Department for Environment Food & Rural Affairs

Air Pollution in the UK 2018

September 2019

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Executive Summary

The UK is currently 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 amendments to the above Directives, in Directive 2015/1480/EC.

This 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 2018 submission on ambient air quality to the European Commission, presenting air quality modelling data and measurements from national air pollution monitoring networks. 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)
- Metals: lead, cadmium, nickel and mercury, and the metalloid arsenic.
- Polycyclic aromatic hydrocarbons (PAH)
- Ozone (O_3)

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

For the purposes of air quality monitoring and assessment of compliance with the above Directives, the UK is divided into 43 zones. The 2018 results are detailed in Section 4 of this report and summarised below:

- The UK met the limit value for hourly mean nitrogen dioxide (NO_2) in 41 out of 43 zones.
- Seven zones were compliant with the limit value for annual mean NO_2. The remaining 36 zones exceeded this limit value. In 25 of these 36 zones the exceedance of the limit value has decreased compared to 2017. Implementation of measures as a result of the 2017 UK Plan for Tackling Roadside Nitrogen Dioxide Concentration has now started, with the effect on compliance expected to be demonstrated in subsequent years.

- All non-agglomeration zones complied with the critical level for annual mean NO_X concentration, set for protection of vegetation.
- Three zones exceeded the target value for benzo[a]pyrene.
- Four zones exceeded the target value for nickel.
- All zones met the target values for arsenic and cadmium.
- All zones met both the target values for ozone; the target value based on the maximum daily eight-hour mean, and the target value based on the AOT40 statistic.
- No zones were compliant with the long-term objective for ozone, set for the protection of human health. This is based on the maximum daily eight-hour mean.
- Five zones met the long-term objective for ozone, set for the protection of vegetation. This is based on the AOT40 statistic.
- All zones met the limit value for daily mean concentration of PM_{10} particulate matter, without the need for subtraction of the contribution from natural sources.
- All zones met the limit value for annual mean concentration of PM_{10} particulate matter, without the need for subtraction of the contribution from natural sources.
- All zones met both limit values for annual mean concentration of $PM_{2.5}$ particulate matter: the Stage 1 limit value, which came into force on 1st January 2015, and the indicative Stage 2 limit value which must be met by 2020.
- The running year Average Exposure Indicator (AEI) for 2018 was within the 2020 exposure reduction target.
- All zones met the EU limit values for sulphur dioxide, carbon monoxide, lead and benzene.

A summary of the air quality assessment for 2018 with a comparison of the submissions carried out in the previous years (since 2008 when the Air Quality Directive came into force) can be found in Section 4 of this report. Copies of those previous annual submissions can be found on the Commission website: http://cdr.eionet.europa.eu/gb/eu/annualair and http://cdr.eionet.europa.eu/gb/eu/aqd/.

For more information on air quality in the UK visit the Defra website at www.gov.uk/defra and the UK Air Quality websites at http://uk-air.defra.gov.uk/, http://www.scottishairquality.scot/, https://airquality.gov.wales and www.airqualityni.co.uk.

Glossary

Air Quality Directive. The European Union's Directive 2008/50/EC of 21st May 2008, on Ambient Air Quality and Cleaner Air for Europe is often – as in this report - referred to as 'the Air Quality Directive'.

Air Quality Strategy. The United Kingdom's own National Air Quality Strategy, containing policies for assessment and management of air quality in the UK. This was first published in 1997, as a requirement of The Environment Act 1995.

Air Quality Strategy Objective. The Air Quality Strategy sets objectives for the maximum concentrations of eight pollutants. These are at least as stringent as the limit values of the Air Quality Directive.

Ambient Air. Outdoor air.

Average Exposure Indicator (AEI). The statistic on which the ***Air Quality Directive***'s national exposure reduction target is based, for $PM_{2.5}$ between 2010 and 2020. The AEI for the UK is calculated as follows: the arithmetic mean $PM_{2.5}$ concentration at appropriate UK urban background sites is calculated for three consecutive calendar years, and the mean of these values taken as the AEI.

Benzene. A chemical compound that is harmful to human health. As an air pollutant, benzene can be emitted from domestic and industrial combustion processes, and road vehicles. Its chemical formula is $C_6 H_6$.

