includes details of the exceedances reported in 2011, with an overview of changes over time.
The pollutants covered in this report are:

- Sulphur dioxide (SO_2)
- Nitrogen oxides (NO_x) comprising NO and NO_2
- PM_{10} and $PM_{2.5}$ particles
- Benzene
- 1,3-Butadiene
- Carbon Monoxide (CO)
- Metallic Pollutants
- 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 2011 results can be summarised as follows:

- There were no exceedances of any EU limit values for SO_2.
- The UK exceeded the limit value for hourly mean nitrogen dioxide in three zones (out of the total of 43).
- The UK exceeded the limit value for annual mean nitrogen dioxide in 40 zones.
- Of these 40 zones, nine were covered by a time extension during 2011; in these cases, the limit value plus a margin of tolerance applied. Five of the nine zones were within the margin of tolerance. Therefore, the number of zones that exceeded the limit value for annual mean NO_2, plus margin of tolerance where applicable, was 35.
- One zone (Greater London Urban Area) exceeded the daily limit value for PM_{10} during the year, after subtraction of the contribution from natural sources. A time extension until June 2011 was granted in respect of this zone and limit value and a margin of tolerance was in force until that date. The limit value plus margin of tolerance was not exceeded in 2011.
- All zones met the limit value for annual mean concentration of PM_{10} particulate matter.
- All zones met the target value for annual mean concentration of $PM_{2.5}$ particulate matter, and the Stage 1 limit value, which comes into force in 2015. After subtraction of the natural contribution, two zones did not meet the Stage 2 limit value which must be met by 2020.
- Exceedances were reported for the long term ozone objective for human health in all 43 zones, and exceedances were reported for the long term ozone objective for vegetation in three zones.
- Two zones exceeded the target value for nickel in 2011, as has been the case since 2008.
- Seven zones exceeded the target value for benzo[a]pyrene in 2011 (compared with eight in 2010).

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 http://uk-air.defra.gov.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 affect human health and quality of life. It can also have major impacts on ecosystems and the 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 European Union (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 the 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 Union must comply with Directive 2008/50/EC on Ambient Air Quality and Cleaner Air for Europe[1] and the 4th Air Quality Daughter Directive[2] (2004/107/EC). These Directives 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.

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 of the assessment are submitted to the European Commission in September each year, in the form of a standard questionnaire which each Member State must complete. This is referred to in this report as "the Questionnaire". 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 2011" continues this series, and this report has two aims:

- To provide a summary of the UK's 2011 annual report to the Commission, based upon measurements and modelling results. A separate Compliance Assessment Summary document, based upon Section 4 of this report, is intended to accompany the UK's 2011 data submission to the Commission, providing information to make it more understandable to the public.

- To provide information to a wider group of stakeholders and members of the public. This includes a detailed analysis of air pollution in the UK, and information on how and why the UK carries out air quality assessments. This report covers not only the UK's statutory monitoring (necessary to fulfill the requirements of the Directives), but also other monitoring, which is not required to be reported to the Commission but is undertaken for research purposes to increase our understanding of the UK's pollution climate.

This report will:

- Outline the legislative and policy framework in Europe and the UK, within which the UK's monitoring is carried out *(Section 2).*

- Describe the evidence base underpinning the UK's air quality assessment: 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 *(Section 3)*.

- Present an assessment of the UK's compliance with the limit values, target values and long term objectives set out in the Air Quality Directive and the 4th Daughter Directive for 2011, and compare this with recent years. This is based upon the data submitted to the European Commission *(Section 4).*

- Investigate the spatial distribution of the main pollutants of concern within the UK during 2011, and look at how ambient concentrations have changed in recent years (*Section 5).*

- Investigate pollution events – "episodes" of high pollution – that occurred during 2011, and discuss their causes and effects (*Section 6*).

- Advise the reader on where to obtain more information (*Section 7*).

The report covers 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, together with a suite of five metallic elements (lead, arsenic, cadmium, nickel and mercury).

Further information on air quality in the UK can be found on Defra's online UK Air Information Resource (UK-AIR), at http://uk-air.defra.gov.uk/.

2 Legislative and Policy Framework

2.1 European Background

European Union 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 Union action is designed to:

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

The air quality policy adopted by the European Union has involved two complementary approaches;

(i) controlling emissions at source, and
(ii) the setting of long-term ambient air quality objectives.

The mechanism of controlling emissions and setting air quality objectives has been through various European Union Directives. All Member States must incorporate - or "transpose" - the provisions of EU Directives into their own national law by a specified date. The two main Directives are described below.

2.1.1 The Air Quality Directive and Fourth Daughter Directive

As summarised in section 1, 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 (referred to as the Air Quality Directive) substantially revised and merged four previous directives and one Decision:

- Directive 1996/62/EC on Ambient Air Quality Assessment and Management (the Framework Directive)[3], 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[4] (1999/30/EC), which set limit values for sulphur dioxide, oxides of nitrogen, particulate matter as PM_{10}, and lead.
- The Second Daughter Directive[5] (2000/69/EC), which set limit values for carbon monoxide (CO) and benzene.
- The Third Daughter Directive[6] (or 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[8]), 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 2008 Air Quality Directive retained all the existing air quality standards, and also introduced a framework for assessing $PM_{2.5}$ particulate matter (a parameter which had not been covered by the previous legislation). This included limit values, an average exposure indicator (AEI) and a national exposure reduction target. The exposure reduction target aims to obtain maximum health benefits for most people by reducing pollutant levels across the whole urban area, rather than focussing action on "hot-spot" areas exceeding limit values.

The Air Quality Directive also provided greater clarity on a number of issues, and set out requirements for:

- Setting up monitoring stations for $PM_{2.5}$.
- Quantification of the contribution from 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 Air Quality Directive and Fourth Daughter Directive were transposed by the Air Quality Standards Regulations 2010[9] in England, the Air Quality Standards (Scotland) Regulations 2010[10] in Scotland, the Air Quality Standards (Wales) Regulations 2010 in Wales[11] and the Air Quality Standards Regulations (Northern Ireland) 2010[12].

As of 12th December 2011, Commission Implementing Decision 2011/850/EU introduced new rules for Directives 2004/107/EC and 2008/50/EC as regards to the reciprocal exchange of information and reporting on ambient air quality. These rules are commonly known as the air quality e-reporting Implementing Provisions for Reporting (IPR).

2.1.2 **The National Emissions Ceilings Directive**

The National Emissions Ceilings Directive[13] (2001/81/EC) came into force in 2001, and has been transposed into UK legislation as The National Emission Ceilings Regulations 2002. This Directive sets national emission limits or "ceilings" for the four main air pollutants responsible for the acidification and eutrophication (nutrient enrichment) of the natural environment, and the formation of ground level ozone which impacts both human health and the environment. Emissions of these pollutants can impact either locally or far from their source. The latter is known as transboundary air pollution. The four pollutants for which national emission ceilings are set are:

- sulphur dioxide,
- oxides of nitrogen,
- volatile organic compounds
- ammonia.

Considerable action has been taken to reduce UK emissions at source including fitting pollution reduction technology to industrial installations and using cleaner fuels. This has helped to ensure that total UK emissions have fallen to levels below the 2010 ceilings set in the Directive. The UK has met all four of its national emission ceilings since 2009.

Total UK emissions for the 2011 calendar year will be published in December 2012. It is expected that a revised National Emissions Ceilings Directive setting tighter emission reduction targets to be met by 2020 and beyond will be proposed following conclusion of the current EU review of air quality 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 is currently estimated to reduce average UK life expectancy (from birth) by 6 months[14]. Moreover, it is now firmly established that air pollution (particulate matter, sulphur dioxide and ozone) contributes to thousands of hospital admissions per year[15].

As highlighted previously, the UK - as a Member State of the European Union - 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[16] 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[17] are at least as stringent as the limit values of the relevant EU 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 that for $PM_{2.5}$, the health impacts of particulate pollution are particularly associated with this fine fraction. The 2007 Strategy introduced:

- **An air quality objective** for $PM_{2.5}$, 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 EU Directive.

2.2.2 National Air Quality Statistics

The UK currently reports on the following two indicators as National Air Quality Statistics for ambient air:

- **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).
- **Number of days in the year when air pollution is "moderate" or higher**. This may relate to any one of five key air pollutants and is based on the UK's air quality index (see section 2.2.3). Until the end of 2011, the five pollutants were nitrogen dioxide, sulphur dioxide, ozone, PM_{10} particles and carbon monoxide. As of 1st Jan 2012, $PM_{2.5}$ particles are planned to replace carbon monoxide in this suite of pollutants. (The thresholds used to define "moderate" and higher pollution levels in the air quality index were also revised at the beginning of 2012.)

A provisional statistical release for 2011 was issued in February 2012 and a final release in April 2012. The National Air Quality Statistics summary for 2011 is available from the Defra website[18].

In previous years these indicators were also reported on as part of a suite of 68 national development indicators for the UK Government's Sustainable Development Strategy[19]. Defra is currently developing a new set of sustainable development indicators. This will make progress towards a more sustainable future more transparent and easier for people to track.

2.2.3 The Air Pollution Forecasting System

The Air Quality Directive (2008/50/EC) states that *"Member States shall ensure that timely information about actual or predicted exceedances of alert thresholds, and any information threshold is provided to the public."* This includes a pollution forecast each day for the following day. UK air pollution forecasts cover five pollutants; nitrogen dioxide, sulphur dioxide, ozone, PM_{10} particles and $PM_{2.5}$ particles (the UK has opted to include PM_{10} and $PM_{2.5}$ although there is currently no alert threshold for these pollutants and therefore no mandatory requirement to include them in forecasts). For 16 of the UK's zones and agglomerations (these are explained in section 4), air pollution levels are predicted for rural areas, urban areas, and 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 index 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, high or very high (Table 2-1). The air quality indices for each pollutant are published on the UK-AIR website at http://uk-air.defra.gov.uk/air-pollution/daqi. The group of pollutants covered, and the thresholds between the various index bands, were updated by Defra as of 1st Jan 2012, in the light of recommendations by the Committee on the Medical Effects of Air Pollutants (COMEAP) in their recent review of the UK air quality index[20]. The UK also opted to add $PM_{2.5}$ particles to the group of pollutants, as of 1st Jan 2012. $PM_{2.5}$ replaced carbon monoxide, which has now been reduced to levels far below legal limits.

An air pollution forecast for the following 24 hours is prepared each afternoon for the 4pm 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://uk-air.defra.gov.uk/subscribe. Further information on how the forecasts are produced can be found on the website.

The daily forecast is available from UK-AIR and from the Scottish, Welsh and Northern Ireland air quality websites (see section 7), and is further disseminated via e-mail and a free recorded information telephone helpline on 0800 556677. Latest forecasts are issued twice daily, at: http://uk-air.defra.gov.uk/forecasting/. Defra also provide automated updates on current and forecast air quality via Twitter – see http://uk-air.defra.gov.uk/twitter.

In addition to forecasts, Defra also issue Air Pollution Alerts via UK-AIR, if any of the information or alert thresholds in the Air Quality Directive are exceeded. These thresholds relate to ozone, sulphur dioxide and nitrogen dioxide. Alerts are displayed for a 24 hour period after the threshold has been exceeded.

Table 2-1 Air Pollution Bandings and Index, and Accompanying Health Messages

Air Pollution Banding	Value	Accompanying health messages for at-risk groups and the general population	
		At-risk individuals*	**General population**
Low	1-3	**Enjoy** your usual outdoor activities.	**Enjoy** your usual outdoor activities.
Moderate	4-6	Adults and children with lung problems, and adults with heart problems, **who experience symptoms**, should **consider reducing** strenuous physical activity, particularly outdoors.	**Enjoy** your usual outdoor activities.
High	7-9	Adults and children with lung problems, and adults with heart problems, should **reduce** strenuous physical exertion, particularly outdoors, and particularly if they experience symptoms. People with asthma may find they need to use their reliever inhaler more often. Older people should also **reduce** physical exertion.	Anyone experiencing discomfort such as sore eyes, cough or sore throat should **consider reducing** activity, particularly outdoors.
Very High	10	Adults and children with lung problems, adults with heart problems, and older people, should **avoid** strenuous physical activity. People with asthma may find they need to use their reliever inhaler more often.	**Reduce** physical exertion, particularly outdoors, especially if you experience symptoms such as cough or sore throat.

**Adults and children with heart or lung problems are at greater risk of symptoms. Follow your doctor's usual advice about exercising and managing your condition. It is possible that very sensitive individuals may experience health effects even on Low air pollution days. Anyone experiencing symptoms should follow the guidance provided on the web page at http://uk-air.defra.gov.uk/air-pollution/daqi .*

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[21]. 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[22] and Policy Guidance[23] 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 Defra's Local Air Quality Management web pages.

Local Authorities in England, Scotland and Wales have completed four rounds of review and assessment against the Strategy's objectives prescribed in the 2000 Air Quality Regulations[24], together with subsequent amendments[25,26,27,28]. The fifth round began in 2012. 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 5 having begun in April 2012.

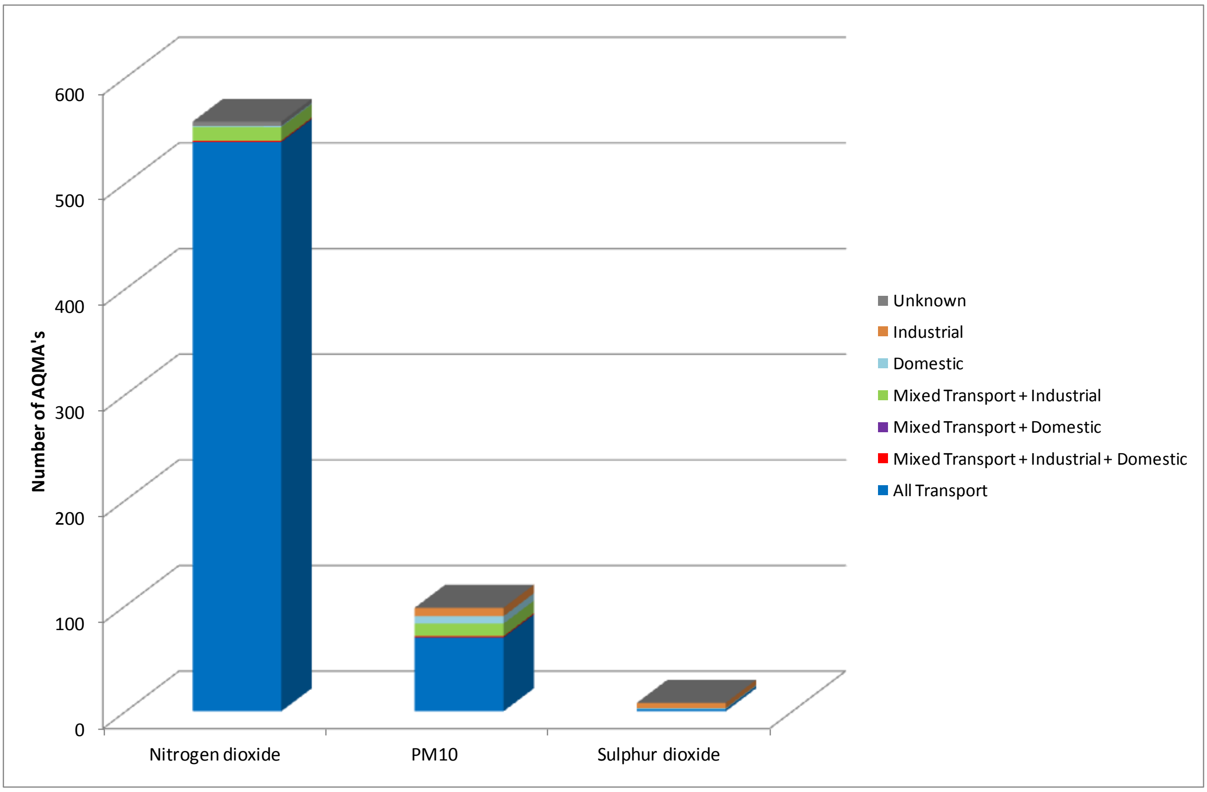
When the Review and Assessment process identifies an exceedance of an Air Quality Strategy objective, the Local Authority must declare an "Air Quality Management Area" (AQMA) and develop an Action Plan to tackle problems in the affected areas. Such a plan may include a variety of measures such as congestion charging, traffic management, planning and financial incentives. At present, 252 Local Authorities – roughly 62% of those in the UK – have one or more AQMAs. Information on the UK's AQMAs is summarised in Table 2-2 below. Please note some AQMAs are for more than one pollutant, and many Local Authorities have more than one AQMA.

Table 2-2 Current UK-wide status of Air Quality Management Areas (AQMAs) and appraised Action Plans (as of Jun 2012 except where specified.)

Region	Total No. of Local Authorities	Number of LAs with AQMAs	Due to NO_2 (as of Jun 2012)	Due to PM_{10} (as of Jun 2012)	Due to SO_2 (as of Dec 2011)	Due to Ben-zene	LA's with Action Plans sub-mitted	LA's with Action Plans awaited
England (exclud-ing London)	292	186	455	43	7	0	156	79
London	33	33	33	29	0	0	33	0
Scotland	32	13	20	19	1	0	9	7
Wales	22	8	31	1	0	0	5	6
N. Ireland	26	12	19	6	0	0	13	5
TOTAL	**405**	**256**	**558**	**98**	**8**	**0**	**216**	**97**

Most Air Quality Management Areas in the UK are in urban areas and result from traffic emissions of nitrogen dioxide or PM_{10}. Emissions from transport (road and other types) are the main source in 97% of the AQMAs declared for NO_2; only a few have been declared as a result of other sources, such as industrial or domestic emissions. Figure 2-1 shows the numbers of AQMAs in the UK that have been declared as a result of various sources of pollutant emissions.

Figure 2-1 Number of Air Quality Management Areas resulting from Various Sources



The locations of the UK's AQMAs are shown in Figure 2-2.

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.

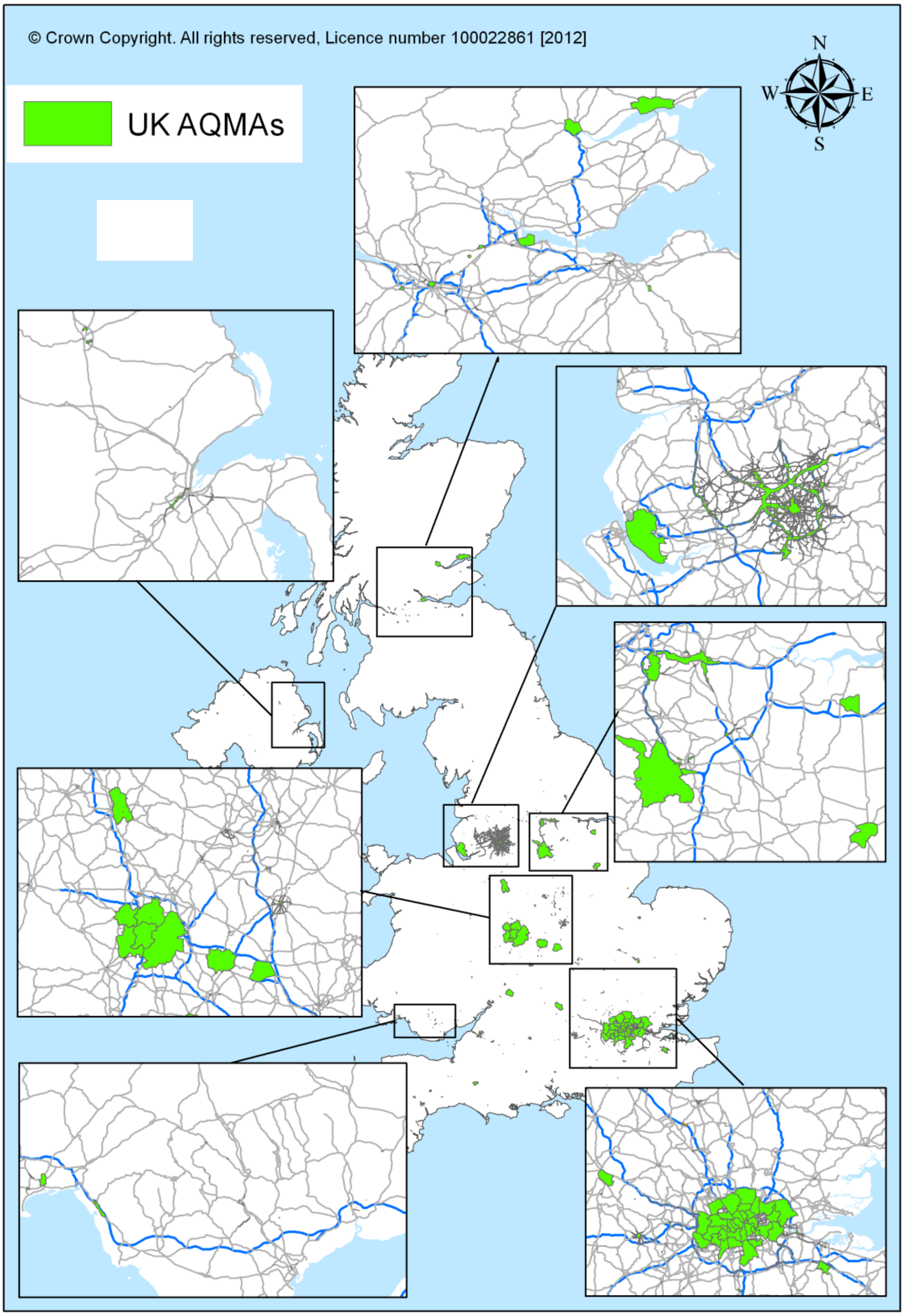
Information on the UK's Air Quality Management Areas (AQMAs) is published on the Defra website. Information is provided on each one, together with a map of the AQMA, where available.

As shown in Table 2-2, a total of 313 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 Government in Wales or Department of Environment in Northern Ireland) to tackle pollution on the motorways/trunk roads.

Advice for Local Authorities on preparing an Action Plan is available from the Defra LAQM web pages at http://laqm.defra.gov.uk/action-planning/aqap-supporting-guidance.html.

Figure 2-2 Air Quality Management Areas in the UK, as at end of 2011



3 The Evidence Base

This section explains the evidence base for the annual assessment of compliance with the EU Directives on ambient air quality. First, the pollutants of concern are briefly described. The section goes on to explain how and where these pollutants are monitored in the UK. It also describes the air quality modelling techniques which are used to supplement the UK's monitoring programme.

3.1 Pollutants of Concern

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, the National Atmospheric Emissions Inventory and UK-AIR.

3.1.1 Sulphur Dioxide

Sulphur dioxide (SO_2) is an acidic gas, formed by the oxidation of sulphur impurities in fuels during combustion processes, particularly of solid fuels and petroleum, which account for about 90% of SO_2 emissions. A very high proportion of UK emissions originate from power stations and industrial sources. These sources usually have high chimneys, ensuring effective dispersion of the emissions under normal conditions. An important source of ground level SO_2 has historically been solid fuel use in domestic heating systems. SO_2 emissions and atmospheric concentrations have decreased sharply, by over 90% in the past forty years, as a result of decreasing use of high sulphur coal and increasing use of abatement equipment in the industrial and power generation sectors. In this report, sulphur dioxide concentrations are expressed in microgrammes per cubic metre (µg m^{-3}) – i.e. 10^{-6} grammes per cubic metre.