Benzo[a]pyrene. One of a group of compounds called ***polycyclic aromatic hydrocarbons (PAHs)*** that can be air pollutants. The main sources of B[a]P in the UK are domestic coal and wood burning, fires, and industrial processes such as coke production.

Beta Attenuation Monitor (BAM). A type of instrument used for monitoring concentrations of particulate matter.

1,3-Butadiene. This is an organic compound emitted into the atmosphere mainly from fuel combustion e.g. petrol and diesel vehicles. 1,3-butadiene is also an important chemical in certain industrial processes, particularly the manufacture of synthetic rubber. 1,3-butadiene is known to cause cancer in humans.

Carbon Monoxide (CO) a pollutant gas found released in road vehicle exhausts. When breathed in, carbon monoxide affects the blood's ability to carry oxygen around the body.

Digitel^{TM} Sampler. A type of sampler used in the PAH Network: air is drawn through a filter which is subsequently analysed for ***polycyclic aromatic hydrocarbons (PAHs).***

Episode (Air Pollution Episode). An 'air pollution episode' means a period of time (usually a day or several days) when air pollution is high (air quality is poor).

FDMS. This stands for 'Filter Dynamic Measurement System' and refers to a type of instrument for monitoring concentrations of particulate matter. The FDMS is a modified form of Tapered Element Oscillating Microbalance (TEOM).

Fidas™. A type of instrument which uses an optical technique for monitoring concentrations of particulate matter.

Gravimetric Sampler. A type of instrument used to measure ambient concentrations of ***particulate matter***. It works by drawing air through a filter, on which the particulate matter is collected. The filter is subsequently weighed and the ambient concentration of particulate matter calculated.

Fourth Daughter Directive. The European Union's Directive 2004/107/EC, which covers the four metallic elements cadmium, arsenic, nickel and mercury together with ***polycyclic aromatic hydrocarbons (PAH)***. (Its name comes from its origin as one of four so-called Daughter Directives set up under an overarching 'framework Directive'.)

Limit value. The Air Quality Directive sets 'limit values' for ambient concentrations of pollutants. Limit values are legally binding and must not be exceeded. All Member States of the EU must make the limit values part of their own air quality legislation.

Long-Term Objectives. As well as limit values and target values, the Air Quality Directive sets 'long-term objectives' for ozone concentration. These are similar to limit values but are not legally mandatory. Member States must take all necessary measures not entailing disproportionate costs to meet the target values and long-term objectives.

Member States. Countries that are part of the European Union.

Microgramme per cubic metre (µg m^{-3}). Unit often used to express concentration of a pollutant in air. 1 µg = 1 millionth of a gramme or 1 x 10^{-6} g.

Micrometre (µm). Unit of length often used for the size of particulate pollutants. 1 µm = 1 millionth of a metre (1 x 10^{-6} m) or one thousandth of a millimetre.

Milligramme per cubic metre (mg m^{-3}). Unit often used to express concentration of carbon monoxide in air. 1 mg = 1 thousandth of a gramme or 1 x 10^{-3} g.

Nickel (Ni) A toxic metallic element found in ambient air as a result of releases from oil and coal combustion, metal processes, manufacturing and other sources.

Nitric oxide (NO). One of the oxides of nitrogen formed in combustion processes. NO is not harmful to human health but combines with oxygen to form nitrogen dioxide.

Nitrogen Dioxide (NO_2) One of the oxides of nitrogen formed in combustion processes. At high concentrations NO_2 is an irritant to the airways. NO_2 can also make people more likely to catch respiratory infections (such as flu), and to react to allergens.

Nitrogen Oxides (NO_X). Compounds formed when nitrogen and oxygen combine. NOx, which comprises nitric oxide (NO) and nitrogen dioxide (NO_2), is emitted from combustion processes. Main sources include power generation, industrial combustion and road transport.

Ozone (O_3). A pollutant gas which is not emitted directly from any source in significant quantities, but is produced by reactions between other pollutants in the presence of sunlight. (This is what is known as a ***'secondary pollutant'***.) Ozone concentrations are greatest in the summer. O_3 can travel long distances and reach high concentrations far away from the original pollutant sources. Ozone is an irritant to the airways of the lungs, throat and eyes: it can also harm vegetation.

Particulate Matter (PM). Small airborne particles. PM may contain many different materials such as soot, wind-blown dust or secondary components, which are formed within the atmosphere as a result of chemical reactions. Some PM is natural and some is man-made. Particulate matter can be harmful to human health when inhaled, and research shows a range of health effects associated with PM. In general, the smaller the particle the deeper it can be inhaled into the lung.

Partisol^{TM}. A type of ***gravimetric sampler*** used for measuring ambient concentrations of PM_{10} or $PM_{2.5}$.

PM_{10}. Particles which pass through a size-selective inlet with a 50 % efficiency cut-off at 10 µm aerodynamic diameter, as defined in ISO 7708:1995, Clause 6. This size fraction is important in the context of human health, as these particles are small enough to be inhaled into the airways of the lung – described as the 'thoracic convention' in the above ISO standard. PM_{10} is often described as '*particles of less than 10 micrometres in diameter*' though this is not strictly correct.

$PM_{2.5}$. Particles which pass through a size-selective inlet with a 50 % efficiency cut-off at 2.5 µm aerodynamic diameter, as defined in ISO 7708:1995, Clause 7.1. This size fraction is important in the context of human health, as these particles are small enough to be inhaled very deep into the lung – described as the 'high risk respirable convention' in the above ISO standard. $PM_{2.5}$ is often described as '*particles of less than 2.5 micrometres in diameter*' though this is not strictly correct.

Polycyclic Aromatic Hydrocarbons (PAH). PAHs are a large group of chemical compounds that are toxic and carcinogenic. Once formed, they can remain in the environment for a long time, and can be passed up the food chain. The main sources are domestic coal and wood burning, outdoor fires, and some industrial processes. The pollutant ***benzo[a]pyrene*** is a PAH, and because it is one of the more toxic PAH compounds it is measured as a 'marker' for this group of pollutants.

Secondary pollutant. A pollutant which is formed by chemical reactions from other pollutants in the atmosphere. Ozone, for example, is a secondary pollutant.

Sulphur dioxide (SO_2). An acid gas formed when fuels containing sulphur impurities are burned. SO_2 irritates the airways of the lung.

Target Value. As well as limit values, the ***Air Quality Directive*** and ***Fourth Daughter Directive*** set target values for some pollutants. These are similar to limit values but are not legally mandatory. ***Member States*** must take all necessary measures not entailing disproportionate costs to meet the target values.

TOMPs. This stands for 'Toxic Organic Micropollutants'. These are compounds that are present in the environment at very low concentrations, but are highly toxic and persistent. They include dioxins and dibenzofurans.

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1 Introduction

A cleaner, healthier environment benefits people and the economy. Clean air is vital for people's health and the environment, essential for making sure our cities are welcoming places for people to live and work now and in the future, and to our prosperity. It is therefore important to monitor levels of air pollution. The broad objectives of monitoring air pollution in the UK are:

- To fulfil statutory air quality reporting requirements.
- To provide a sound scientific basis for the development of cost-effective control policies.
- To provide the public with open, reliable and up-to-date information on air pollution, enabling them to take appropriate action to minimise health impacts.
- To evaluate potential impacts on population, ecosystems and our natural environment.

Air quality standards are set in European Union (EU) Directive 2008/50/EC on Ambient Air Quality and Cleaner Air for Europe[1] and the Fourth Daughter Directive[2] (2004/107/EC). These Directives require all Member States 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 must be submitted to the European Commission each year. As of 2013, the air quality compliance assessment has been submitted to the Commission via e-Reporting (see Section 2.1.2). The UK's annual submission for 2018 can be found on the Commission website at http://cdr.eionet.europa.eu/gb/eu/aqd. All the compliance results are reported under 'Information on the Attainment of Environmental Objectives' in e-Reporting Data Flow G. Submissions for years up to and including 2012 (which were in the form of a standard questionnaire) can be found at 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. '*Air Pollution in the UK 2018*' continues this series, and this report has two aims:

- To provide a summary of the UK's 2018 air quality report to the Commission. A separate Compliance Assessment Summary document, based upon Section 4 of this report, accompanies the UK's 2018 data submission to the Commission. This provides a concise summary aimed at the public.
- To act as a State of the Environment report, making information on the ambient air quality evidence base for the year publicly available. This includes an

assessment of trends and spatial distribution, together with information on pollution events during the year.