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 UK towns and cities are generally below peak limit values set by the European Commission to protect human health. The limit value for hourly mean SO_2 (which may be exceeded up to 24 times in the calendar year) is 350 µg m^{-3}. In 2011 the maximum hourly mean measured at any site in the UK national monitoring network, the Automatic Urban and Rural Network (AURN), was 460 µg m^{-3}. This was measured at an industrial site. At background and traffic sites the maximum hourly mean in the AURN was 293 µg m^{-3}. The annual average across all sites in the AURN (including traffic sites) was just 2.9 µg m^{-3}. Apart from industrial locations, the 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 the formation of secondary sulphate particles in the atmosphere. Health studies have shown that increased concentrations of particulate matter (PM), especially the fine particle fractions which include sulphates, can have a significant negative effect on human health. 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 plants at high concentrations of SO_2, 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.

3.1.2 Nitrogen Oxides

In the context of air quality, nitrogen oxides usually 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, industrial combustion and road transport. In this report, concentrations of oxides of nitrogen are expressed in units of microgrammes per cubic metre ($\mu g\ m^{-3}$).

NO is not considered to be of concern with respect to human health. However, it is rapidly oxidised in the environment, forming NO_2. At high concentrations NO_2 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 as other pollutants.

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, particularly in locations with poor dispersion characteristics such as street canyons. Annual mean concentrations of NO_2 beside busy urban roads frequently exceed 40 $\mu g\ m^{-3}$ (the limit value set by the European Union to protect human health) and may reach 80 $\mu g\ m^{-3}$ or higher (as observed in 2011 at the London Marylebone Road monitoring station). Concentrations above the Air Quality Directive limit values for human health occur at roadside in most large cities in the UK. This is not a problem specific to the UK and is common in many other European countries.

At urban background locations in the UK, i.e. within built-up areas but away from busy roads, annual mean NO_2 concentrations are lower, typically in the range 15-40 $\mu g\ m^{-3}$. However, some urban background sites (for example in central London, Manchester and Glasgow) often measure annual mean concentrations above 40 $\mu g\ m^{-3}$.

Peak hourly mean concentrations exceed 100 $\mu g\ m^{-3}$ at most urban locations, and occasionally exceed 300 $\mu g\ m^{-3}$ at the most congested urban roadside sites.

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. Nitrogen dioxide can undergo chemical reactions in air to produce acidic compounds such as nitric acid, which contribute to the production of acid deposition.

In the presence of sunlight, nitrogen oxides can react with Volatile Organic Compounds (VOCs) to produce photochemical pollutants including ozone, which is associated with ill-health and can also damage vegetation. NO_X also contributes to the formation of secondary nitrate particles in the atmosphere, thus is implicated in the well studied adverse health effects of increased concentrations of fine particulate matter.

3.1.3 **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, e.g. vehicles 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 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 $\mu g\ m^{-3}$) of PM that is less than 10 µm in diameter[a]. $PM_{2.5}$ refers to the mass concentration of particles less than 2.5 µm in diameter. Both PM_{10} and $PM_{2.5}$ are reported in units of microgrammes per cubic metre ($\mu g\ m^{-3}$).

[a] 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.

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, particles in both the >$PM_{2.5}$ and <$PM_{2.5}$ size fractions 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 of the 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 below about 50 µg m^{-3} for PM_{10}.

Annual mean PM_{10} concentrations for urban background and roadside sites are also reported annually as a National Air Quality Statistic. The annual mean PM_{10} concentration for 2011 across all sites was 21 µg m^{-3}.

3.1.4 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 broken down by chemical reactions in the atmosphere over a period of 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 concentrations are expressed here in microgrammes per cubic metre (µg m^{-3}).

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, a European limit value has been set, of 5 µg m^{-3} as an annual mean. Below this value, the risk of health effects is very small. The UK is compliant with this limit value for benzene in all outdoor non-occupational locations. No sites in the UK exceeded the benzene limit value in 2011, and the annual average across all UK monitoring sites was just 0.7 µg m^{-3}.

3.1.5 Carbon Monoxide

Carbon monoxide (CO) is a colourless, odourless gas produced when fuels containing carbon (such as gas, oil, coke, 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.

Ambient concentrations of CO are higher than those of the other pollutants featured here, and are usually expressed in milligrammes (i.e. 10^{-3} grammes) per cubic metre, mg m^{-3}. However, the UK is compliant with the European limit value for CO in all outdoor non-occupational locations, with the 8-hour running mean concentration consistently below 10 mg m^{-3} at all monitoring sites in recent years.

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.

3.1.6 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. Ozone concentrations are greatest in the summer (usually on hot, sunny, windless days) and lowest in the winter months.

The main influences on ozone concentrations have been discussed in detail by AQEG[29]. These influences vary geographically and between different seasons and impact in different ways on different ozone metrics such as annual means and exceedance statistics. These influences are:

- Regional photochemical ozone production, which has a strong influence on peak ozone concentrations;
- An urban decrement due to local emissions of NOx, as described above;
- The hemispheric background.

Rural sites in the north west of the UK are the most likely to show the influences of changes in the hemispheric background.

O_3 is an oxidising agent and acts as an irritant, causing 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. It is possible that very sensitive individuals may experience health effects even on Low air pollution days

Ozone concentrations are expressed here in microgrammes per cubic metre (µg m^{-3}). In 2011, the annual mean daily maximum 8-hour running mean was typically in the range 40-60 µg m^{-3} at urban sites, and typically in the range 65-78 µg m^{-3} at rural sites where ozone concentrations are typically higher.

Controls limiting the emissions of VOCs from road transport and large scale industry have led 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 exceedances 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.

3.1.7 **Lead**

The majority of lead (Pb) 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 cause 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}.

Concentrations of Pb in this report are given in nanogrammes per cubic metre (ng m^{-3}). Recent typical annual mean concentrations of lead range from less than 5 ng m^{-3} at rural monitoring sites, to 50-90 ng m^{-3} at urban industrial sites. The EU limit value for Pb (0.5 µg m^{-3} or 500 ng m^{-3}) is met throughout the UK.

3.1.8 **Other Metallic Elements**

Four metallic pollutants are covered by the Fourth Daughter Directive: nickel (Ni), arsenic (As), cadmium (Cd) and mercury (Hg). Concentrations are reported in nanogrammes per cubic metre (ng m^{-3}). Health effects of these metals are only expected at elevated levels in excess of the 4th Daughter Directive target values.

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. Annual mean ambient particulate phase concentrations in the urban environment are typically of the order of 1 ng m^{-3} with the exception of a few industrial areas, where annual means above 20 ng m^{-3} may occur, exceeding the 4th Daughter Directive target value of 20 ng m^{-3}.

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. Measured UK annual mean concentrations in the particulate phase range from approximately 0.1 ng m^{-3} to approximately 1.2 ng m^{-3}, meeting the 4th Daughter Directive target value of 6 ng m^{-3}.

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. Annual mean particulate phase concentrations in the UK currently range from approximately 0.02 ng m^{-3} to approximately 3 ng m^{-3}, and meet the 4th Daughter Directive target value of 5 ng m^{-3}.

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. There is no target value for mercury. Annual mean ambient concentrations (total of vapour and particulate phases) are typically in the range 1-3 ng m^{-3}, although higher concentrations (tens of ng m^{-3}) have been measured at industrial sites.

3.1.9 **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. Concentrations of PAH including benzo[a]pyrene are reported in nanogrammes per cubic metre (ng m^{-3}).

The main sources of ambient B[a]P include road transport, domestic solid fuel use and activities at iron and steel plants. 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.

Annual mean concentrations in most urban areas are below the EU target value of 1.0 ng m^{-3}: the only exceptions are areas with specific local sources – such as industrial installations or domestic solid fuel burning.

3.2 Assessment of Air Quality in the UK

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 for compliance assessment. 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. Modelled compliance assessments are required for a total of 12 air pollutants each year. The models have been designed to provide a systematic and consistent assessment for all of these pollutants. This assessment needs to be completed each year over the relatively short period between the time when the input data, including ratified monitoring data and emission inventories, are first available and the deadline for reporting of the end of September.

Local Air Quality Management (LAQM) modelling is different in scope, purpose and methodology from the national modelling and 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 3.5 for more details on modelling.

3.3 Current UK Air Quality Monitoring

During 2011 there were 277 national air quality monitoring sites across the UK, comprising several networks, 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 (the numbers of sites shown in this table add up to considerably more than 277, because some sites belong to more than one network – for example the 37 Non-Automatic Hydrocarbon Network sites are co-located with AURN sites). This table shows the numbers of sites in operation during part or all of 2011.

3.3.1 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 Defra's online UK Air Information Resource, UK-AIR at http://uk-air.defra.gov.uk/.

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.

3.3.1.1 Use of Non Reference Method Techniques for Particulate Matter

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 instruments deployed in the original tests (the FDMS 8500, Partisol 2025 and PM_{10} Unheated Beta Attenuation Monitor 1020), the results and recommendations are still valid[32]. This justifies the UK's continued use of these instruments within the AURN.

Table 3-1 The UK's Air Quality Monitoring Networks in 2011

Network	Statutory or Research	Pollutants	Number of Sites in 2011
Automatic Urban and Rural Network (AURN)	Statutory	CO, NOx, NO_2, SO_2, O_3, PM_{10}, $PM_{2.5}$.	131
UK Urban and Industrial Metals Network	Statutory	Metals : As,Cd,Co,Cr,Cu,Fe,Hg[p],Hg[t],Mn,Ni,Pb, Pt,Se,V,Zn	24
Non-Automatic Hydrocarbon	Statutory	Benzene	37
Automatic Hydrocarbon	Statutory	Range of VOCs	4
Polycyclic Aromatic Hydrocarbons (PAH). Digitel samplers	Statutory	21 PAH species including benzo[a]pyrene	31
Toxic Organic Micropollutants	Research	Range of toxic organics including dioxins and dibenzofurans.	6
UK Eutrophying and Acidifying Pollutants: NO_2Net (rural diffusion tubes)	Research	NO_2	24
UK Eutrophying and Acidifying Pollutants: AGANet	Research	NO_3,HCl,HNO_3,HONO,SO_2,SO_4	30
UK Eutrophying and Acidifying Pollutants: NAMN	Research	NH_3 and/or NH_4	58
UK Eutrophying and Acidifying Pollutants : PrecipNet	Research	Major ions in rain water	38
European Monitoring and Evaluation Programme (EMEP)	Research and statutory	Wide range of parameters relating to air quality, precipitation, meteorology and composition of aerosol in PM_{10} and $PM_{2.5}$.	2
Particle concentrations and numbers	Research	Total particle number, concentration, size distribution, anions, EC/OC. PM_{10} and $PM_{2.5}$ speciation	5
Black Carbon	Research	Black Carbon	22
Acid Waters Monitoring	Research	Chemical and biological species in water	22
Rural Metals Network	Research	Al,As,Ba,Be,Cd,Co,Cr,Cs,Cu,Fe,Li,Mn,Mo, Ni,Pb,Rb,Sb,Sc,Se,Sn,Sr,Ti,U,V,W,Zn	11 in particulate 14 in rainwater

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"[33]	**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"[34]	**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"[35]	**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"[36]	**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."[37] EN 14907:2005 "Ambient air quality - Standard gravimetric measurement method for the determination of the $PM_{2.5}$ mass fraction of suspended particulate matter"[38]	The AURN uses three methods which are equivalent for one or both pollutants: 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 the **Partisol –** a gravimetric sampler that collects daily samples onto a filter for subsequent weighing.

3.3.2 The UK Urban and Industrial Metals Network

The UK Urban and Industrial 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 and industrial sites, using a method equivalent to the CEN standard method[39]. In 2011, it comprised 24 sites, all of which monitored 15 metals including arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), mercury (Hg), manganese (Mn), nickel (Ni), lead (Pb), platinum (Pt), vanadium (V) and zinc (Zn).

3.3.3 Non-Automatic Hydrocarbon Network

In this network of 37 sites, ambient concentrations of benzene are measured by the CEN standard method[40], 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's limit value for benzene. All sites in the Non-Automatic Hydrocarbon Network are co-located with AURN sites.

3.3.4 Automatic Hydrocarbon Network

The Air Quality Directive also requires measurement and reporting of ozone precursor substances (29 species), which include volatile organic compounds (VOCs). Annex X (ten) of the Directive provides a list of compounds recommended for measurement. Ozone precursor measurement is carried out by the Automatic Hydrocarbon Network.

Automatic hourly measurements of a range of hydrocarbon species (including all those specified in Annex X of the Directive except formaldehyde and total non-methane hydrocarbons), are made using automated pumped sampling with *in-situ* gas chromatography, at five sites in the UK. The VOCs monitored include benzene, which is covered by the Air Quality Directive as a pollutant in its own right.

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.

3.3.5 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, not to be exceeded after 31st December 2012. This network uses the PM_{10} Digitel sampler. Ambient air is sampled through glass fibre filters and polyurethane foam pads, which capture the PAH compounds for later analysis in a laboratory. During 2011, there were 31 sites in this network.

3.3.6 TOMPS Network

This network monitors a range of toxic organic micropollutants (compounds that are present in the environment at very low concentrations, but are highly toxic and persistent). These include dioxins, dibenzofurans and polychlorinated biphenyls. The TOMPS Network consists of six sites in England and Scotland.

3.3.7 UK Eutrophying and Acidifying Pollutants

The UK Eutrophying and Acidifying Atmospheric Pollutants (UKEAP) network provides information on deposition of eutrophying and 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 UKEAP network is an "umbrella" project covering four groups of sites:

- The UKEAP rural NO_2 diffusion tube network (NO_2Net), which measures NO_2 at 24 rural sites.
- The Acid Gas and Aerosol Network (AGANet) which currently comprises 30 sites in the UK, measuring wet bulk deposition on a fortnightly basis.
- The National Ammonia Monitoring Network (NAMN) which characterizes ammonia and ammonium concentrations using passive samplers at 58 locations.
- The Precipitation Network (PrecipNet) which in 2011 consisted of 38 sites at which the chemical composition of precipitation (i.e. rainwater) is measured. The network allows estimates of wet deposition of sulphur and nitrogen chemicals. Samples are collected fortnightly at all 38 sites and daily at 2 sites.

3.3.8 EMEP

EMEP (European Monitoring and Evaluation Programme) is an EU programme set up by Member States to provide governments with qualified scientific information on air pollutants, under the UNECE 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.
- Metallic elements in PM_{10} and precipitation.
- Deposition of inorganic ions.
- Trace gases (ozone, NO_x and SO_2).
- Black carbon, organic carbon (OC) and elemental carbon (EC).
- Ammonia.
- Daily and hourly PM_{10} and $PM_{2.5}$ mass.
- Volatile Organic Compounds.
- Carbonyls.
- CH_4 and N_2O fluxes.

3.3.9 **Particle Concentrations and Numbers**

This research-oriented network currently consists of five measurement sites; two in London, two rural sites at Auchencorth Moss and Harwell, 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 carbon (OC) and elemental carbon (EC).
- 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.

The Air Quality Directive requires that the chemical composition of $PM_{2.5}$ is characterised at background locations in the United Kingdom. Monitoring of the major ions in $PM_{2.5}$ began in 2006 and 2009 at Auchencorth Moss and Harwell, respectively. Measurements of elemental carbon (EC) and organic carbon (OC) began at both stations at the start of 2011. At both stations EC and OC measurements are made using a thermal/optical method involving both reflectance and transmission correction methods. Comparing both correction methods will provide valuable understanding of the measurement process for EC and OC.

3.3.10 **Black Carbon**

Black carbon is fine, dark carbonaceous particulate matter produced from the incomplete combustion of materials containing carbon (such as coal, oil, and biomass such as wood). It is of concern due to health effects, and also as a suspected contributor to climate change.

In 2011 the Black Carbon Network comprises 21 sites across the UK, measuring this parameter using an automatic instrument called an aethalometer. The aethalometer measures black carbon directly, using a real-time optical transmission technique. In 2012 the network was revised to 14 sites[41] to meet the following objectives:

- To maintain coverage of black smoke measurements across the whole UK;
- To maintain continuity of historic datasets;
- To gather data for epidemiological studies of black carbon and health effects
- To gather information about black carbon PM sources in the UK;
- To assess PM reductions from air quality management interventions;
- To quantify the contribution of wood burning to black carbon and ambient PM in the UK; and
- To gather data to address future policy considerations including black carbon and climate change.

The network was developed from a much older and larger national monitoring network, which operated from 1961 to 2006 and measured SO_2 together with "black smoke" - a manual measurement of dark particulate matter. The old black smoke samplers were replaced with automatic aethalometers in 2008 and the network's name was changed to reflect the new parameter.

3.3.11 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 22 monitoring sites including 11 lakes and 11 streams across the UK, monitoring a range of parameters and life forms including sediment, water chemistry, fish, invertebrates, and aquatic organisms.

3.3.12 Rural Metals

The Rural Metals (metals deposition mapping) network measures metal concentrations in PM_{10} (at 11 rural sites) and concentrations in rain water (at 14 rural sites). The concentration fields 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 UK Metals Network (described in section 3.3.2), which predominantly monitors at industrial and urban locations.

3.4 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 Quality 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 over 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 EU limit values where applicable.
- Consistent with Data Quality Objectives[42]. 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 in relation to uncertainty.
- Consistent with methodology guidance defined in EU 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 the process of checking and validating the data. Data entered on the Defra Air Information Resource (UK-AIR at http://uk-air.defra.gov.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 case of the AURN) from the report "QA/QC Procedures for the UK Automatic Urban and Rural Air Quality Monitoring Network (AURN)"[43] available from Defra's air quality web pages.

3.5 Modelling

3.5.1 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 for compliance with European air quality Directives – freeing up resources and ensuring value for money.
- 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.
- Providing 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.

3.5.2 How the Models Work

The national modelling methodology varies between pollutants. The detailed methodology is explained in separate reports[44],[45] (the latest versions of these can be found in the Library section of Defra's UK-AIR website[46]).

Defra's air quality national modelling assessment for the UK consists of two components:

- 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 metals as these are deemed not to have significant traffic-related sources.

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

3.5.3 **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.

3.5.4 **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[47] (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 Assessment of Compliance

4.1 Definition of Zones

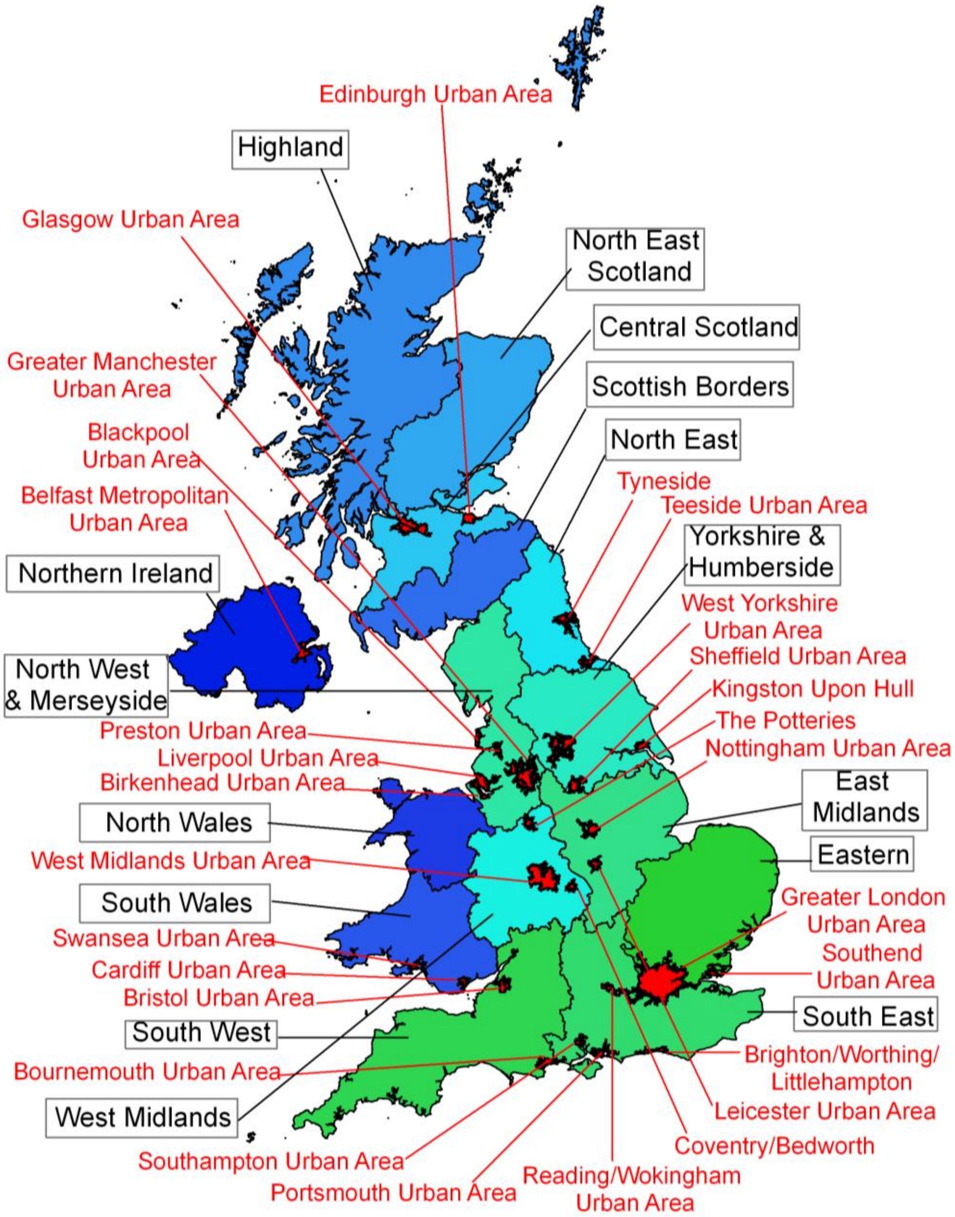
The UK is divided into 43 zones for air quality assessment. There are 28 agglomeration zones (large urban areas) and 15 non-agglomeration zones. Details are included in Form 2 of the Questionnaire (the annual compliance assessment report to the European Commission). Each zone is assigned an identification code. Zones are listed in Table 4-1 and shown in Figure 4-1.

Table 4-1 UK Zones and Agglomerations for Ambient Air Quality Reporting 2011

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 4-1 UK zones and agglomerations for ambient air quality reporting 2011



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

4.2 Air Quality Assessment for 2011

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 the tables below. The tables have been completed as follows:

- Where all measurements were within the relevant limit values in 2011, the table shows this as "OK".
- Where a margin of tolerance is applicable, if some or all measurements were above the limit value, but within the limit value plus margin of tolerance, the table shows this as "≤LV +MOT".
- In the above cases, where compliance was determined by modelling or supplementary assessment, this is indicated by "(m)" – i.e. "OK (m)" or "≤LV +MOT (m)" as appropriate.
- Where locations were identified as exceeding a limit value, limit value plus margin of tolerance, target value, long-term objective, this is identified as ">LV", ">LV+MOT", ">TV" or ">LTO" as applicable.
- Where an exceedance was determined by modelling or supplementary assessment, 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.

Where a time extension has been granted, and a margin of tolerance applies, zones that exceeded the relevant limit value but not the limit value plus margin of tolerance are shaded orange.

The abbreviation "n/a" (not applicable) means that an assessment is not relevant for this zone, such as for the NO_X vegetation critical level in agglomeration zones.

4.2.1 Directive 2008/50/EC on Ambient Air Quality and Cleaner Air for Europe

Sulphur dioxide: the results of the air quality assessment for sulphur dioxide are presented in Form 8a of the Questionnaire.

In 2011, all zones and agglomerations within the UK complied with the limit values for 1-hour mean and 24-hour mean SO_2 concentration, set for protection of human health.

All non-agglomeration zones within the UK also complied with the critical levels for annual mean and winter mean SO_2 concentration, set for protection of ecosystems. (These are not applicable to built-up areas).

Nitrogen dioxide: the results of the air quality assessment for nitrogen dioxide for each zone are presented in Form 8b of the Questionnaire, and summarised in Table 4-2.

Three agglomeration zones - **Greater London Urban Area (UK0001), Glasgow Urban Area (UK0024)** and the **South East (UK0031)** had locations which exceeded the 1-hour limit value (200 µg m^{-3}) on more than the permitted 18 occasions during 2011.

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 (40 µg m^{-3}). This was the case in 40 out of the 43 zones. Three zones ***met*** the annual mean limit value in 2011:

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

The UK has been granted a time extension for compliance with the NO_2 annual limit value in the following zones and agglomerations;

- Nottingham Urban Area,
- Leicester Urban Area,
- Portsmouth Urban Area,
- Reading/Wokingham Urban Area,
- Southend Urban Area,
- Edinburgh Urban Area,
- Cardiff Urban Area,
- Central Scotland zone, and
- North Wales zone.

This exemption applies until 1st January 2015 for all but Reading/Wokingham Urban Area, for which it applies until 1st January 2013. Article 2 of the Commission Decision of 26th June 2012 requires the UK to provide the Commission with data indicating that the concentration levels in these zones remain below the annual limit value plus the maximum margin of tolerance (60 µg m^{-3}) specified in Annex XI to Directive 2008/50/EC. The following zones exceeded the annual mean limit value, but were within the annual mean limit value plus margin of tolerance in 2011:

- Reading/Wokingham Urban Area,
- Southend Urban Area,
- Edinburgh Urban Area,
- Cardiff Urban Area, and
- Central Scotland.

All other 35 zones and agglomerations exceeded the annual mean limit value, or annual mean limit value plus margin of tolerance.

All non-agglomeration zones within the UK complied with the critical level for annual mean NO_X concentration, set for protection of vegetation.

Annual mean concentrations of NO_2 were typically lower in 2011 than in 2010. 2010 was a relatively high year for this pollutant; cold winter weather increased fuel use and therefore emissions.

PM_{10} Particulate matter: the results of the air quality assessment for PM_{10} for each zone are presented in Form 8c of the Questionnaire, and summarised in Table 4-3.

The UK has been granted a time extension for compliance with the 24-hour PM_{10} limit value in the Greater London Urban Area **(UK0001)**. This exemption applies for the period from 11th June 2008 to 10th June 2011. Article 2 of the Commission Decision of 11th March 2011 requires the UK to provide the Commission with data indicating that the concentration levels in this zone have remained below the daily limit value plus the maximum margin of tolerance specified in Annex XI to Directive 2008/50/EC (daily mean of 75 µg m^{-3}, not to be exceeded more than 35 times per calendar year). As a result, for the UK 2011 compliance assessment, the PM_{10} time extension decision for the Greater London Urban Area requires assessment against the maximum margin of tolerance (MOT) of 75 µg m^{-3} as a daily mean between 1st January 2011 and 10th June 2011 and the limit value (LV) of 50 µg m^{-3} as a daily mean between 11th June 2011 and 31st December 2011. In order to be compliant with the requirements of the time extension the total of these two numbers of exceedance days should not exceed 35.

The daily limit value was exceeded in this zone in 2011 but the Greater London Urban Area is classified as compliant due to the maximum MOT in place until 10th June - there were a total of 26 measured exceedances in 2011 (combining exceedances of 75 µg m^{-3} until 10th June and exceedances of 50 µg m^{-3} thereafter). **The daily limit value plus the maximum margin of tolerance was also not exceeded during the period from 11th June 2008 to 31st December 2008 nor in 2009, nor in 2010.**

Provision is made in EU legislation for Member States to subtract the PM_{10} contribution due to natural events or natural contributions (2008/50/EC Article 20), and this has been carried out where it is required. Prior to the subtraction of natural sources, the West Midlands agglomeration exceeded the 24-hour PM_{10} limit value on more than 35 occasions in 2011: no time extension is in force for this zone. However, subtraction of the contribution from natural sources, as is required by the Directive, reduced the number of exceedances from 37 to 31, which is within the permitted maximum.

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

$PM_{2.5}$ Particulate matter: the results of the air quality assessment for $PM_{2.5}$ for each zone are presented in Form 9c of the Questionnaire, and summarised in Table 4-4. This table includes the target value (25 µg m^{-3} to be achieved by 1st Jan 2010) the Stage 1 limit value (25 µg m^{-3} to be achieved by 1st Jan 2015) and the Stage 2 limit value (20 µg m^{-3} to be achieved by 1st Jan 2020). All three apply to the calendar year mean.

Natural contributions have been removed from $PM_{2.5}$ exceedances listed in Table 4-4. Exceedance of limit values of $PM_{2.5}$ due to natural events (1999/30/EC Article 5(4)) or natural contributions (2008/50/EC Article 20) are as follows:

- The modelled exceedance of the Stage 2 limit value in zone UK0002 (West Midlands) is removed by the subtraction of the natural contribution (sea salt).
- The measured exceedances of the Stage 2 limit value in zone UK0001 (site: Marylebone Road, annual mean: 24 µg m^{-3}) and zone UK0024 (site: Glasgow Kerbside, annual mean: 22 µg m^{-3}) remain even if the natural contribution (sea salt) is subtracted.

Annual mean concentrations of $PM_{2.5}$ were within the target value of 25 µg m^{-3} in all zones and agglomerations. Under the Air Quality Directive, Member States will be required to achieve a national exposure reduction target for $PM_{2.5}$, over the period 2010 to 2020. This is based on the Average Exposure Indicator statistic. The Average Exposure Indicator (AEI) for the UK has been calculated as follows: the mean $PM_{2.5}$ concentration at appropriate UK background urban sites only was calculated for three consecutive calendar years 2009, 2010 and 2011. The values obtained were as follows:

- 2009: 13 µg m^{-3}
- 2010: 13 µg m^{-3}
- 2011: 14 µg m^{-3}.

The mean of these three values (to the nearest integer) is 13 µg m^{-3}. This is taken as the AEI for the reference year of 2010. The AEI for the reference year 2010 determines the National Exposure Reduction Target (NERT), to be achieved by 2020 (see Annex XIV of the Air Quality Directive). With a reference year AEI of 13 µg m^{-3}, the Air Quality Directive sets an exposure reduction target of 15%. The detailed methodology and results of this calculation are presented in Defra's technical report on UK air quality assessment[48].

Carbon monoxide, benzene and lead: the results of the air quality assessment for lead, benzene and CO are presented in Forms 8d, 8e and 8f of the Questionnaire respectively. All zones or agglomerations were compliant with the limit values for these three pollutants in 2011.

Ozone: the results of the air quality assessment for ozone for each zone are presented in Form 9a of the Questionnaire, and summarised in Table 4-5.

For ozone, there is a target value based on the maximum daily 8-hour mean. There is also a long-term objective for protection of human health, based on the maximum daily 8-hour mean. All 43 zones and agglomerations were compliant with this target value. However, all 43 zones and agglomerations were above the long-term objective (LTO) for health.

There is also a target value based on the AOT40 statistic[1]. The AOT40 statistic (expressed in µg m^{-3} .hours) is the sum of the difference between hourly concentrations greater than 80 µg m^{-3} (= 40 ppb) and 80 µg m^{-3} over a given period using only the one-hour values measured between 0800 and 2000 Central European Time each day. All 43 zones and agglomerations met the target value based on the AOT40 statistic. There is also a long-term objective, for protection of vegetation, based on this statistic. Three zones were above the long-term objective for vegetation: **Greater London, Eastern and East Midlands.**

Table 4-2 Results of Air Quality Assessment for Nitrogen Dioxide in 2011

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

LV = limit value, MOT = margin of tolerance, (m) indicates that the compliance or exceedance was determined by modelling.

Asterisk (*) indicates a time extension granted.

Table 4-3 Results of Air Quality Assessment for PM_{10} in 2011 After Subtraction of Contribution from Natural Sources.

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

**Note: The UK has been granted a time extension to achieve compliance with the daily mean limit value for PM_{10} in Greater London Urban Area. Consequently, the maximum margin of tolerance is in force for the duration of the extension.*

Prior to the subtraction of natural source contribution the West Midlands (UK0002) exceeded the daily mean limit value on more than the permitted 35 occasions: no time extension is in force. However, subtraction of the contribution from natural sources reduced the number of exceedances of this limit value from 37 to 31 which is within the permitted maximum. Natural sources have only been subtracted for zones UK0001 and UK0002 in this table.

LV = limit value, (m) indicates that the compliance or exceedance was determined by modelling.

Table 4-4 Results of Air Quality Assessment for $PM_{2.5}$ in 2011 After Subtraction of Contribution from Natural Sources.

Zone	Zone code	$PM_{2.5}$ target value (annual mean)	$PM_{2.5}$ Stage 1 limit value (annual mean, for 1st Jan 2015)	$PM_{2.5}$ Stage 2 limit value (annual mean, for 1st Jan 2020)
Greater London Urban Area	UK0001	OK	OK	> LV
West Midlands Urban Area	UK0002	OK	OK	OK (m)
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	OK	OK
Nottingham Urban Area	UK0008	OK	OK	OK
Bristol Urban Area	UK0009	OK	OK	OK
Brighton/Worthing/Littlehampton	UK0010	OK	OK	OK
Leicester Urban Area	UK0011	OK	OK	OK
Portsmouth Urban Area	UK0012	OK	OK	OK
Teesside Urban Area	UK0013	OK	OK	OK
The Potteries	UK0014	OK	OK	OK
Bournemouth Urban Area	UK0015	OK	OK	OK
Reading/Wokingham Urban Area	UK0016	OK	OK	OK
Coventry/Bedworth	UK0017	OK (m)	OK (m)	OK (m)
Kingston upon Hull	UK0018	OK	OK	OK
Southampton Urban Area	UK0019	OK	OK	OK
Birkenhead Urban Area	UK0020	OK	OK	OK
Southend Urban Area	UK0021	OK (m)	OK (m)	OK (m)
Blackpool Urban Area	UK0022	OK (m)	OK (m)	OK (m)
Preston Urban Area	UK0023	OK	OK	OK
Glasgow Urban Area	UK0024	OK	OK	> LV
Edinburgh Urban Area	UK0025	OK	OK	OK
Cardiff Urban Area	UK0026	OK (m)	OK (m)	OK (m)
Swansea Urban Area	UK0027	OK	OK	OK
Belfast Urban Area	UK0028	OK	OK	OK
Eastern	UK0029	OK	OK	OK
South West	UK0030	OK	OK	OK
South East	UK0031	OK	OK	OK
East Midlands	UK0032	OK	OK	OK
North West & Merseyside	UK0033	OK	OK	OK
Yorkshire & Humberside	UK0034	OK (m)	OK (m)	OK (m)
West Midlands	UK0035	OK (m)	OK (m)	OK (m)
North East	UK0036	OK	OK	OK
Central Scotland	UK0037	OK	OK	OK
North East Scotland	UK0038	OK	OK	OK
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
Northern Ireland	UK0043	OK (m)	OK (m)	OK (m)

Prior to subtraction of natural source contribution, the West Midlands Urban Area exceeded the Stage 2 limit value (to be met by 1st Jan 2020). Subtraction of natural $PM_{2.5}$ reduced the (modelled) annual mean $PM_{2.5}$ concentration to within the stage 2 limit value. Natural sources have only been subtracted for zones UK0001, UK0002 and UK0024 in this table.

LV = limit value (m) indicates that the compliance or exceedance was determined by modelling.

Table 4-5 Results of Air Quality Assessment for Ozone in 2011

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

TV = target value, LTO = long-term objective, (m) indicates that the compliance or exceedance was determined by modelling.

Measured exceedances of limit values, target values, long term objectives, information thresholds and alert thresholds are also listed within the annual air quality assessment questionnaire. Summary statistics for the exceedances identified at specific monitoring sites are provided in Table 4-6 to Table 4-10.

Table 4-6 Measured Exceedances of the NO_2 Limit Value for Health (1 hour mean)

Site name	Zone code	Number of 1-hour exceedances of LV	Maximum 1-hour concentration ($\mu g\ m^{-3}$)
Camden Kerbside	UK0001	77	342
London Marylebone Road	UK0001	229	304
Glasgow Kerbside	UK0024	31	260
Oxford Centre Roadside	UK0031	35	279

Table 4-7 Measured Exceedances of the NO_2 Limit Value for Health (annual mean)

Site name	Zone code	Annual mean concentration ($\mu g\ m^{-3}$)
Camden Kerbside	UK0001	72
London Bloomsbury	UK0001	50
London Cromwell Road 2	UK0001	66
London Hillingdon	UK0001	55
London Marylebone Road	UK0001	97
London Westminster	UK0001	41
Tower Hamlets Roadside	UK0001	57
Birmingham Tyburn Roadside	UK0002	45
Manchester Piccadilly	UK0003	44
Leeds Headingley Kerbside	UK0004	44
Glasgow Kerbside	UK0024	72
Bath Roadside	UK0030	57
Oxford Centre Roadside	UK0031	61
Aberdeen Union Street Roadside	UK0038	44

Table 4-8 Measured Exceedances of the Ozone Information Threshold Value

Site name	Zone code	Number of 1-hour exceedances of alert threshold	Maximum 1-hour concentration ($\mu g\ m^{-3}$)
No exceedances	-	-	-

Table 4-9 Measured Exceedances of the Ozone Alert Threshold Value

Site name	Zone code	Number of 1-hour exceedances of information threshold	Maximum 1-hour concentration ($\mu g\ m^{-3}$)
No exceedances	-	-	-

Table 4-10 Measured Exceedances of the Ozone Long Term Objective for Health Protection

Site name	Zone code	Number of days with exceedances	Maximum 8-hour concentration ($\mu g\ m^{-3}$)
London Eltham	UK0001	3	127
London Harlington	UK0001	3	133
London N. Kensington	UK0001	6	138
London Teddington	UK0001	15	160
London Westminster	UK0001	1	122
Sandwell West Bromwich	UK0002	2	136
Liverpool Speke	UK0006	4	139
Bristol St Paul's	UK0009	2	128
Reading New Town	UK0016	3	133
Port Talbot Margam	UK0027	2	141
Sibton	UK0029	6	138
St Osyth	UK0029	1	122
Weybourne	UK0029	10	147
Wicken Fen	UK0029	3	153
Charlton Mackrell	UK0030	6	143
Yarner Wood	UK0030	4	148
Harwell	UK0031	3	138
Bottesford	UK0032	3	125
Ladybower	UK0032	4	131
Northampton	UK0032	9	153
Glazebury	UK0033	3	144
High Muffles	UK0034	5	166
Coventry Memorial Park	UK0017	3	121
Leamington Spa	UK0035	5	134
Leominster	UK0035	3	132
Auchencorth Moss	UK0037	2	125
Eskdalemuir	UK0040	2	148
Peebles	UK0040	2	141
Cwmbran	UK0041	1	124
London Haringey	UK0001	5	143
Manchester South	UK0003	4	144
Salford Eccles	UK0003	1	132
Brighton Preston Park	UK0010	7	146
Leicester Centre	UK0011	1	121
Portsmouth	UK0012	1	124
Stoke-on-Trent Centre	UK0014	1	124
Bournemouth	UK0015	3	132
Wirral Tranmere	UK0020	3	131
Blackpool Marton	UK0022	3	152
Preston	UK0023	1	137
Thurrock	UK0029	3	132
Canterbury	UK0031	6	140
Lullington Heath	UK0031	7	132
Rochester Stoke	UK0031	3	144
Wigan Centre	UK0033	4	143
Sunderland Silksworth	UK0036	2	128
Aberdeen	UK0038	2	131
Fort William	UK0039	2	158
Lerwick	UK0039	4	132
Strathvaich	UK0039	2	150
Narberth	UK0041	1	133
Aston Hill	UK0042	5	133
Mold	UK0042	1	123
Derry	UK0043	1	130
Lough Navar	UK0043	3	123

4.2.2 **Fourth Daughter Directive 2004/107/EC**

The results of the air quality assessment for arsenic (As), cadmium (Cd), nickel (Ni) and benzo[a]pyrene (B[a]P) for each zone are presented in Form 9b of the Questionnaire, and illustrated in Table 4-11.

All zones and agglomerations met the target values for arsenic and cadmium. Two zones (Swansea Urban Area and the South Wales zone) exceeded the target value for nickel. Concentrations of B[a]P were above the target value in seven zones (Teesside Urban Area, Swansea Urban Area, Belfast Urban Area, Yorkshire and Humberside, the North East, South Wales and Northern Ireland). All the remaining zones were compliant with the target value for B[a]P.

Table 4-11 Results of Air Quality Assessment for As, Cd, Ni and benzo[a]pyrene in 2011

Zone	Zone code	As TV	Cd TV	Ni TV	B[a]P TV
Greater London Urban Area	UK0001	OK	OK	OK	OK
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 (m)	OK (m)	OK (m)	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	> TV (m)
Belfast Urban Area	UK0028	OK	OK	OK	> TV (m)
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 (m)	OK (m)	OK (m)	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

TV = Target Value, (m) indicates that the compliance or exceedance was determined by modelling.

4.3 Comparison with Previous Years

Table 4-12 to Table 4-17 summarise the results of the air quality assessment for 2011 and provide a comparison with the results of the assessments carried out in previous years. In Table 4-13, "n/a" (not applicable) indicates that there was no applicable margin of tolerance for the specified year.

Table 4-12 (Part 1 of 2) Exceedances of Limit Values for Ambient Air Quality Directive (1st and 2nd Daughter Directives prior to 2008)

Pollut-ant	Averag-ing time	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001
SO_2	1-hour	None	None	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[i]	None	None	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[ii]	None	None	None	None	None	None	None	None	None	None	None
SO_2	Winter[ii]	None	None	None	None	None	None	None	None	None	None	not assessed
NO_2	1-hour[iii]	3 zones measured (London, Glasgow, South East)	3 zones measured (London, Teesside, Glasgow)	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
NO_2	Annual[i]	40 zones (8 measured, + 32 modelled)	40 zones (11 measured + 29 modelled)	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[ii]	None	None	None	None	None	None	None	None	None	None	None

[i] No MOT defined except where a time extension has been granted, LV + MOT = LV
[ii] Applies to vegetation and ecosystem areas only. Critical Levels are already in force, no MOT.
[iii] No modelling for 1-hour LV.

Table 4-12 is continued on next page.

Table 4-12 (Part 2 of 2) Exceedances of Limit Values for Ambient Air Quality Directive (1st and 2nd Daughter Directives prior to 2008)

Pollut-ant	Averag-ing time	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001
PM_{10}	Daily	1 (modelled, after subtraction of natural contrib.: time ext. granted.)	1 (modelled, after subtraction of natural contrib..: time ext. granted.)	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	None	None	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	None	None
Benz-ene	Annual	None	None	None	None	None	1 zone modelled (Yorkshire & H'side)	2 zones modelled (Yorkshire & H'side, Central Scotland)	None	1 zone modelled (Greater London Urban Area)	not assessed	not assessed
CO	8-hour	None	None	None	None	None	None	None	None	None	not assessed	not assessed

The UK has been compliant with the limit values for both lead and CO since 2003, and for benzene since 2007.

Table 4-13 Exceedances of Limit Values plus Margins Of Tolerance (where applicable) for Ambient Air Quality Directive (1st and 2nd Daughter Directives prior to 2008). (This table only shows limit values that have been exceeded during 2001-2011).

Pollutant	Averaging time	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001
SO_2	1-hour	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1 zone modelled (Eastern)	1 zone modelled (Eastern)	None	None
SO_2	24-hour	n/a	n/a	n/a	n/a	n/a	n/a	n/a	None	1 zone modelled (Eastern)	None	1 zone measured (Belfast Urban Area)
NO_2	1-hour[i]	n/a	n/a	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	4, all modelled (MOT in place due to TEN).	n/a	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)
PM_{10}	Daily	None	None	None	None	None	None	None	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)
PM_{10}	Annual	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1 zone modelled (Gr. London Urban Area)	10 zones (1 measured + 9 modelled)	1 zone modelled (Gr. London Urban Area)	1 zone modelled (Gr.London Urban Area)
Benzene	Annual	n/a	n/a	None	None	None	None	None	None	None	not assessed	not assessed

[i] No modelling for 1-hour LV

Table 4-14 Ambient Air Quality Directive (3rd Daughter Directive prior to 2008) Target Values

Pollutant	Averaging time	2011	2010	2009	2008	2007	2006	2005	2004
O_3	8-hour	None	None	None	1 zone measured (Eastern)	None	None	None	None
O_3	AOT40	None	None	None	None	None	None	None	None

Table 4-15 Ambient Air Quality Directive (3rd Daughter Directive prior to 2008) Long Term Objectives

Pollutant	Averaging time	2011	2010	2009	2008	2007	2006	2005	2004
O_3	8-hour	43 zones (31 measured + 12 modelled)	41 zones (19 measured + 22 modelled)	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	3 zones (2 measured + 1 modelled)	6 zones (3 measured + 3 modelled)	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 4-16 4th Daughter Directive Target Values

Pollutant	Averaging time	2011	2010	2009	2008	2007
As	Annual	None	None	None	None	None
Cd	Annual	None	None	None	None	None
Ni	Annual	2 zones, 1 measured 1 modelled (Swansea, S Wales)	2 zones modelled (Swansea, S Wales)	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)
B[a]P	Annual	7 zones (2 measured; Yorkshire & Humberside, N Ireland, + 5 modelled; Teesside, Swansea, Belfast, North East, South Wales)	8 zones, (2 zones measured: Yorkshire & Humberside, N Ireland + 6 zones modelled; Teesside, Belfast, W Midlands, North East, S Wales, N Wales.)	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, Teesside, N Ireland + 3 zones modelled Swansea, S Wales, Belfast)	1 zone measured (Yorkshire & Humberside)

Table 4-17 Ambient Air Quality Directive Target Value for $PM_{2.5}$

Pollutant	Averaging time	2011	2010	2009
$PM_{2.5}$	Annual	None	None	None

5 Spatial Variation and Changes Over Time

This section looks at the spatial distribution of pollutants across the UK, based upon the modelled maps of ambient pollutant concentration discussed in section 3.5 of this report, "Modelling". In the case of traffic-related pollutants such as NO_2, both roadside and background concentrations are discussed.

For each pollutant, this section also discusses how ambient concentrations have changed over time, using data from the relevant ambient air quality monitoring networks: the Automatic Urban and Rural Network (AURN), the Automatic Hydrocarbon Network, the Non-Automatic Hydrocarbon Network, the Urban and Industrial Metals Network (and its predecessors), and the PAH Network.

These changes over time are compared to changes in estimated total UK emissions where appropriate. Estimated UK emission data are taken from the National Atmospheric Emissions Inventory (NAEI) website at http://naei.defra.gov.uk/index.php. (Please note that the most recent year for which NAEI emission estimates are available is 2010).