This report:

- Outlines the air quality legislative and policy framework in Europe and the UK (Section 2).
- Describes the evidence base underpinning the UK's air quality assessment: the pollutants of concern, and where and how air pollution is measured and modelled (Section 3).
- Presents 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 Fourth Daughter Directive for 2018, and compares this with previous recent years (Section 4).
- Explains the spatial distribution of the main pollutants of concern within the UK during 2018 and looks at how ambient concentrations have changed in recent years (Section 5).
- Explains pollution events – 'episodes' of high pollution – that occurred during 2018 (Section 6).

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

The UK air quality framework is derived from a mixture of domestic, EU and international legislation and consists of three main strands:

1) Legislation regulating total emissions of air pollutants – the UK is bound by both EU law (the National Emission Ceilings Directive) and international law (the Gothenburg Protocol to the UNECE Convention on Long-range Transboundary Air Pollution);

2) Legislation regulating concentrations of pollutants in the air; and

3) Legislation regulating emissions from specific sources such as legislation implementing the Industrial Emissions Directive, Medium Combustion Plant Directive, and the Clean Air Act.

Reducing air pollution requires action to reduce domestic emissions as well as working closely with international partners to reduce transboundary emissions (pollutants blown over from other countries) which, at times, can account for a significant proportion of pollutant concentrations experienced in the UK. For example, a 2013 report[3] prepared by the Air Quality Expert Group on behalf of Defra estimated that emission sources within the UK only accounted for 50-55% of measured annual average fine particulate matter ($PM_{2.5}$) concentrations, the remainder being formed or emitted elsewhere.

2.1 European and International Background

European Union (EU) air pollution legislation follows two complementary approaches:

(i) Controlling emissions at source, and

(ii) Setting of ambient air quality standards and long-term objectives.

All Member States must incorporate - or ‘transpose’ - the provisions of EU Directives into their own national law by a specified date and comply with legally binding implementing rules set out in the Decisions. The main Directives and Decisions are described below.

The UK is fully committed to tackling air pollution, and this is independent of being a member of the EU. The European Union (Withdrawal) Act will ensure that the whole body of existing EU environmental law continues to have effect in UK law. Under the Withdrawal Act, the Government has laid in Parliament Statutory Instruments which ensure the continuity of air quality regulation, standards and transparency.

2.1.1 The Air Quality Directive and Fourth Daughter Directive

Directive 2008/50/EC of 21st May 2008, on Ambient Air Quality and Cleaner Air for Europe – referred to in this report as ‘the Air Quality Directive’[1] - covers the following pollutants; sulphur dioxide, nitrogen oxides, particulate matter (as PM_{10} and $PM_{2.5}$), lead, benzene, carbon monoxide and ozone. It revised and consolidated existing EU air quality legislation relating to the above pollutants.

Directive 2004/107/EC of 15th December 2004, relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air - referred to in this report as 'the Fourth Daughter Directive'[2] - covers the four elements cadmium, arsenic, nickel and mercury, together with polycyclic aromatic hydrocarbons (PAH).

These two Directives set 'limit values', 'target values' and 'long-term objectives' for ambient concentrations of pollutants.

Limit values are legally binding and must not be exceeded. They are set for individual pollutants and comprise a concentration value, an averaging period for the concentration value, a number of exceedances allowed (per year) and a date by which it must be achieved. Some pollutants have more than one limit value, for example relating to short-term average concentrations (such as the hourly mean) and long-term average concentrations (such as the annual mean).

Target values and long-term objectives are set for some pollutants and are configured in the same way as limit values. Member States must take all necessary measures not entailing disproportionate costs to meet the target values and long-term objectives.