5.1 Sulphur Dioxide

5.1.1 SO_2: Spatial Distribution in the UK

Figure 5-1 shows the 99.73rd percentile[b] of hourly mean sulphur dioxide concentration varied across the UK during 2011. This statistic corresponds approximately to the 25th highest hourly 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 5-1 shows an interesting spatial distribution in that highest peak hourly mean SO_2 concentrations appear to have occurred around some of the UK's main ports – for example Southampton, Merseyside, Humberside and Pembroke. Shipping is known to be a significant source of SO_2: however, two major ports (Dover and Harwich) have large amounts of shipping but show no SO_2 "hot-spot". This may indicate that it is not necessarily shipping itself that accounts for these high SO_2 concentrations, but nearby industry associated with the ports.

Figure 5-2 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 exceedances in the year. There were no areas of the UK where this was the case in 2011.

[b] Where the Directive allows exceedances on a number of occasions (i.e. limit value not to be exceeded more than a specified number of times), percentiles are used to illustrate this.

Figure 5-1 99.73rd percentile of 1-hour mean SO_2 concentration, 2011 ($\mu g\ m^{-3}$)

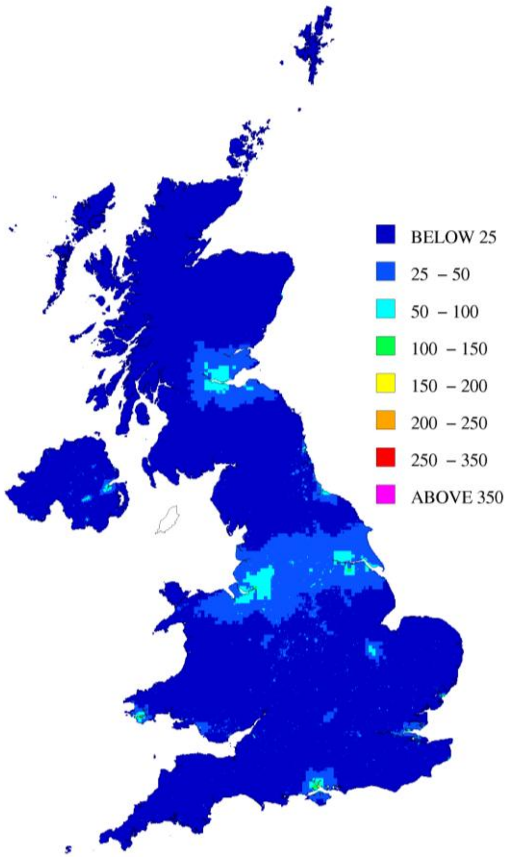
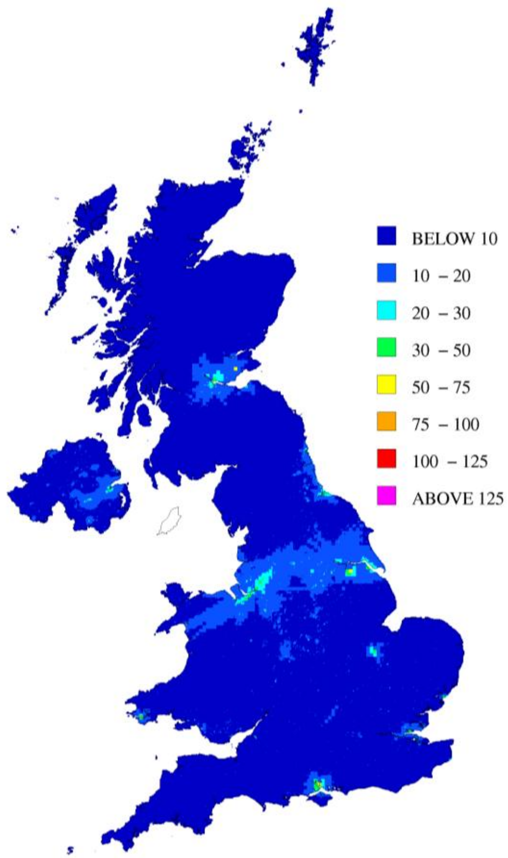


Figure 5-2 99.18th percentile of 24-hour mean SO_2 concentration, 2011 ($\mu g\ m^{-3}$)



5.1.2 SO_2: Changes Over Time

Figure 5-3 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 year-on-year decrease continued in the following decade.

Figure 5-3 Average annual mean SO_2 concentration: all background urban AURN sites

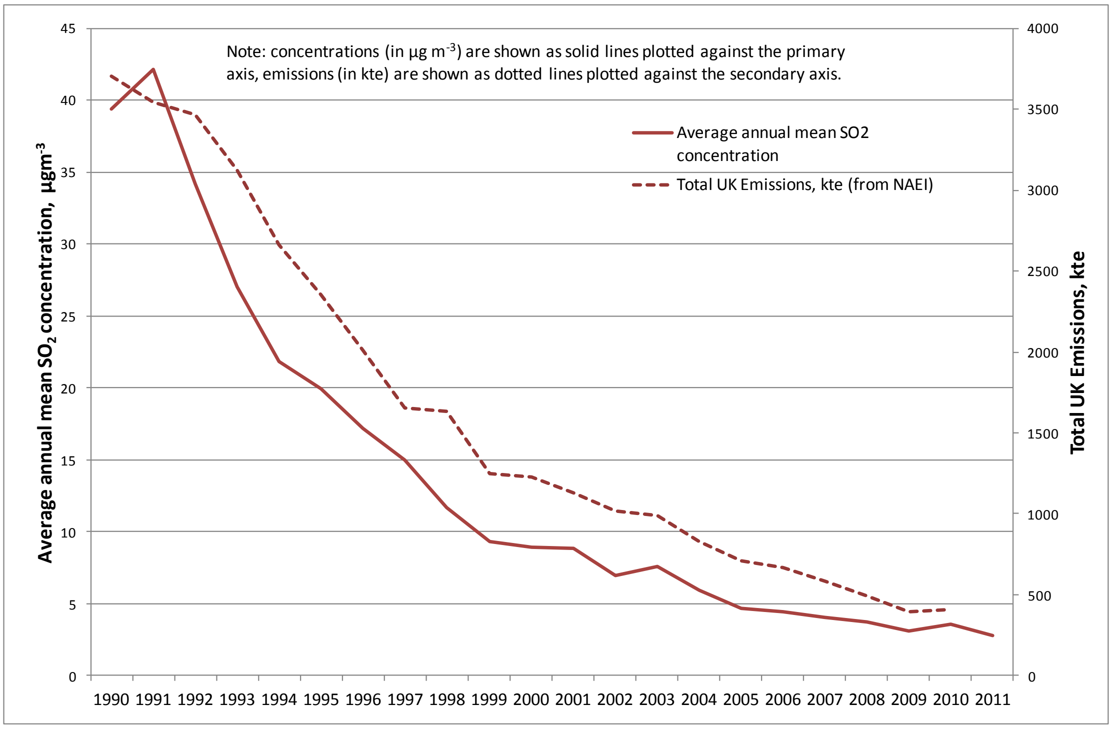


Figure 5-3 also shows how the UK's estimated total emissions of sulphur dioxide have decreased since 1990 (based on data from the NAEI available at www.naei.org.uk, shown in the graph as a dotted line). The main source of this pollutant is fossil fuel combustion. SO_2 emissions in the UK have decreased 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 by a corresponding fall in ambient concentration. It should be noted that the decrease in emissions over time 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.

5.2 Nitrogen Dioxide

5.2.1 NO_2: Spatial Distribution in the UK

Figure 5-4 shows the annual mean NO_2 concentrations for 2011, at *urban roadside* locations only. Although not every road link is clearly visible, many are shaded yellow, orange and red - indicating that they had annual mean NO_2 concentrations above the limit value of 40 µg m^{-3}. These locations are widespread in London and also visible in urban areas elsewhere in the UK.

Figure 5-5 shows the annual mean *background* NO_2 concentrations for 2011. The major urban areas, and principal road links, are clearly visible. Most background locations were within the limit value of 40 µg m^{-3}, but some (mostly in city centres) were not. These are shaded yellow, orange and red. Most of these are in central London; there are also a few small areas in the centres of other cities such as Birmingham and Southampton. However, there appear to be fewer such areas in 2011 than in 2010, reflecting the fact that NO_2 concentrations in 2011 were typically lower than in the previous year.

Figure 5-4 Urban major roads, annual mean roadside NO_2 concentration, 2011 ($\mu g\ m^{-3}$)

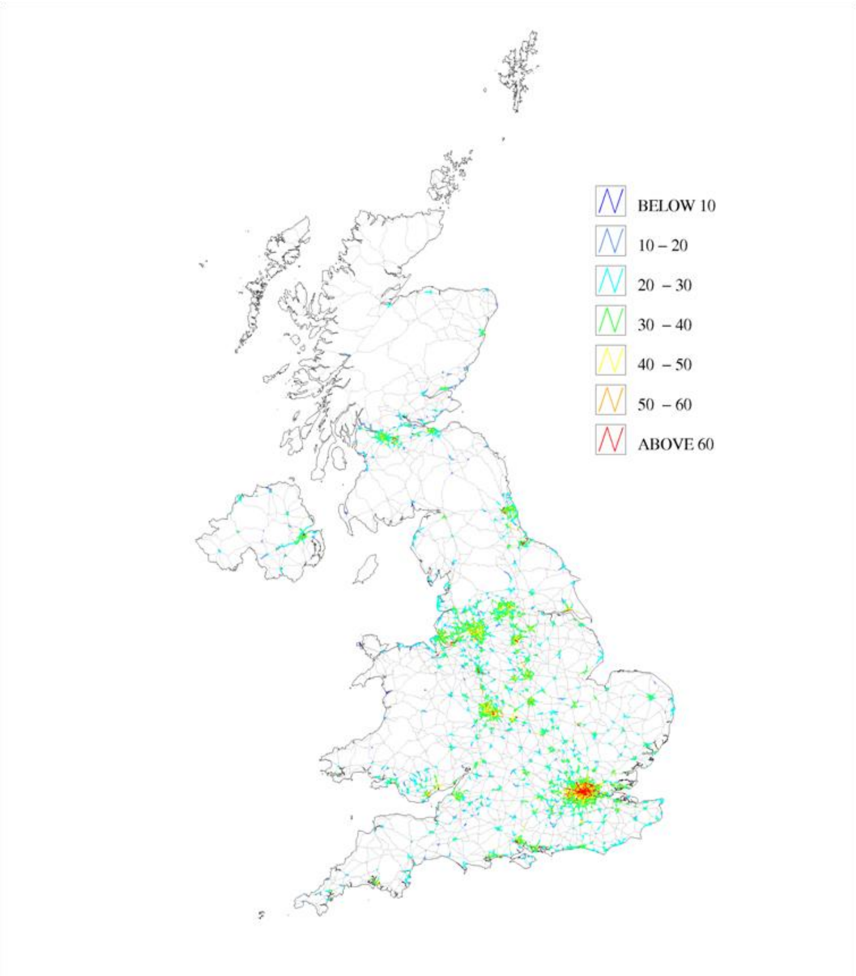
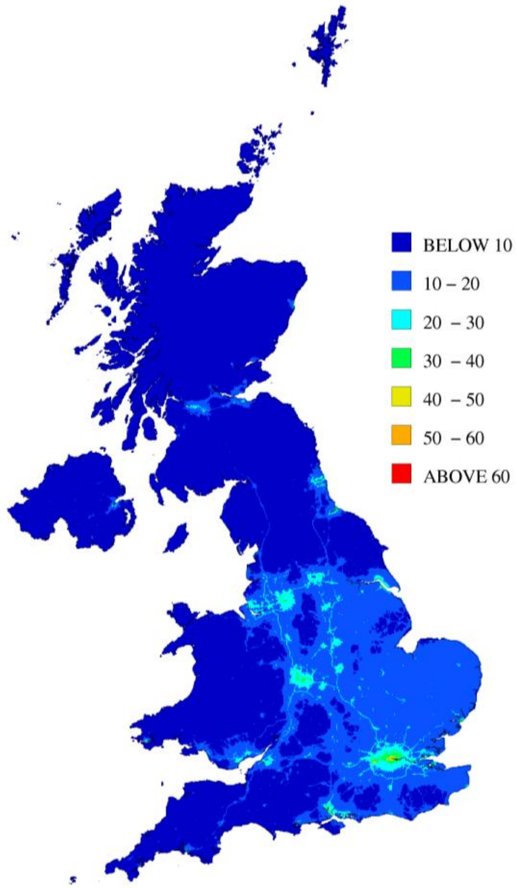


Figure 5-5 Annual mean background NO_2 concentration, 2011 ($\mu g\ m^{-3}$)



5.2.2 NO_2: Changes Over Time

Figure 5-6 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).
- From 1993 onwards, a set of ten long-running urban background sites (Belfast Centre, Billingham, Birmingham Centre, Cardiff Centre, Glasgow City Chambers, Leeds Centre, London Bloomsbury, Newcastle Centre, Sheffield Tinsley, Southampton Centre). These have been in operation from 1993 until 2011 (except Southampton Centre which started in 1994, Birmingham Centre which closed in 2009 and Glasgow City Chambers which closed in 2011). This is intended to show changes over time without any effects due to changes in the number and distribution of sites.
- All traffic-related urban monitoring sites, mostly less than five metres from the kerb of a major road. 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 2011 (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 changes over time without any effects due to changes in the number and distribution of sites. (Haringey Roadside was not included in 2011 as its data capture was less than 75%.)

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

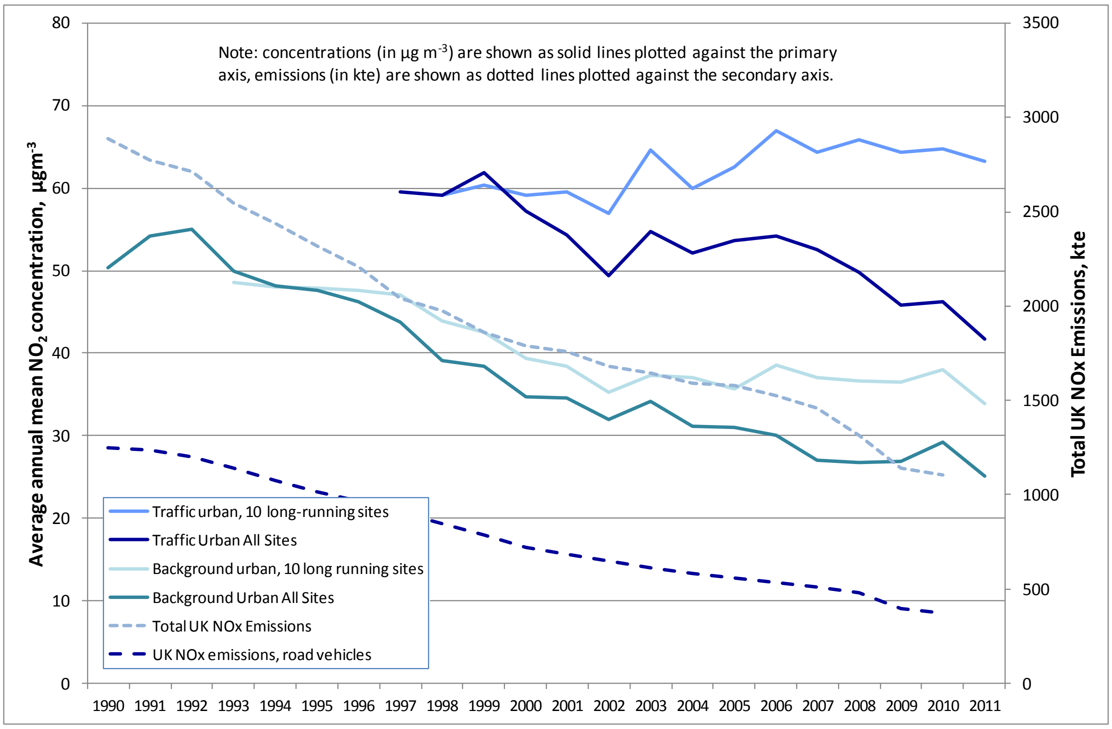
The annual mean NO_2 concentration averaged for all background urban sites in the AURN shows a steady decrease, generally consistent with the downward trend in the amount of total NO_X emitted until the mid-2000s. After this time, the estimated NOx emission continues to fall while the annual mean NO_2 concentration levels off.

The annual mean NO_2 concentration averaged for the ten long-running background urban sites also shows a steady decrease, again generally consistent with the downward trend in the amount of total NO_X emitted, until the early part of the last decade (around 2002). Subsequently, the average concentration at this subset of sites has remained stable, or even increased slightly – again, departing from the pattern shown by the estimated total NOx emission.

The annual mean NO_2 concentration averaged for all traffic urban AURN sites is higher than the averages for background sites, but shows a similar (though less consistent) decrease over time. However, the annual mean averaged over the ten long-running traffic urban sites shows a different pattern: in contrast to the decrease shown by the average for all sites, the average for long-running sites shows a slight *increase* in recent years.

A recent study by King's College London, the University of Leeds and AEA has carried out trend analysis for ambient concentrations of NOx and NO_2[49]. The report highlights the fact that from 2004 onwards, ambient concentrations of oxides of nitrogen have decreased less than would be predicted on the basis of emissions estimates. Using vehicle remote sensing data, the study concludes firstly that older petrol vehicles (Euro 1-3) emit more NOx than previously thought, which is likely to be due to emissions system degradation. Secondly the study concludes that NOx emissions from diesel cars and light goods vehicles (LGV) have decreased little in the past 15–20 years and that the Euro Standards have failed to deliver the expected improvements for these vehicles, for this pollutant.

Figure 5-6 Average annual mean NO_2 concentration: background urban and traffic urban AURN sites



5.3 PM_{10} Particulate Matter

5.3.1 PM_{10}: Spatial Distribution

Figure 5-7 shows annual mean urban roadside PM_{10} concentrations in 2011. No roadside locations had annual mean concentration greater than 40 µg m^{-3}. This is consistent with the compliance assessment reported in section 4.

Figure 5-8 shows annual mean background PM_{10} concentrations in 2011. Background concentrations are higher in the southern and eastern parts of the country, because these regions receive a larger transboundary contribution of particulate pollution from mainland Europe. The elevated levels of PM_{10} associated with urban areas and major roads can also be seen.

The concentration bands used in Figure 5-7 and Figure 5-8 are 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. Road links with annual mean concentrations greater than 31.5 µg m^{-3} are shaded red in Figure 5-7. Some red shaded road links are just visible on the map, in London; as highlighted in section 4, the modelled 24-hour mean was reported to be greater than 50 µg m^{-3} on more than 35 occasions at some roadside locations in London, and a time extension has been granted in respect of this (see section 4).

Figure 5-7 Urban major roads, annual mean roadside PM_{10} concentration, 2011 ($\mu g\ m^{-3}$, gravimetric)

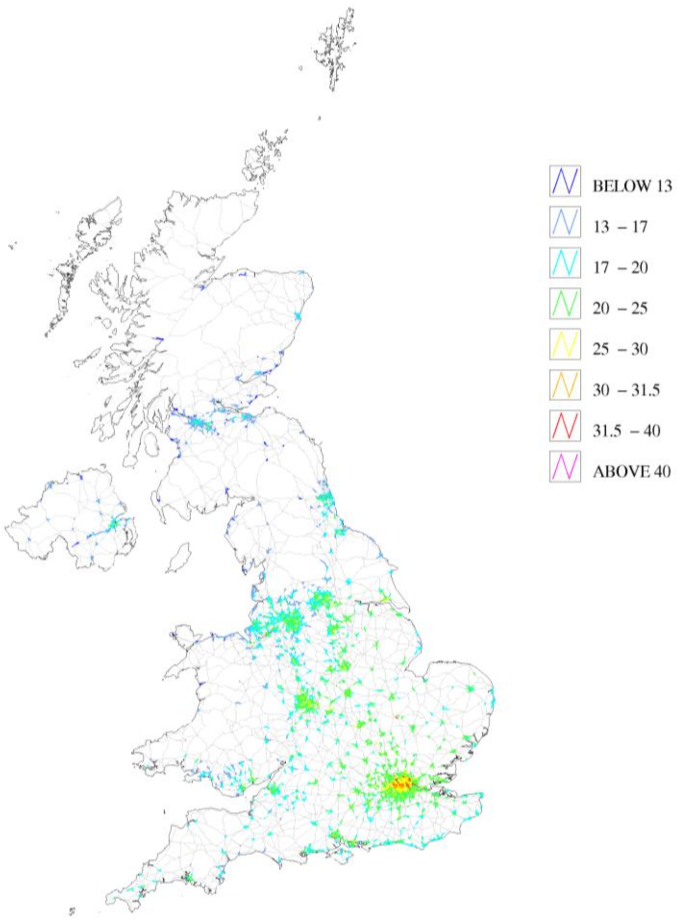
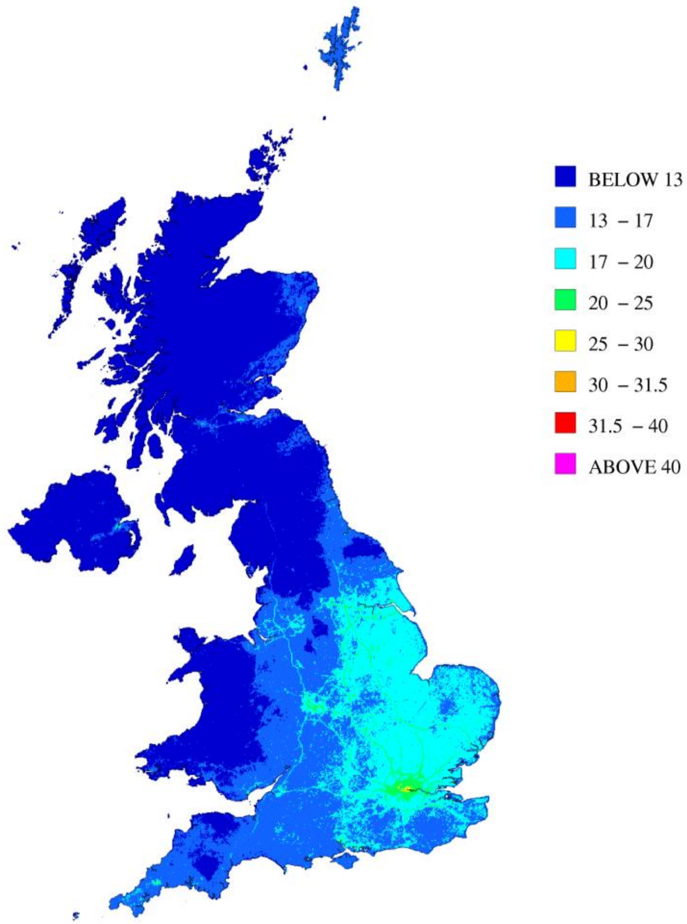


Figure 5-8 Annual mean background PM_{10} concentration, 2011 ($\mu g\ m^{-3}$, gravimetric)



5.3.2 PM_{10} Changes Over Time

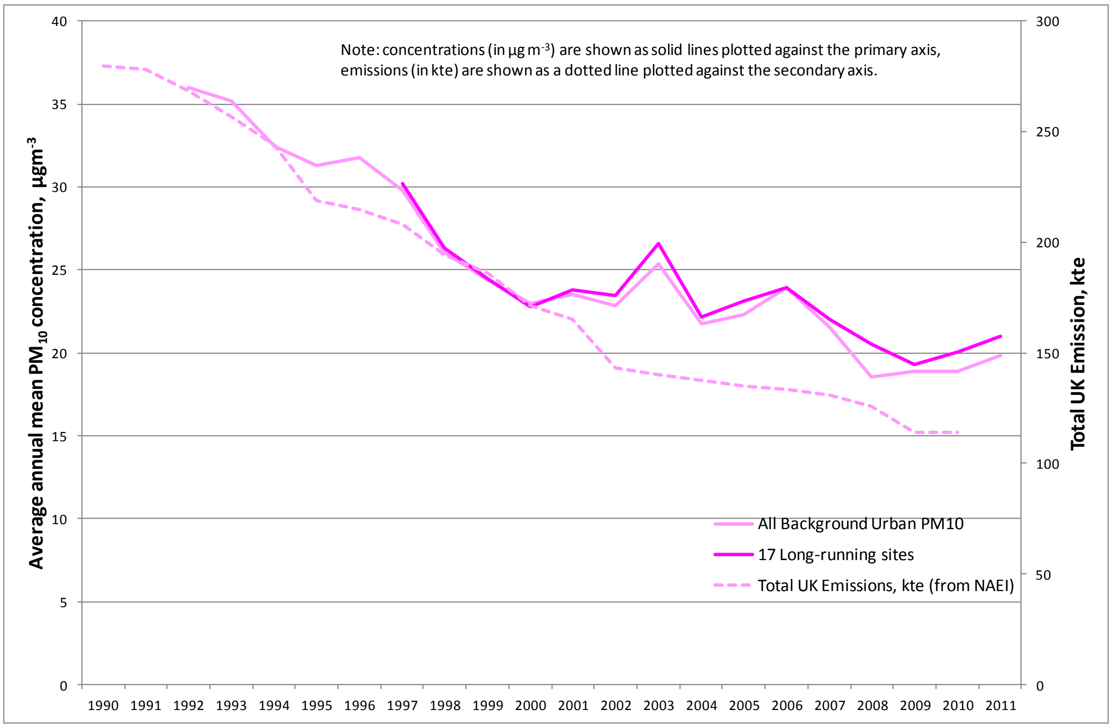
Figure 5-9 shows a time series graph of annual mean ambient PM_{10} concentration. This shows the average of all background urban sites in the AURN. The earliest data are from 1992. Also shown is the average of 17 long-running background urban sites in the AURN, all of which have been in operation since 1997. This is intended to show changes over time without any influences due to changes in the number and distribution of sites. The 17 sites used are Belfast Centre, Cardiff Centre, Derry, Glasgow Centre, Leamington Spa, Leeds Centre, Leicester Centre, London Bloomsbury, London North Kensington, Middlesbrough, Newcastle Centre, Nottingham Centre, Salford Eccles, Sheffield Centre, Southampton Centre, Stoke on Trent and Thurrock.

In this case, the mean for all sites shows a similar pattern to the mean for the subset of long-running sites. In both cases, ambient concentrations decreased steadily throughout the 1990s, before levelling off slightly in the early 2000s.

After a further decrease during 2006-2008, concentrations appear to have risen slightly in 2010 and 2011. Possible reasons for the slightly higher mean PM_{10} concentrations include:

- Cold weather at the beginning and end of 2010, giving rise to "winter" type pollution episodes in some regions.
- High concentrations of secondary particulate matter (notably, $PM_{2.5}$) during the spring of 2011.

Figure 5-9 Annual mean ambient PM_{10} concentration, and total annual emissions.



Also shown (by the dotted line, plotted against the right-hand axis) is the total UK annual emission of particulate matter (as PM_{10}), as estimated in the NAEI. Throughout the past two decades, the observed decrease in ambient PM_{10} concentration appears to reflect estimated reductions in emissions, including some levelling off in the early 2000s.

5.4 $PM_{2.5}$ Particulate Matter

5.4.1 $PM_{2.5}$: Spatial Distribution

Figure 5-10 shows the annual mean urban roadside $PM_{2.5}$ concentrations in 2011. No roadside locations had annual means greater than the target value of 25 µg m^{-3} although many were in the range 20 - 25 µg m^{-3} especially in London. Figure 5-11 shows annual mean background $PM_{2.5}$ concentrations in 2011. 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. The area with background annual mean $PM_{2.5}$ concentration greater than 10 µg m^{-3} was slightly greater than in 2010, covering the whole of the south east and most of the Midlands.

5.4.2 $PM_{2.5}$: Changes Over Time

Until 2008, routine monitoring of $PM_{2.5}$ was only carried out at one urban background AURN site (London Bloomsbury). This site is thought to have been affected by emissions from localised sources in recent years. For this reason, a graph of changes over time is not included here. Also, 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.

Figure 5-10 Urban major roads, annual mean roadside $PM_{2.5}$ concentration, 2011 (μg m^{-3}, gravimetric)

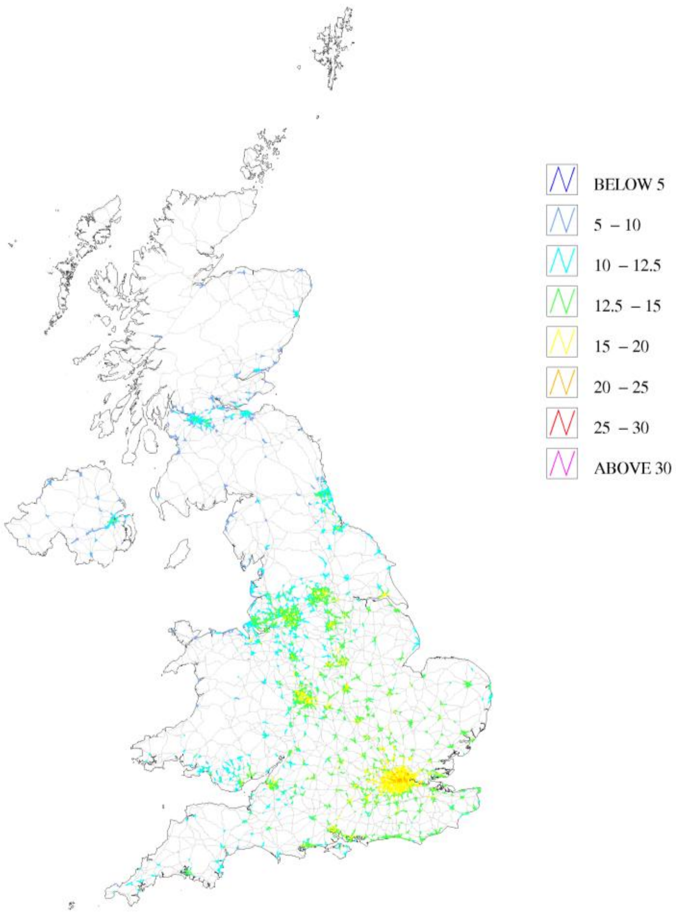
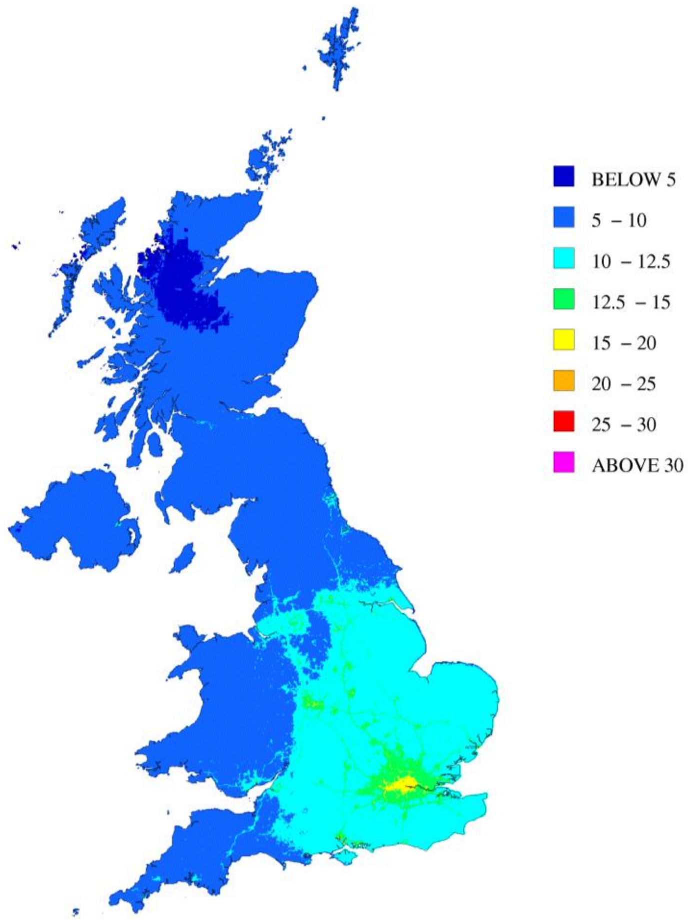


Figure 5-11 Annual mean background $PM_{2.5}$ concentration, 2011 (μg m^{-3}, gravimetric)



5.5 Benzene

5.5.1 Benzene: Spatial Distribution

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

Figure 5-12 shows annual mean benzene concentrations at roadside locations in 2011. Figure 5-13 shows the modelled annual mean background concentrations of benzene in 2011. Background concentrations are less than 0.5 µg m^{-3} over much of the UK. Marginally higher concentrations are modelled for urban areas, and parts of the east of England. However, background concentrations everywhere are well below the limit value for benzene.

Figure 5-12 Urban major roads, annual mean roadside benzene concentration, 2011 (μg m^{-3})

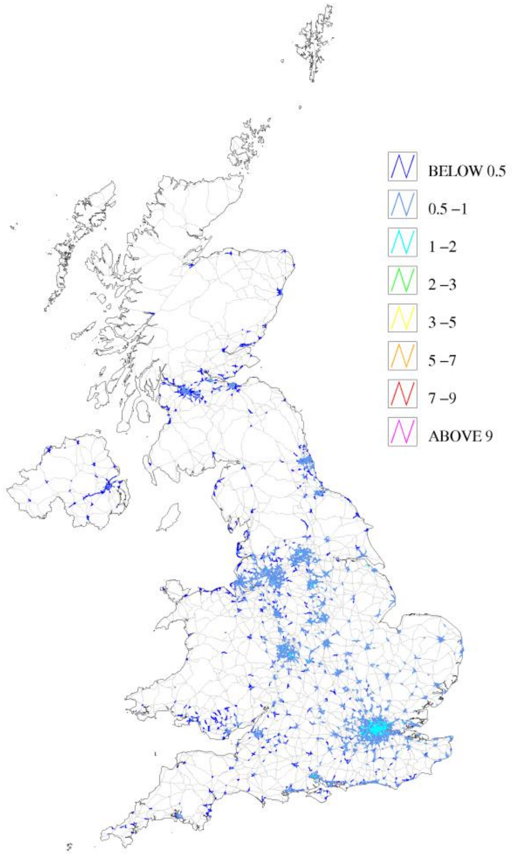
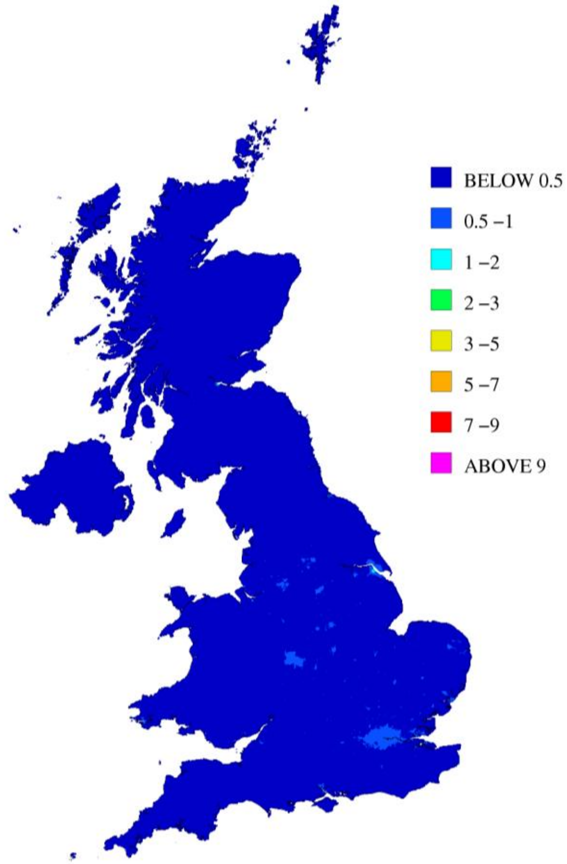


Figure 5-13 Annual mean background benzene concentration, 2011 (μg m^{-3})



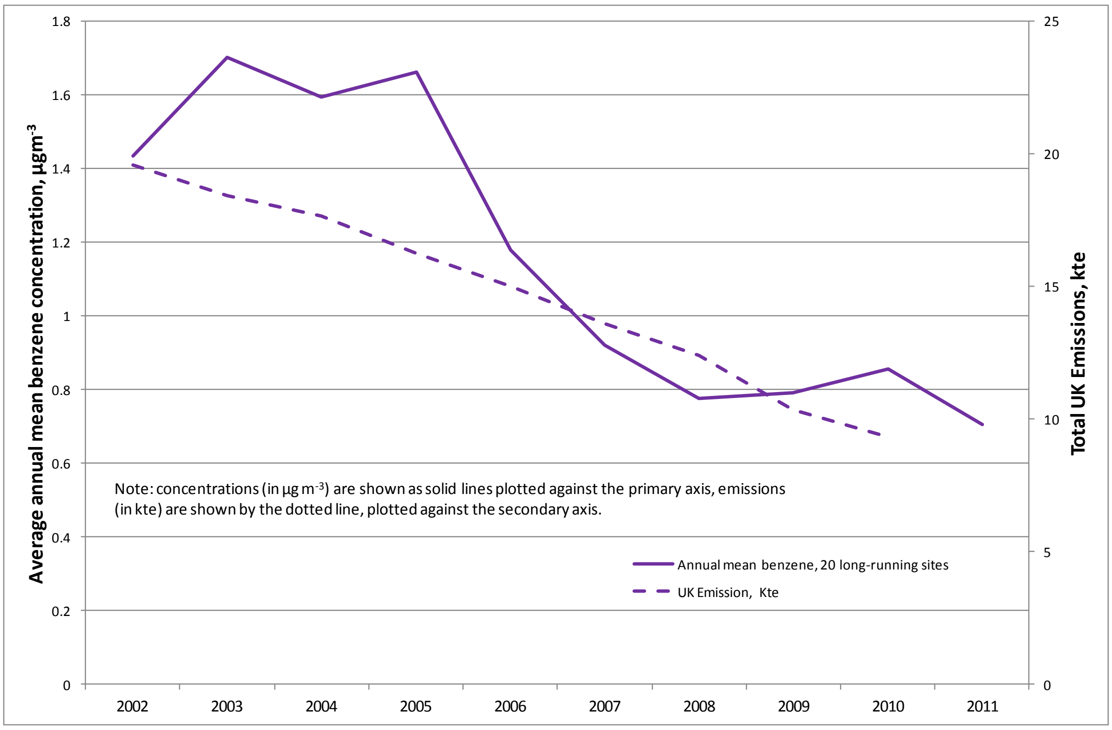
5.5.1 Benzene: Changes Over Time

Figure 5-14 shows a time series of annual mean benzene concentrations, based upon the average of 20 long-running sites in the Non-Automatic Hydrocarbon Network. These are: Barnsley Gawber, Belfast Centre, Bristol Old Market, Coventry Memorial Park, Grangemouth, Haringey Roadside, Leamington Spa, Leeds Centre, Leicester Centre, Liverpool Centre, London Bloomsbury, Manchester Piccadilly, Middlesbrough, Newcastle Centre, Northampton, Nottingham Centre, Oxford Centre Roadside, Plymouth Centre, Southampton Centre and Stoke on Trent Centre. All of these sites have at least 75% data capture for all years between 2002 and 2011.

The average for these 20 sites shows a general decrease from 2002 to 2011. Although the decrease has not been consistent from year to year, ambient concentrations have been lower in recent years than at the beginning of the period shown.

The dotted line on the graph shows the estimated total annual UK emission of benzene (in kilotonnes), plotted against the right-hand y-axis. This too appears to have decreased over the past nine years – although more steadily than the average measured ambient concentration.

Figure 5-14 Annual mean benzene concentration, mean of 20 long-running non-automatic sites



5.6 1,3-Butadiene

5.6.1 1,3-Butadiene: Compliance with AQS Objective

The ambient concentration of 1,3-butadiene is not covered by any EU Directives. However, it is within the scope of the UK Air Quality Strategy. In 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.

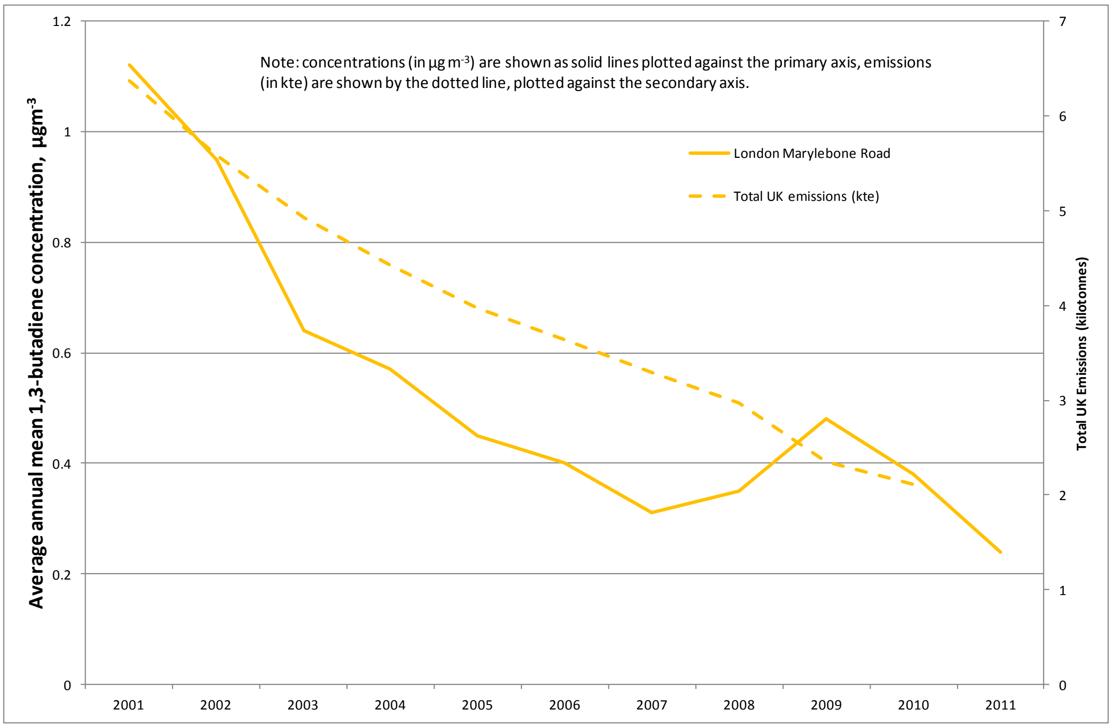
Only one network currently measures ambient concentrations of 1,3-butadiene: the Automatic Hydrocarbon Network. This network currently consists of two rural sites (Auchencorth Moss and Harwell) and two urban sites (London Eltham and London Marylebone Road). The running annual means at all four sites were within the Air Quality Strategy objective in 2011, although only Harwell achieved 75% data capture.

5.6.2 1,3-Butadiene: Changes Over Time

Figure 5-15 shows the annual mean 1,3-butadiene concentration measured from 2001 at London Marylebone Road. This site has been selected because it typically records the highest results of any site in the network, has been operating for a long period of time and has good data capture in most years. The minimum data capture for inclusion in this chart in 50%: a lower threshold has been used here than in other similar charts. The reason for this is that ambient concentrations of 1,3-butadiene at all the sites are very low, and frequently below the detection limit. When this occurs, the data are counted as null. Therefore, data capture figures for this pollutant tend to be low.

Also shown (plotted against the right-hand y-axis) is the total estimated UK annual emission of this compound, in kilotonnes. This appears to have decreased steadily over the past decade. The main source of 1,3-butadiene is vehicle emissions, and the use of catalytic converters since the early 1990s has reduced emissions by over 80% between 1990 and 2010.

Figure 5-15 Annual mean 1,3-butadiene concentration at London Marylebone Road



5.7 Carbon Monoxide

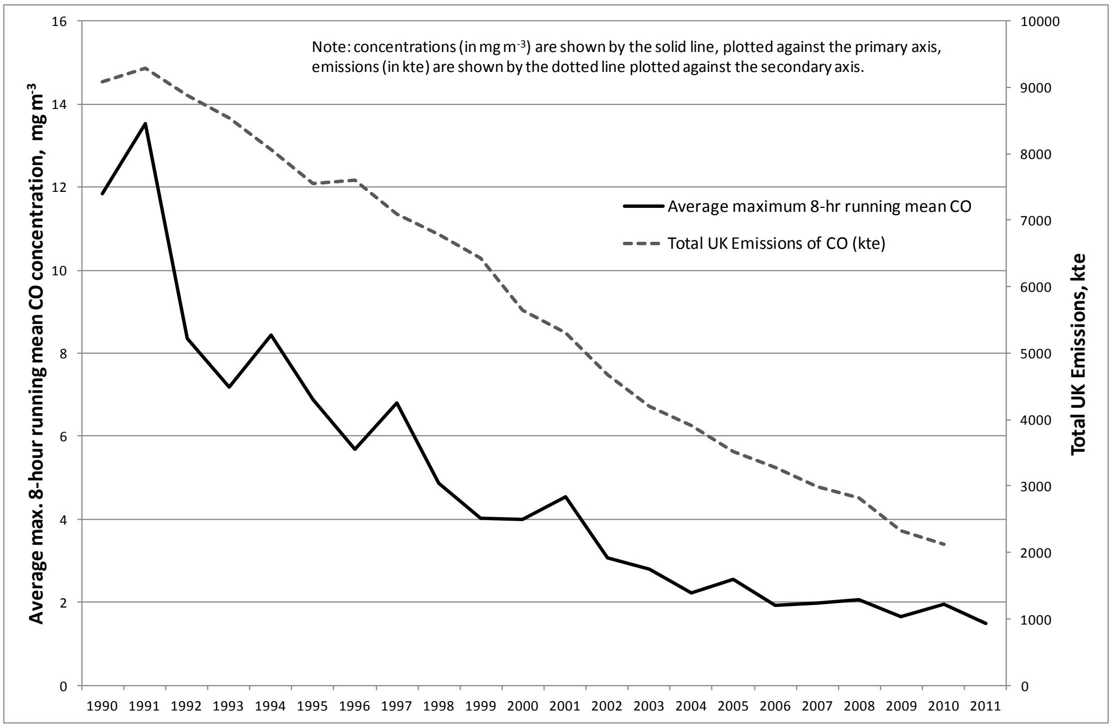
5.7.1 CO: Spatial Distribution

Previous reports in this series have shown modelled maps of the annual maximum 8-hour mean CO concentration, alongside major urban roads and at background locations. However, as ambient concentrations throughout the UK have been well within the limit value for many years, maps are no longer routinely produced for CO.

5.7.2 CO: Changes over time

Figure 5-16 shows a time series chart of the average maximum 8-hour running mean CO concentration, for all AURN sites 1990 - 2011. There is a clear decrease with time. Figure 5-16 also shows total annual UK emissions of CO for the same period. The decreasing ambient concentrations reflect declining emissions over the last two decades. UK emissions of this pollutant have decreased by 73% between 1970 and 2009 (most of this occurring between 1990 and 2009). The NAEI attributes this decrease to *"significant reductions in emissions from road transport, agricultural field burning and the domestic sector"*.[50]

Figure 5-16 Time series graph of average maximum 8-hour running mean CO concentration, all AURN sites.



5.8 Ozone

5.8.1 O_3: Spatial Distribution

Figure 5-17 shows the average number of days per year with ozone concentration > 120 µg m^{-3}, over the **three** years 2009-2011. This average was less than five days over most of the UK, but higher (5-10 days) in a small area of coastal East Anglia: this pattern reflects the nature of ozone as a transboundary, secondary pollutant.

Figure 5-18 shows the same statistic, for 2011 only (i.e. not averaged over three years). Ozone concentrations for 2011 were slightly higher than the three-year average, but still no parts of the UK had more than 10 days above the target value.

Figure 5-19 shows the AOT40 statistic, averaged over the past **five** complete years, 2007-2011. The AOT40 statistic (expressed in µg m^{-3}.hours) is the sum of the difference between hourly concentrations greater than 80 µg m^{-3} (= 40 ppb) and 80 µg m^{-3} over a given period using only the one-hour values measured between 0800 and 2000 Central European Time each day.

Figure 5-20 shows the same statistic, for 2011 only. The values for 2011 only are lower than those for the past five years.

Figure 5-17 Average no. of days with ozone concentration > 120 µg m^{-3} 2009-2011

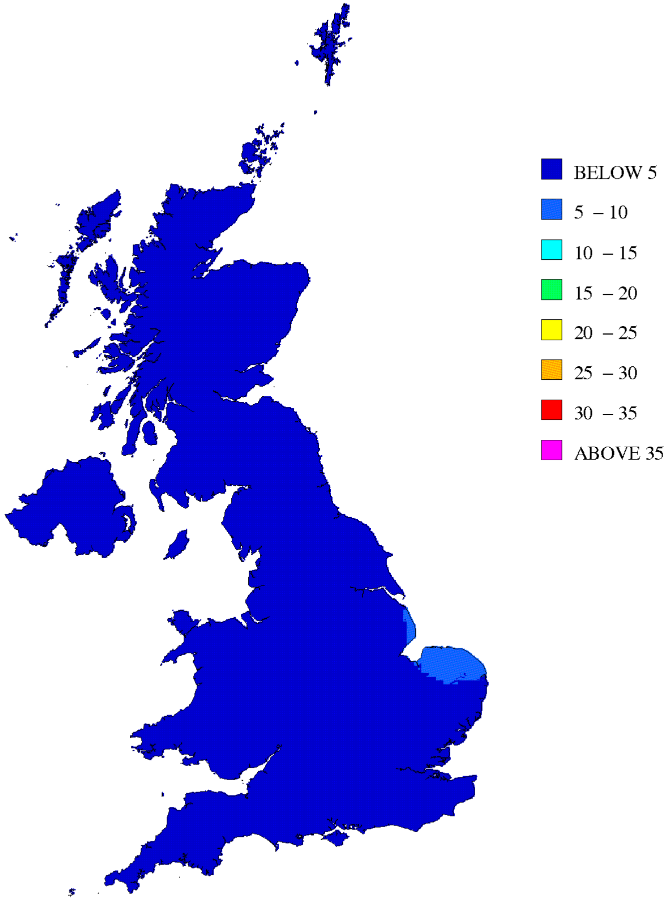


Figure 5-18 Days with ozone concentration > 120 µg m^{-3} in 2011

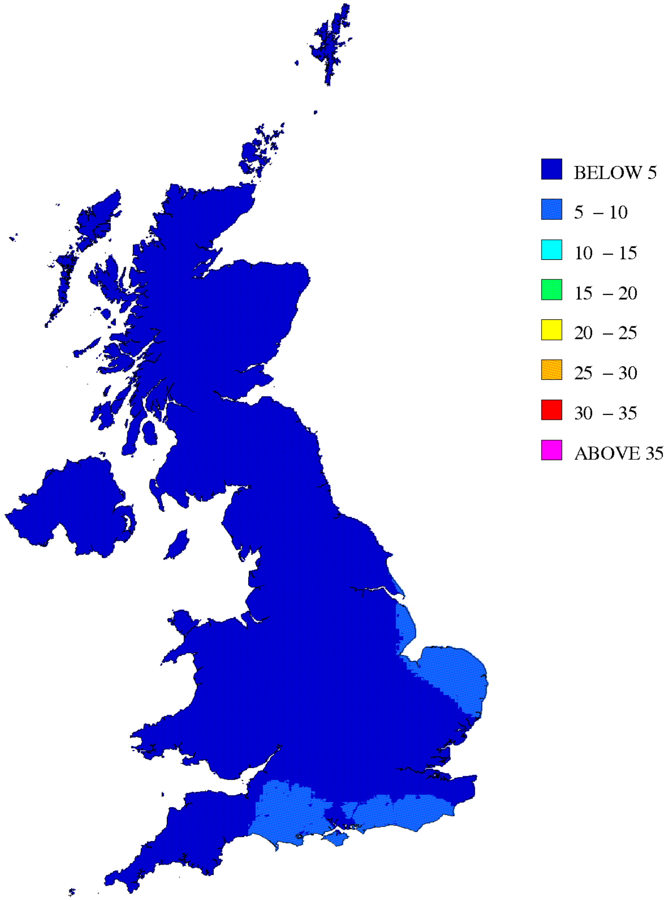


Figure 5-19 Average AOT40, 2007-2011(µg m^{-3}.hours)

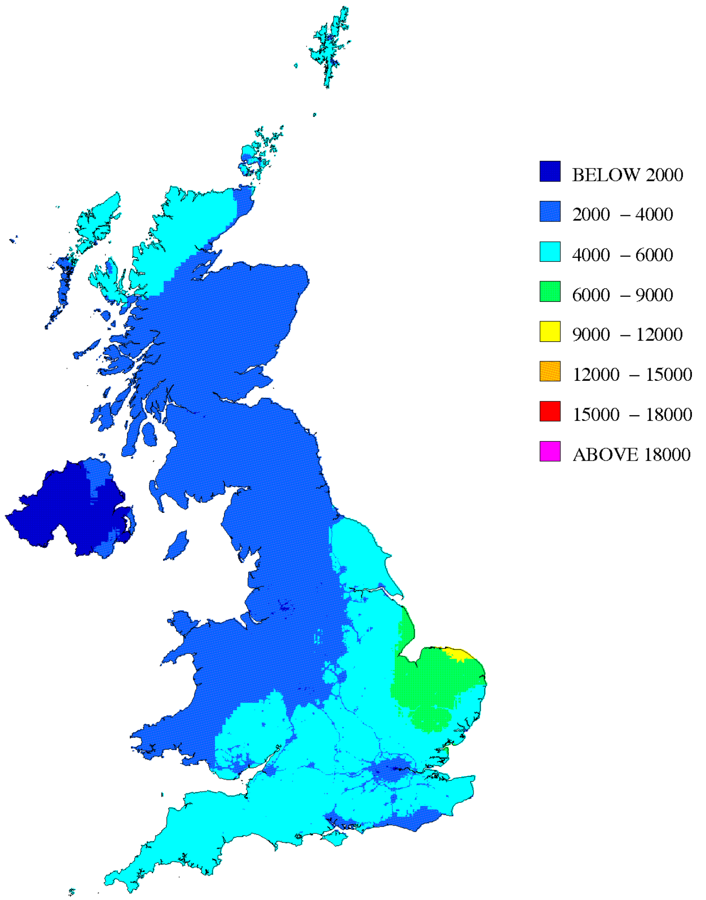
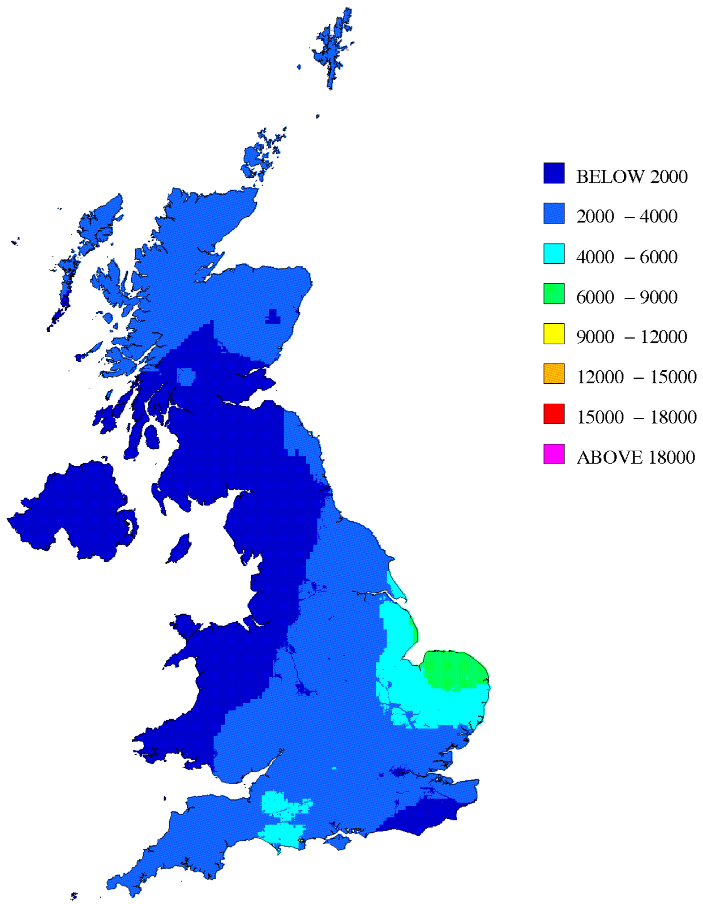


Figure 5-20 Average AOT40, 2011 (µg m^{-3}.hours)

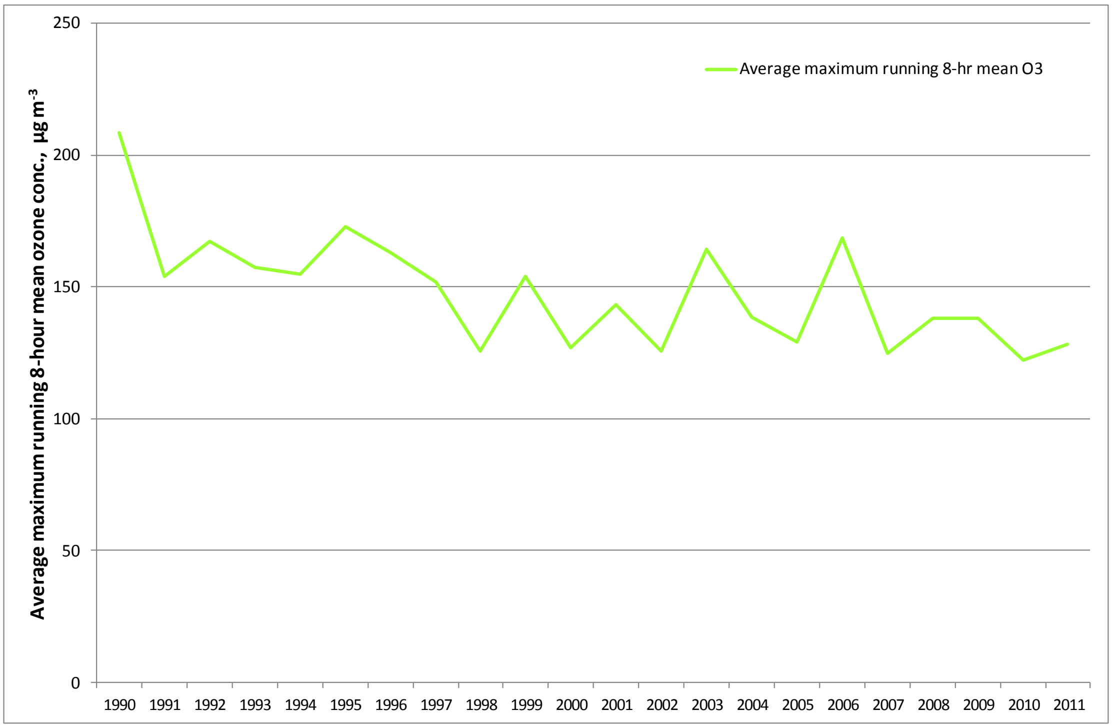


5.8.2 O_3: Changes Over Time

Figure 5-21 shows a time series graph of 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 slope. The implication of this is that areas currently at risk of exceeding target values are likely to remain at risk of exceeding in the near future.

No emissions 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 5-21 Time series of annual maximum 8-hour running mean, all AURN sites.



5.9 Metallic Pollutants

5.9.1 Metals: Spatial Distribution

Figures 5-22, 5-23, 5-24 and 5-25 show modelled annual mean concentrations of Pb, As, Cd and Ni respectively in 2011. 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 visible 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. Please note that the scale used for Cd concentrations was changed in the 2010 report in this series, reflecting the decrease observed in ambient concentrations over recent years.

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

Figure 5-22 Annual mean background Lead concentration, 2011 (ng m^{-3})

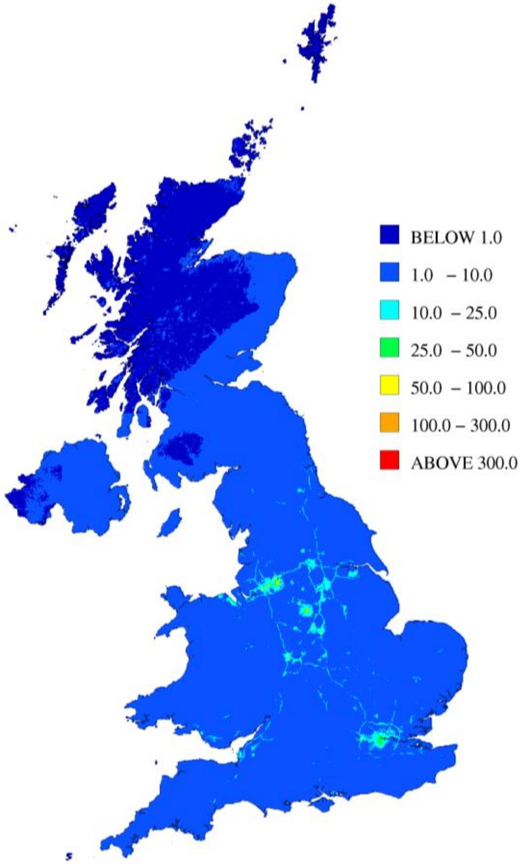


Figure 5-23 Annual mean background Arsenic concentration, 2011 (ng m^{-3})

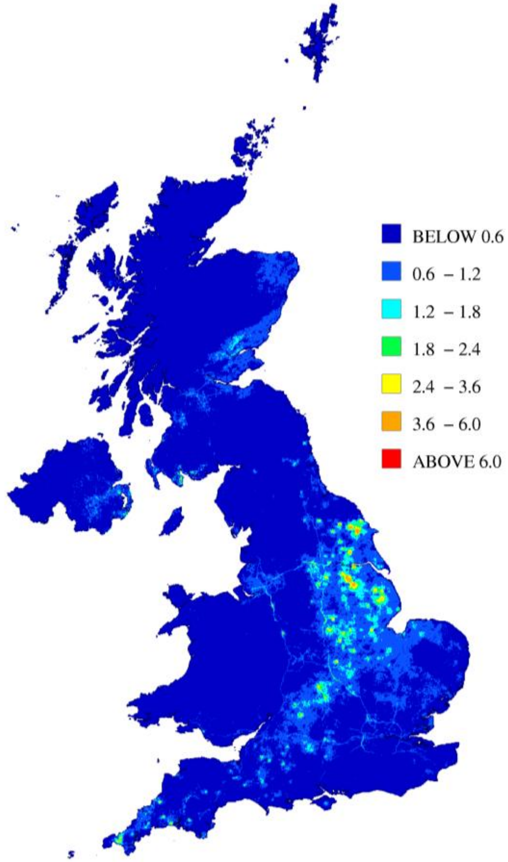


Figure 5-24 Annual mean background Cadmium concentration, 2011 (ng m^{-3})

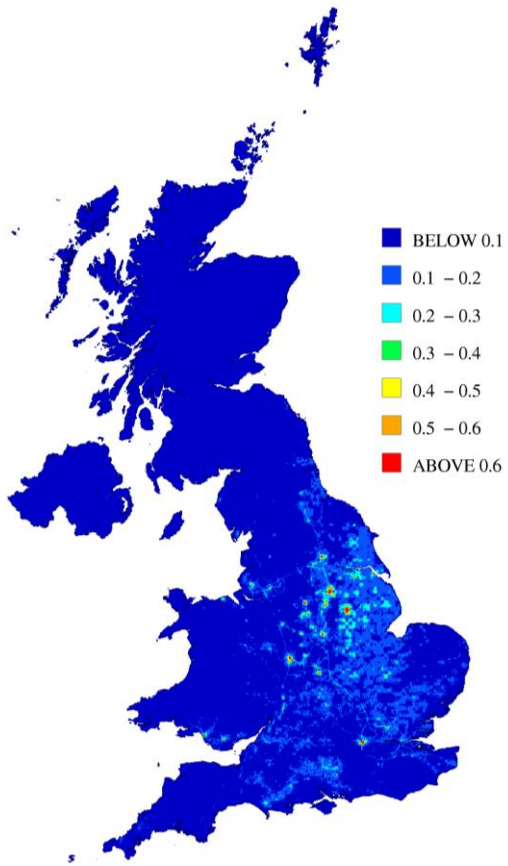
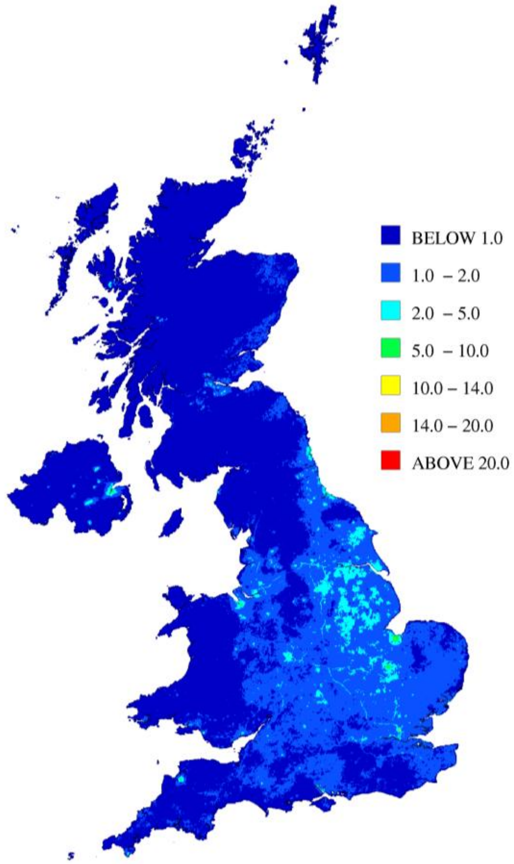


Figure 5-25 Annual mean background Nickel concentration, 2011 (ng m^{-3})



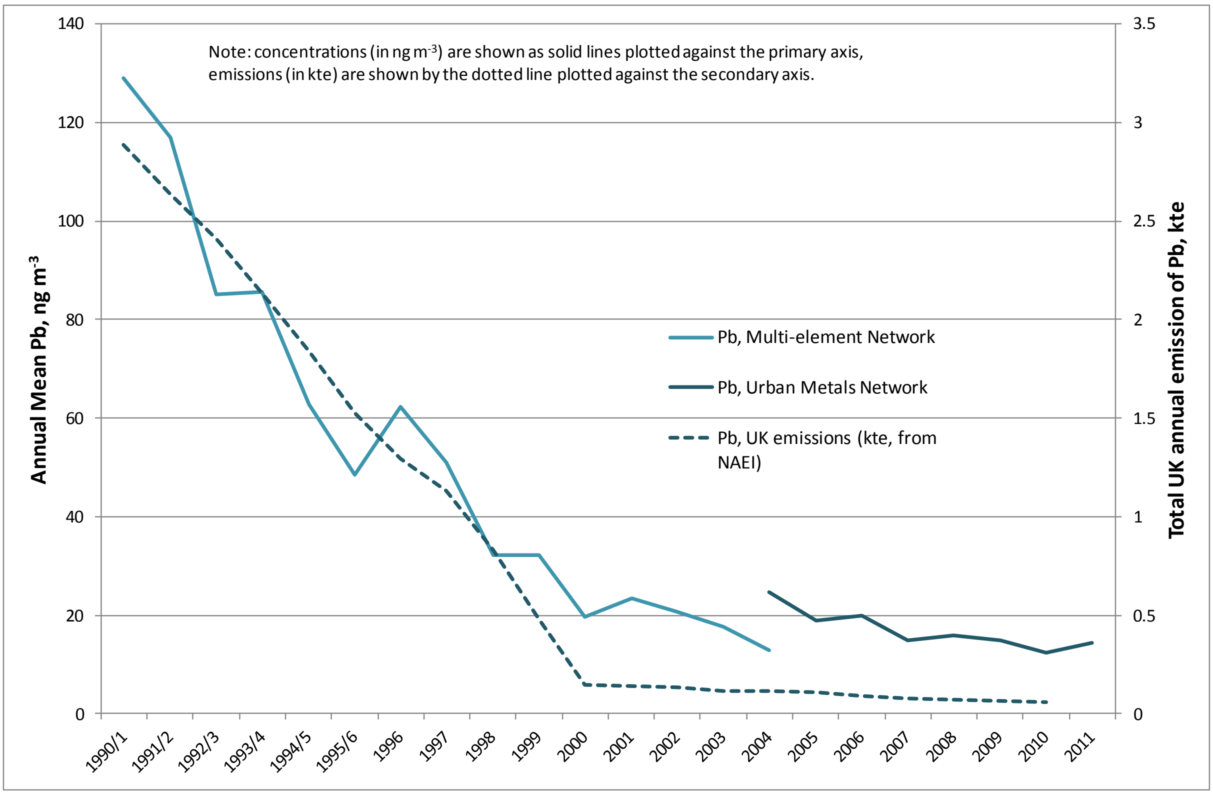
5.9.2 Lead: Changes Over Time

Figure 5-26 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. (The sampling method used by this network was not size-selective.)

From 2004 onwards, Pb was monitored in the PM_{10} fraction by the Urban and Industrial Metals Network, described in section 3.3.2 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 5-26 also shows estimated total annual UK emissions of this metal, from the NAEI (plotted as a dotted line, on the right-hand y-axis). Measured ambient concentrations follow the same pattern, with a steep downward slope throughout the 1990s, levelling off after 2000.

Figure 5-26 Ambient Concentrations of Particulate-phase Pb, and Total UK Emissions



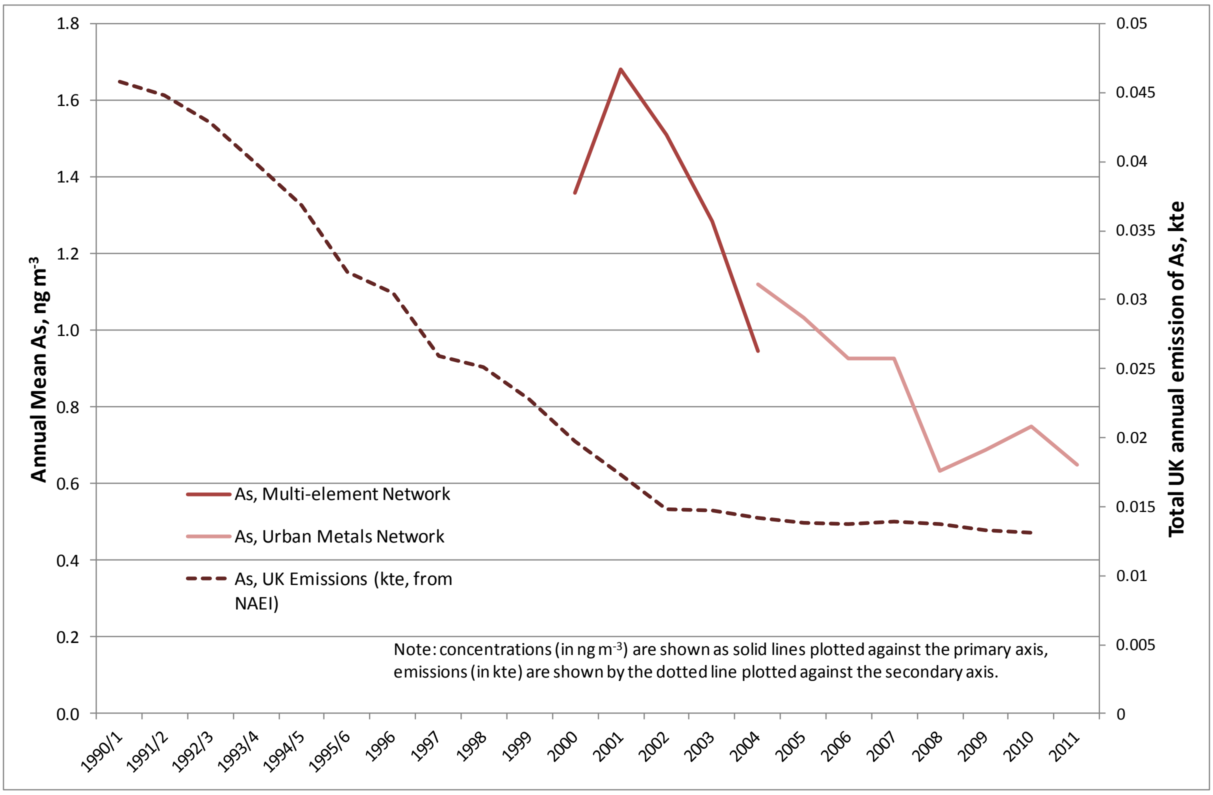
5.9.3 Arsenic: Changes Over Time

Figure 5-27 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 Urban and Industrial Metals Network, described in section 3.3.2 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 (from the NAEI), in kilotonnes. This is plotted as a dotted line, against the right-hand y-axis. The decrease in emissions is generally reflected in the decrease in measured ambient concentrations.

Figure 5-27 Ambient Concentrations of Particulate-phase As, and Total UK Emissions



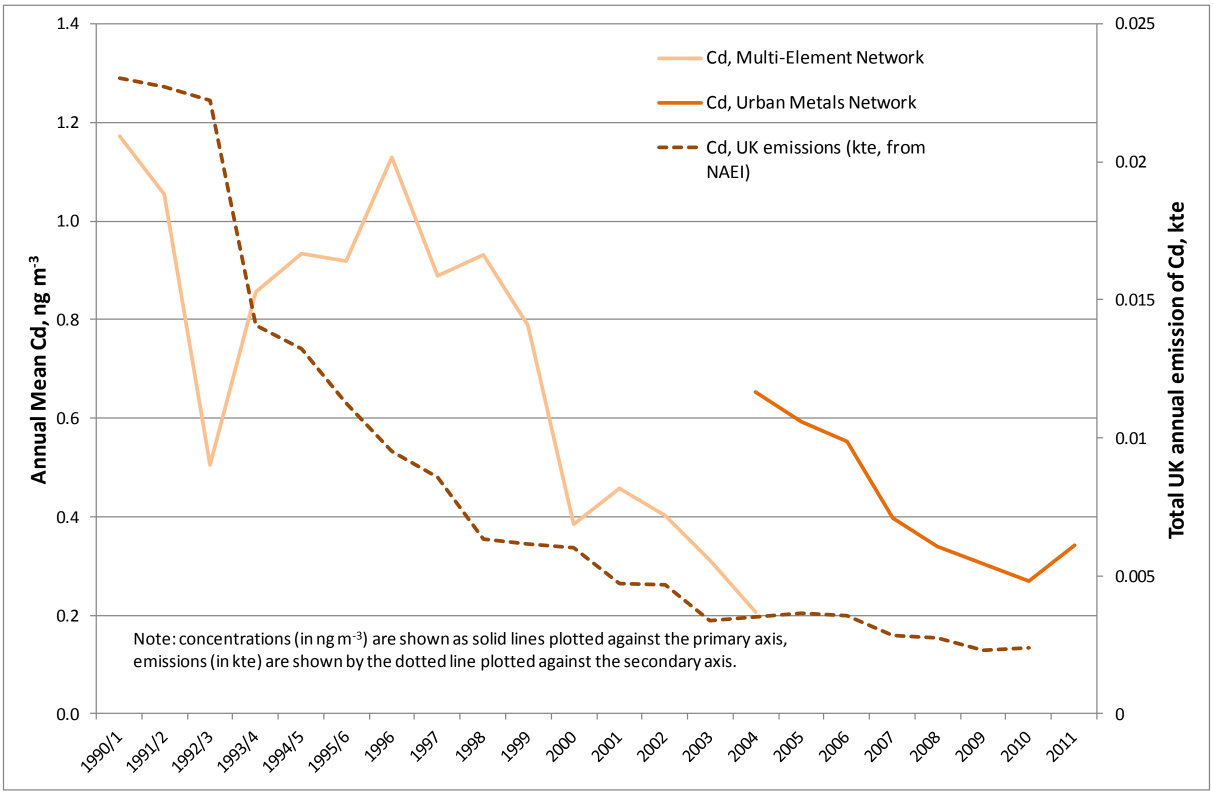
5.9.4 Cadmium: Changes Over Time

Figure 5-28 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 Urban and Industrial Metals Network, described in section 3.3.2 above. The annual mean of all sites is shown. There is a 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. In 2011 there appears to have been an increase in the annual mean Cd concentration measured by all sites – the first such increase since 2004. This appears to be due to a few of the industrial sites measuring slightly higher concentrations in 2011. However, this parameter is well within the Fourth Daughter Directive target value of 5 ng m^{-3} at all sites.

Also shown (plotted as a dotted line, against the right-hand axis) is the UK's estimated total annual emission of Cd (in kilotonnes), from the NAEI. The decrease in emissions is generally reflected in the decrease in measured ambient concentrations.

Figure 5-28 Ambient Concentrations of Particulate-phase Cd, and Total UK Emissions



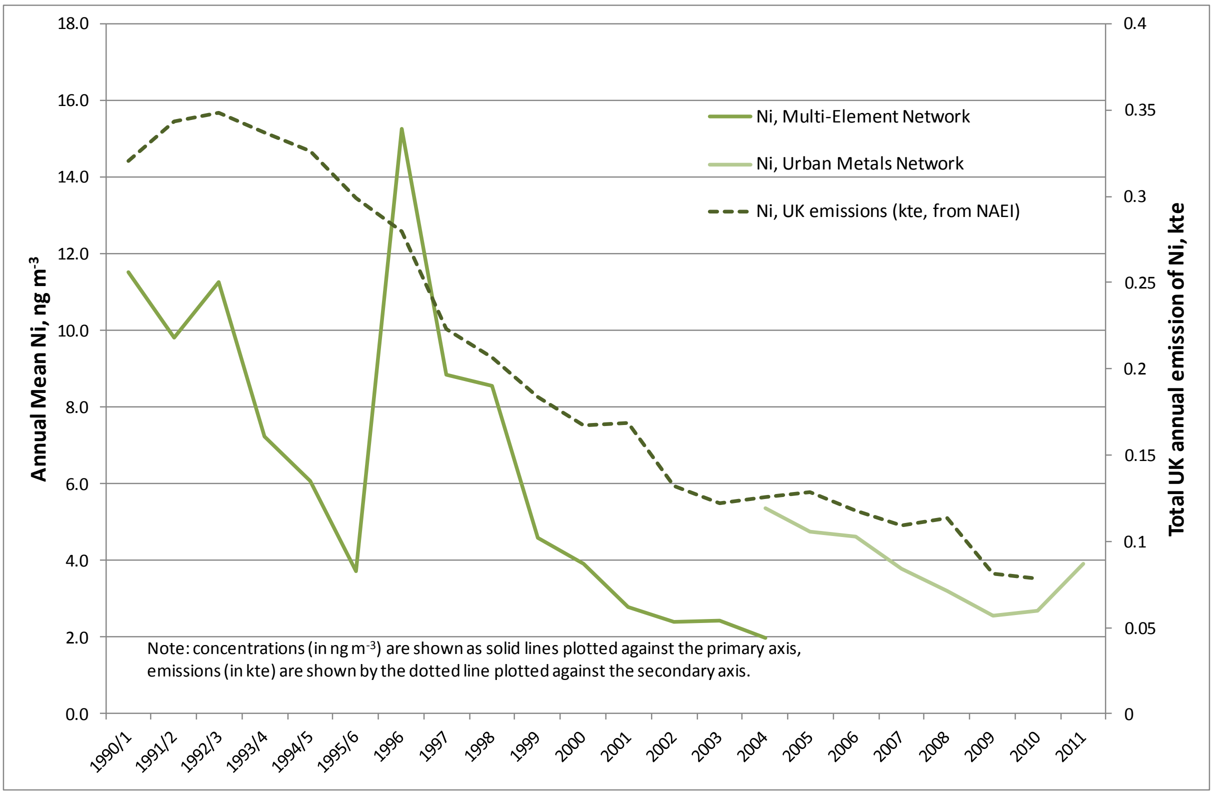
5.9.5 Nickel: Changes Over Time

Figure 5-29 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 Urban and Industrial Metals Network. Although the mean for all sites was well within the Fourth Daughter Directive target value of 20 ng m^{-3}, there was one measured exceedance in 2011: an annual mean of 28 ng m^{-3} at a new site in Pontardawe. Also, as highlighted in Table 4-10, there were *modelled* exceedances in the South Wales zone in 2011.

Figure 5-29 also shows total estimated annual UK emissions of Ni, from the NAEI (as a dotted line, plotted against the right-hand axis). From the late 1990s, 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. The peak in 1996 is due to an unusually high annual mean at one of the six Multi-Element Network sites (London Brent) that year.

Like Cd, ambient concentrations of Ni have also shown a small increase in 2011 – possibly due to the introduction to the network of the Pontardawe site.

Figure 5-29 Ambient Concentrations of Particulate-phase Ni, and Total UK Emissions



5.9.6 Mercury: Changes Over Time

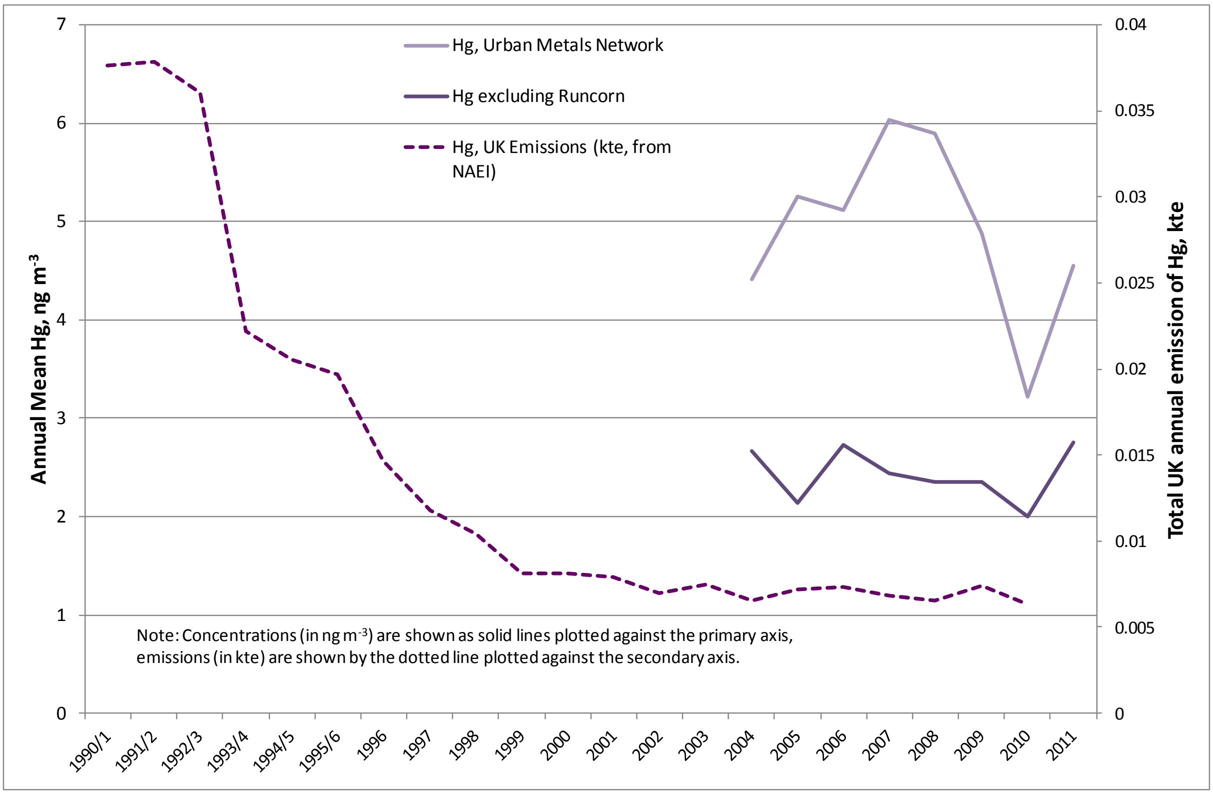
Figure 5-30 shows a time series of total annual mean concentrations of Hg, as measured by the Urban and Industrial Metals Network from 2004. The graph shows the sum of the vapour phase and particulate phase components: the majority of ambient Hg is in the vapour phase. Although the former Multi-Element Network began measuring particulate phase mercury in 2000, vapour phase measurements are only available from 2004 onwards.

Two lines are shown for annual mean ambient Hg: the lighter coloured line represents the mean of all sites in the network. However, this average is dominated by one site, Runcorn Weston Point. This site is located near an industrial installation (a chlor-alkali plant) that used to use mercury in the past, and measures ambient Hg concentrations an order of magnitude greater than any other sites in the network.

The second, darker coloured line shows the annual mean for all sites *excluding* Runcorn Weston Point. This is likely to be more representative of changes over time. On the basis of this average, the ambient total Hg concentration appears to have remained stable in the range 2-3 ng m^{-3} over the past eight years.

Figure 5-30 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 seven years. This is reflected in the mean ambient concentration for all sites excluding Runcorn.

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



5.10 Benzo [a] Pyrene

5.10.1 B[a]P: Spatial Distribution

Figure 5-31 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 the Belfast area and other urban parts of Northern Ireland: also parts of Yorkshire, Humberside and South Wales.

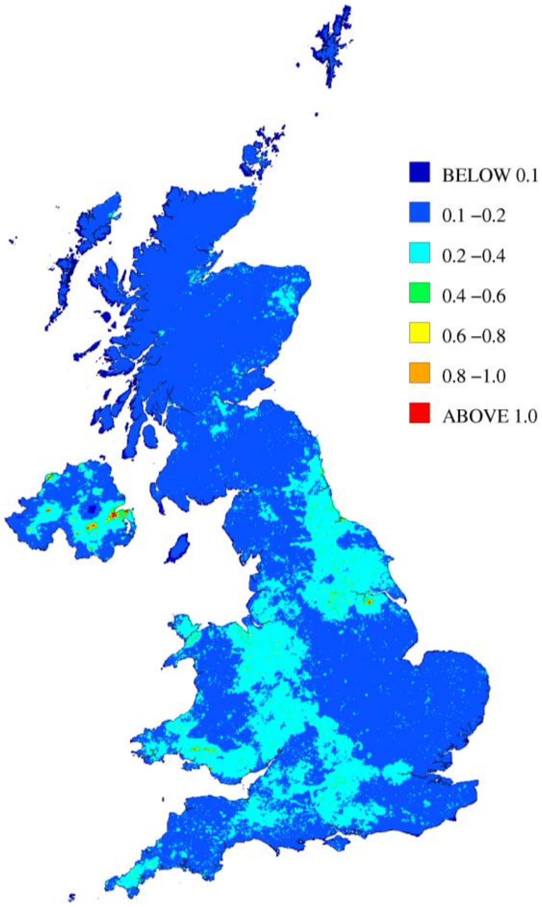
5.10.2 B[a]P: Changes Over Time

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, including a change of sampling technique.

The newer sampling technique used at most sites from 2008 onwards (the Digitel PM_{10} sampler) 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[51].

Because of these changes in the composition of the network, and in particular the techniques used, temporal variation in PAH concentrations 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 5-31 Annual mean background B[a]P concentration, 2011 (ng m^{-3})



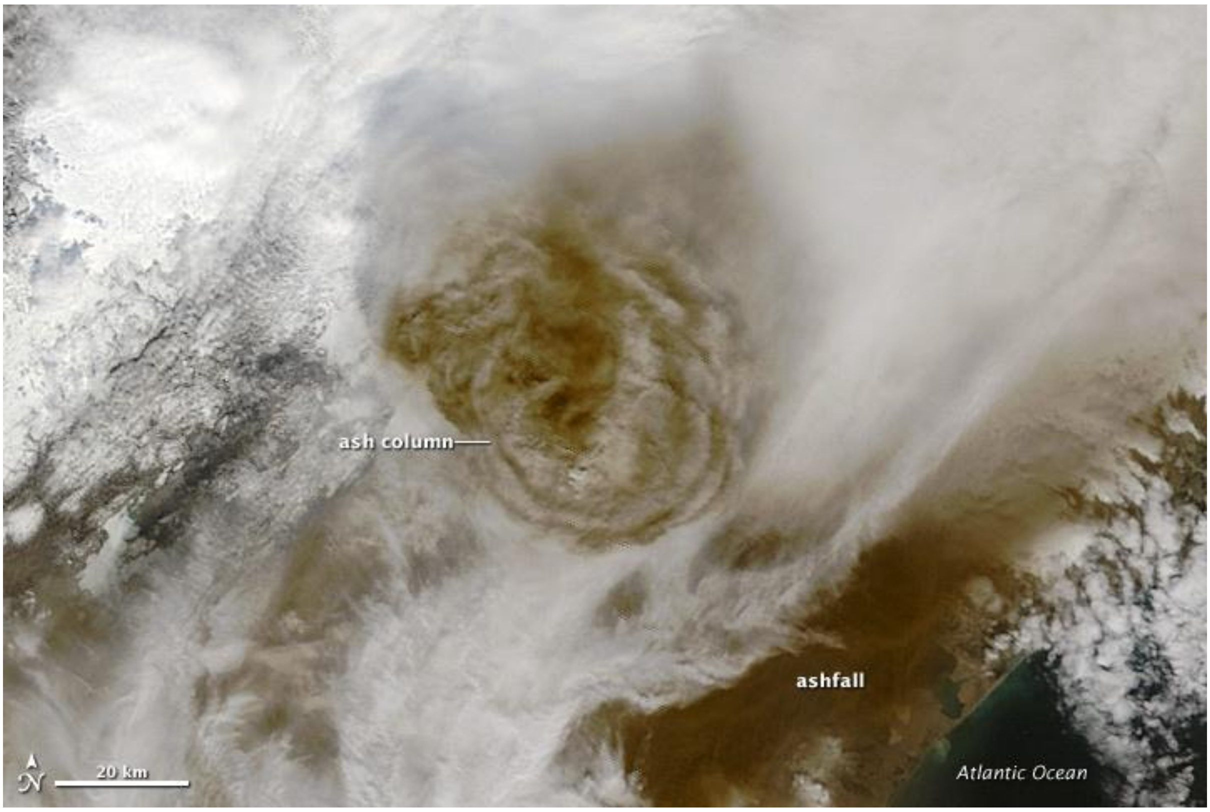
6 Pollution Events in 2011

6.1 Grímsvötn Volcanic Eruption

On 22nd May 2011, the Grímsvötn volcano in Iceland erupted. The Icelandic Met Office reported that the volcano sent a plume of ash and steam about 20 kilometres into the atmosphere, dropping to 15 kilometres overnight. The plume was being carried by the wind in the direction of the UK. The AEA UK Air Quality Forecasting team monitored the situation closely using the Met Office Advisory notes and satellite imagery, and also carried out daily model runs using the NOAA Hysplit model to track the likely path and elevation of the plume. However, the ash particles from this eruption were large, and were settling out of the atmosphere very quickly. They were therefore less likely to remain airborne long enough to reach European airspace.

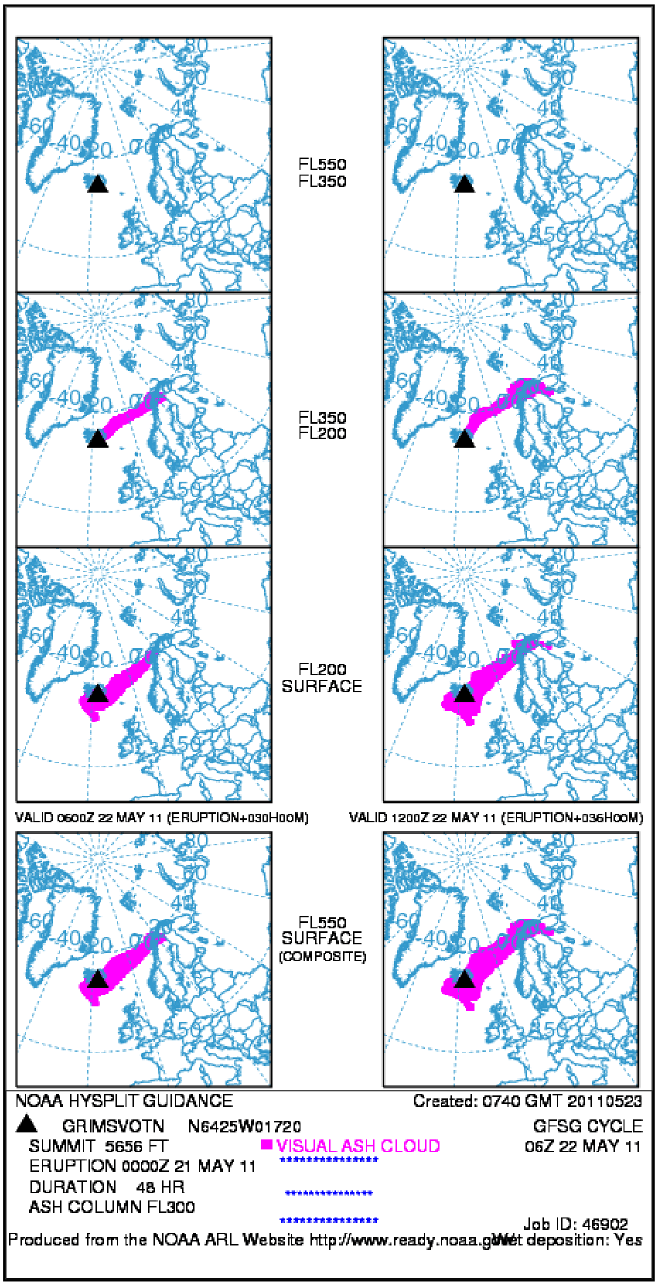
Figure 6-1 shows the volcanic ash plume as captured by NASA's Terra satellite - Moderate Resolution Imaging Spectroradiometer (MODIS) on May 22nd, 2011.

Figure 6-1 Satellite image of the eruption from Grímsvötn volcano



Daily updates were provided by the forecasting team during the week of the eruption and examples of such analyses are shown in Figure 6-2 and Figure 6-3.

Figure 6-2 NOAA Hysplit Model Results for 22nd and 24th May 2011.



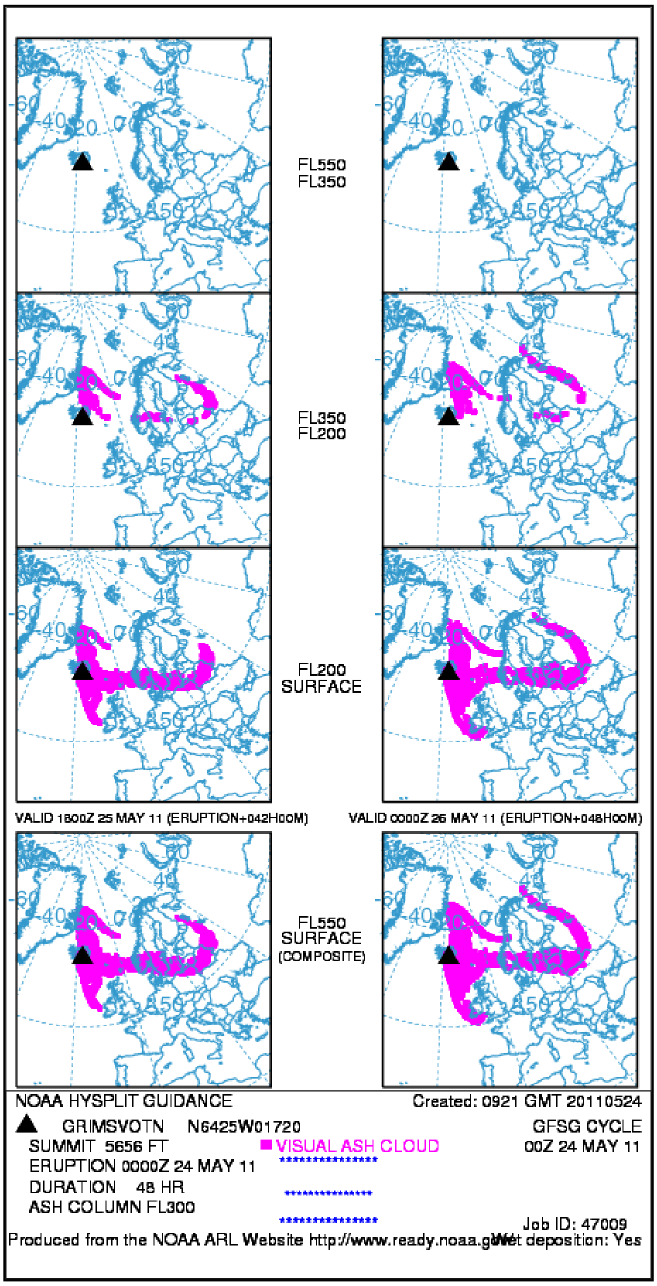
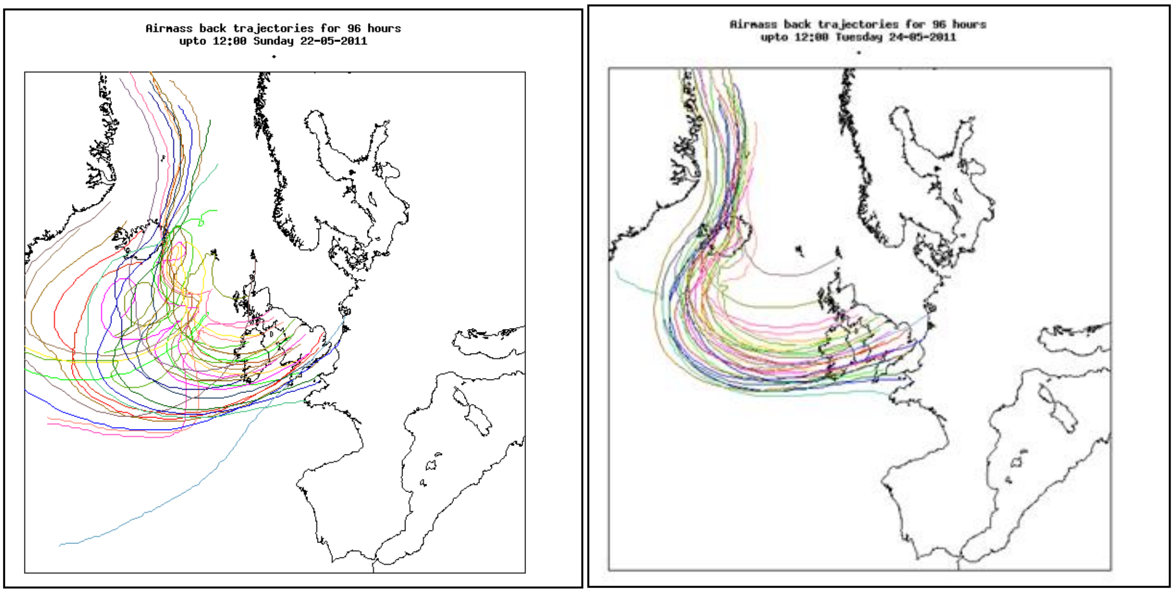
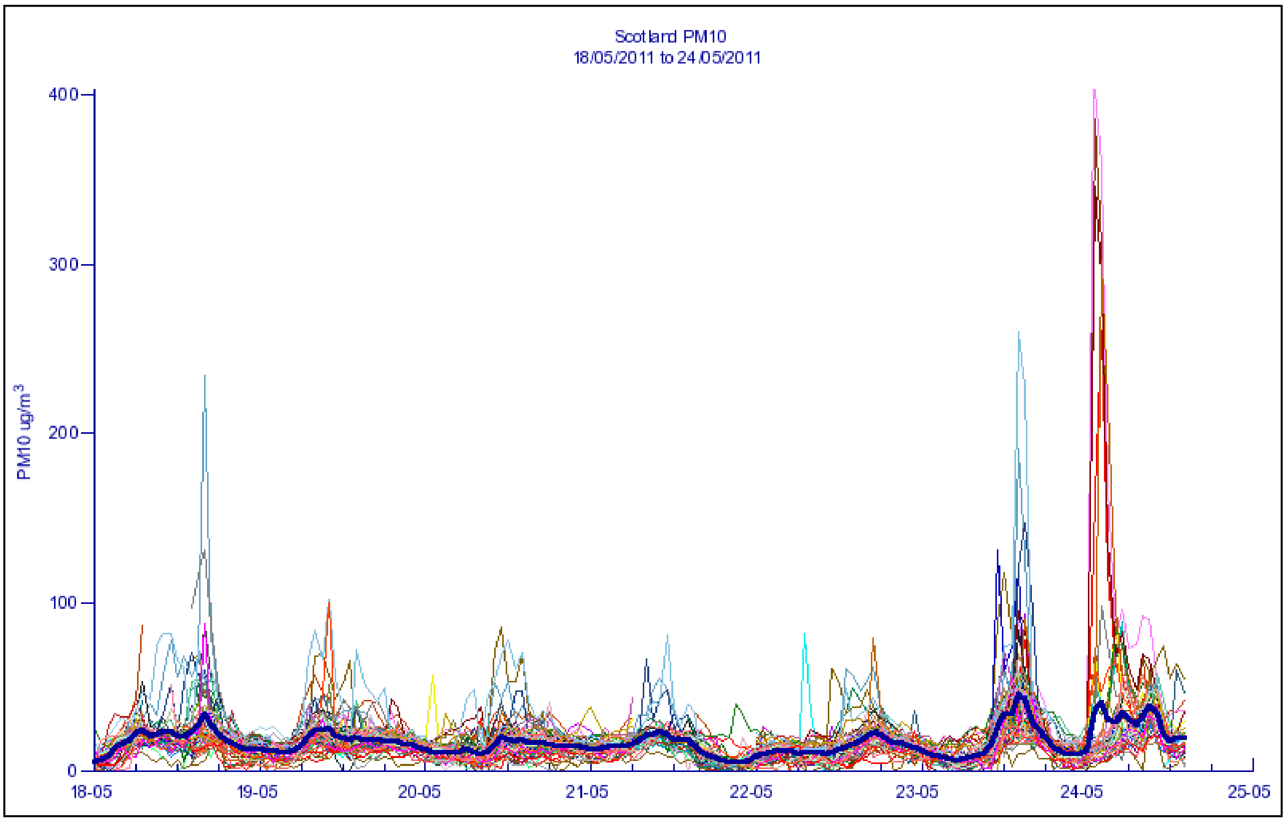


Figure 6-3 Airmass back trajectories for 22nd and 24th May 2011.



The plume was tracked across Scotland and Northern Ireland with some evidence of increased ground-level concentrations of PM_{10} for a few hours at Aberdeen sites in particular, although the peaks were not dramatic in size compared to normal daily variations in concentrations at these locations (Figure 6-4).

Figure 6-4 PM_{10} concentrations as measured by the AURN sites in Scotland 18th -25th May 2011.



6.2 Autumn Ozone Episode

Air pollution episodes due to ozone usually occur in the summer and late spring. However, during 2011 there was an unusually late ozone episode, in early autumn. During the first few days of October, "Moderate" ozone (air pollution index 5, based on the bandings in use during 2011), was recorded widely across the UK, reaching air pollution index 6 at Northampton. This unusually late summer pollution episode was caused by a period of stable high pressure and exceptionally high temperatures for the time of the year. Concentrations declined by Wednesday October 5th and then remained generally "Low" everywhere for the remainder of the month. Figure 6-5 shows ozone concentrations at rural AURN sites over this period. The daily peaks are clearly visible.

Figure 6-5 Ozone concentrations as measured by the rural AURN sites, 27th September - 6th October 2011.

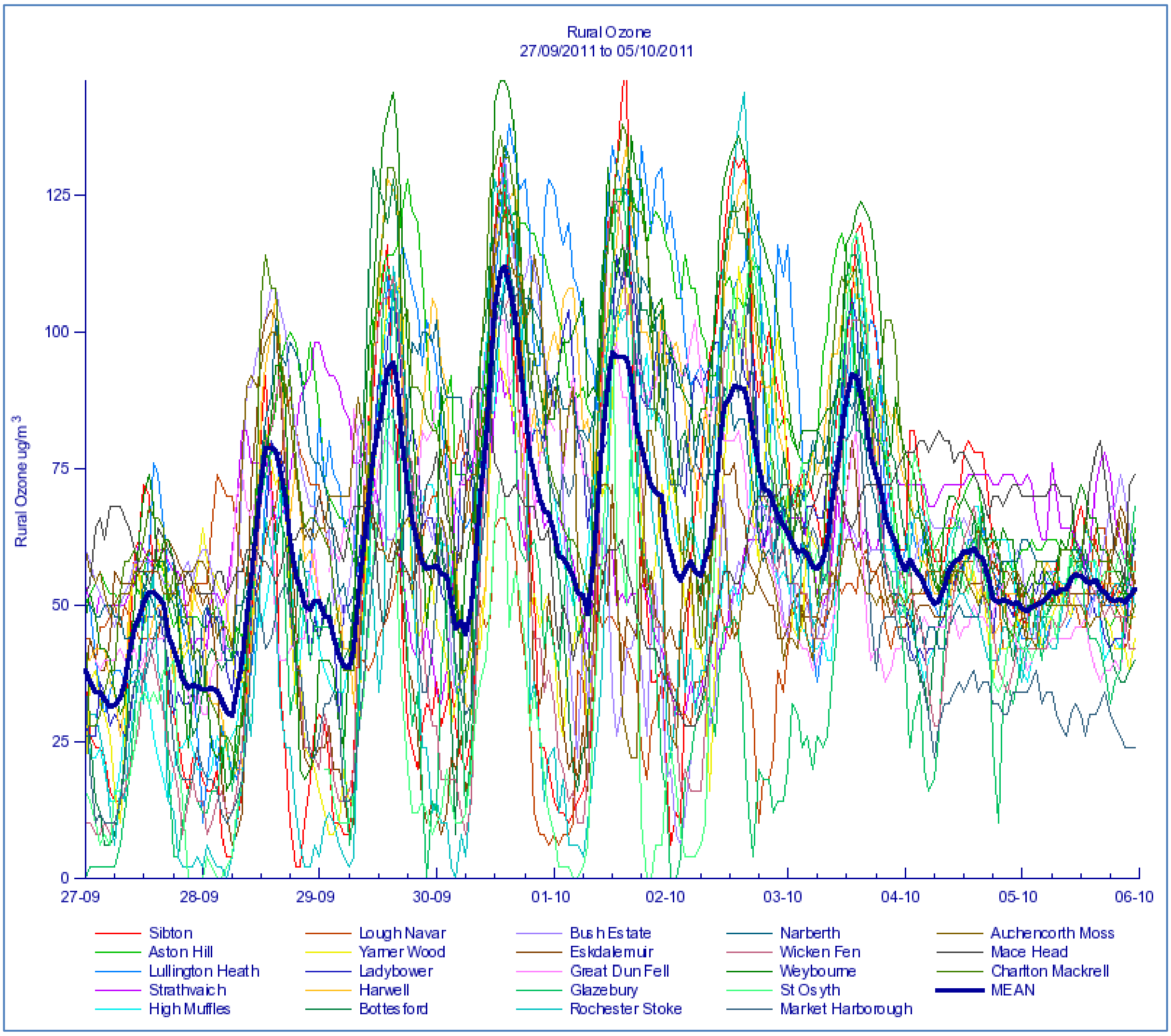
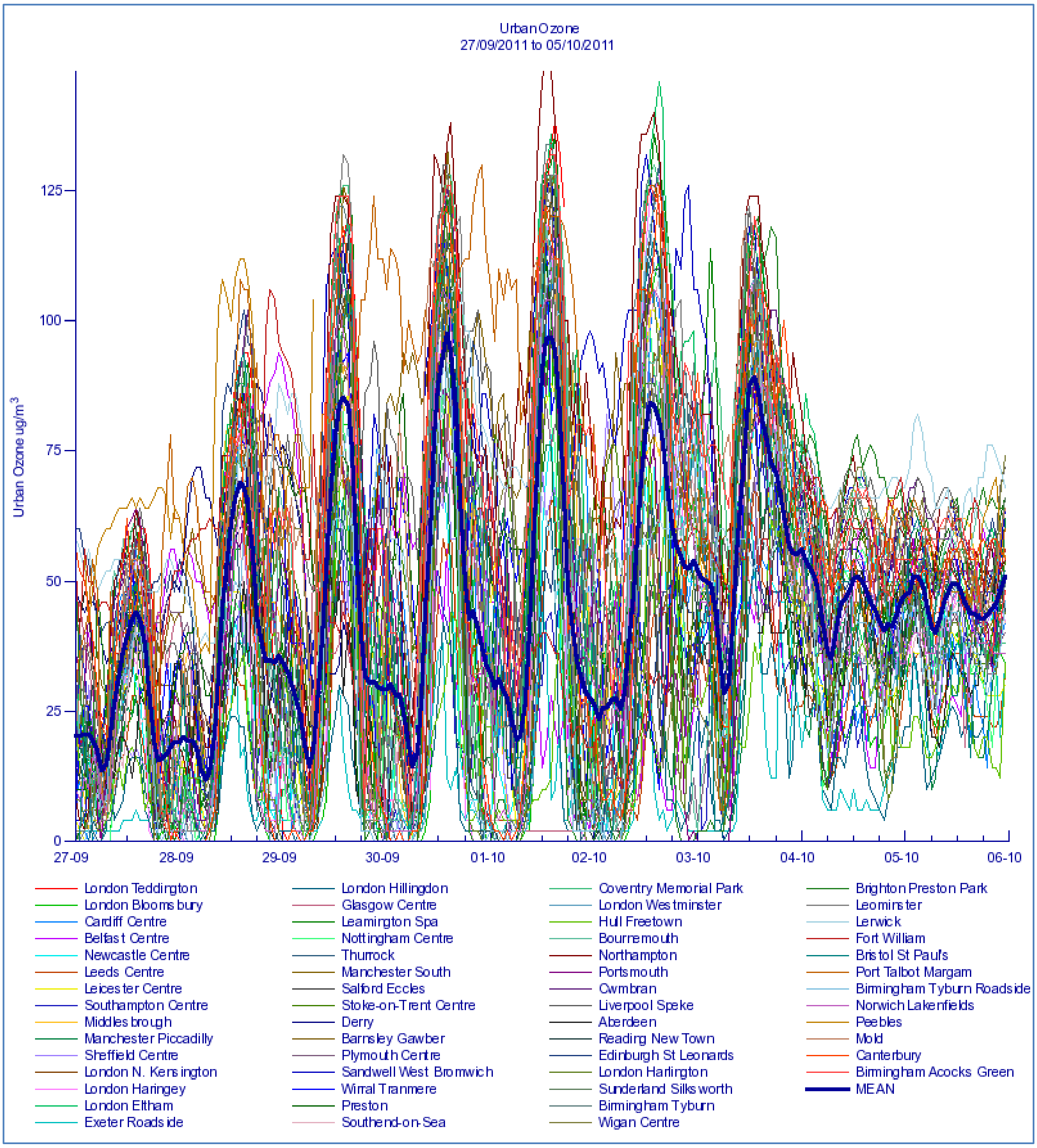


Figure 6-6 shows a similar time series graph, for the AURN's urban monitoring sites.

Figure 6-6 Ozone concentrations as measured by urban AURN sites, 27th September - 6th October 2011.



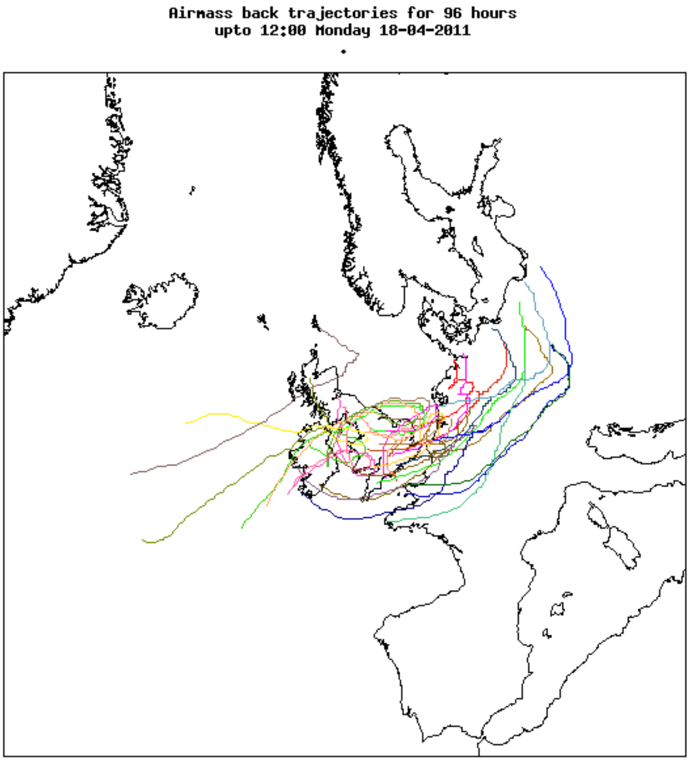
6.3 Spring Particulate Pollution Episode

During two periods in the spring of 2011 (25th – 30th March and 20th – 25th April), elevated concentrations of particulate matter were recorded by AURN monitoring sites across most of England and Wales, in particular Greater London. During the earlier episode, 24-hour running mean PM_{10} concentrations at one site (Leeds Headingley Kerbside) reached the "High" band (based upon the bandings in use in 2011), and on 29th March (the peak of the episode), 37 AURN sites recorded daily mean PM_{10} concentrations in excess of the EU limit value of 50 μgm^{-3}. At the peak of the later episode, several sites (including London Marylebone Road, Thurrock and Stanford Le Hope) measured 24-hour running mean PM_{10} concentrations in the "High" band and 31 AURN sites recorded daily mean PM_{10} concentrations in excess of the EU limit value. Figure 6-7 shows a "snapshot" of the air pollution index levels in England and Wales at one point during 22nd April 2011.

Figure 6-7 Air Pollution Levels on 22nd April 2011 as shown by UK-AIR

This was a relatively complex air pollution event, with several contributing factors. Firstly, warm, dry spring weather over continental Europe encouraged the formation of secondary particulate matter, mostly nitrate and sulphate particles. The wind direction resulted in polluted air masses with significantly enhanced background pollutant levels arriving over the UK. An area of high pressure resulted in still weather with low wind speeds, which allowed pollutants from the UK's own local emission sources to build up, elevating ambient concentrations of particulate matter still further. Figure 6-8 shows the forecast air mass back-trajectories for the 96 hours up to 12:00 on 21st Apr 2011. These pollution episodes are summarised in a short report available on UK-AIR[52].

Figure 6-8 Forecast Air Mass Back Trajectories for 96 hours up to 12:00 on 18th April



7 Where to Find Out More

Defra's Air Quality web pages at http://www.defra.gov.uk/environment/quality/air/air-quality/ provide details of what the UK is doing to tackle air pollution, and the science and research programmes in place.

Information on the UK's air quality, now and in the past, is provided by UK-AIR, the Defra online air quality resource at http://uk-air.defra.gov.uk/. UK-AIR is the national repository for historical ambient air quality data. It contains measurements from automatic measurement programmes dating back to 1972, together with non-automatic sampler measurements dating back to the 1960s. The data archive brings together into one coherent database both data and information from all the UK's measurement networks.

Similar national online air quality resources 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.

UK-AIR also provides a daily air quality forecast, which is further disseminated via e-mail, via a free telephone service on 0800 556677, and via Twitter (see http://uk-air.defra.gov.uk/twitter). Latest forecasts are issued twice daily, at http://uk-air.defra.gov.uk/forecasting/.

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 of Scotland, Wales and Northern Ireland can be found at:

- The Scottish Government Air Quality pages on http://www.scotland.gov.uk/Topics/Environment/waste-and-pollution/Pollution-1/16215

- The Welsh Government Environment link at http://wales.gov.uk/topics/environmentcountryside/epq/airqualitypollution/airquality/?lang=en

- The Northern Ireland DoE Environmental Policy Division website at http://www.doeni.gov.uk/index/protect_the_environment/local_environmental_issues/air_and_environmental_quality.htm

The Devolved Administrations each produce their own short annual report, providing more specific information on air quality in their regions. These reports are available from the above websites.

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