The Air Quality Directive and Fourth Daughter Directive include detailed provisions on monitoring and reporting air quality, including:

- The division of the UK into zones for the purposes of compliance reporting.
- The location and number of sampling points.
- The measurement methods to be used.
- Data quality objectives.
- Siting criteria each monitoring station must meet.
- Provision for reporting compliance.
- Provision of information to the public.

The Air Quality Directive also makes provisions for adapting standardised procedures to streamline the data provision, assessment and reporting of air quality, to electronically release information in line with the INSPIRE Directive (2007/2/EC). This led to the adoption of new implementing provisions for reporting (IPR) (Decision 2011/850/EC, referred to in this report as the Air Quality e-Reporting IPR). Section 2.1.2 provides a detailed description of the Air Quality e-Reporting IPR. The report of 2013 was the first in which e-Reporting was used to report emissions.

The provisions of the Air Quality Directive and Fourth Daughter Directive were transposed by the Air Quality Standards Regulations 2010[4] in England, the Air Quality Standards (Scotland) Regulations 2010[5] in Scotland, the Air Quality Standards (Wales) Regulations 2010 in Wales[6] and the Air Quality Standards Regulations (Northern

Ireland) 2010[7]. All the provisions made by the Directives are therefore incorporated into UK legislation.

The above Directives were amended by the Technical Directive 2015/1480/EC[8] (which amended some details of the Directives' annexes relating to reference methods, data validation and locations of sampling points). The relevant regulations were amended accordingly in December 2016.

2.1.2 Air Quality e-Reporting

Defra is committed to the principles of Open Data. Air Quality e-Reporting is a process, developed by the European Commission, for reporting of compliance and provision of data under the Air Quality Directive. The development has been driven by the requirements of the INSPIRE Directive (which is concerned with the sharing of spatial data across EU Member States in a consistent and computer-readable format). Air Quality e-Reporting is a key tool to help ensure UK air quality data systems comply with the INSPIRE Directive and are available across Europe in a comparable form with other Member States. Operational Air Quality e-Reporting started on 1st January 2014; as of 21st October 2015, newly collected or extensively restructured spatial data sets have had to be available in INSPIRE conformant formats, and as of 10th December 2015 web based spatial data download services have been required to conform to INSPIRE Regulations.

European Commission Implementing Decision 2011/850/EU[9] was introduced on 12th December 2011. This Decision laid down rules for the reciprocal exchange of information, and reporting on ambient air quality, in relation to the Air Quality Directive. The Decision provided an opportunity to modernise data reporting, improve data quality, facilitate information sharing and reduce the administrative burden of reporting. In adapting the procedures, Air Quality e-Reporting has embraced digital formats for reporting, and the internet as the core medium for reporting. Air Quality e-Reporting extends the core requirements of the INSPIRE Directive to meet the particular requirements of regulatory and informative air quality reporting.

The European Commission developed these procedures with assistance from the European Topic Centre on Air and Climate Change Mitigation and the European Environment Agency (EEA), and in close liaison with the European Environment Information and Observation Network (EIONET) air quality community. The e-Reporting system covers all regulatory and information reporting agreements set out by the Exchange of Information Decision (EoI) (Council Decision 97/101/EC[10]), the Air Quality Directive and the 4th Daughter Directive. By adopting data modelling approaches prescribed by INSPIRE, the e-Reporting data model is streamlined, internally consistent and meets modern standards for data encoding and data sharing. The data model is now organised into eight broad air quality data themes that service all reporting and information sharing needs of the air quality community.

2.1.3 The National Emission Ceilings Directive

The original National Emission Ceilings Directive (2001/81/EC) came into force in 2001 and was transposed into UK legislation by the National Emission Ceilings Regulations 2002. This Directive set national emission limits or 'ceilings' for sulphur dioxide, oxides of nitrogen, volatile organic compounds, and ammonia. These are 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. The ceilings had to be met by 2010 and have applied since. They reflect the ceilings agreed internationally in the 1999 Gothenburg Protocol to the UNECE Convention on Long Range Transboundary Air Pollution (CLRTAP). Emissions of these pollutants can impact either locally or across national borders: the latter is known as 'transboundary' air pollution.

The UK meets all current emission ceilings set under the National Emission Ceilings Directive. The National Emission Ceilings Directive report is available at https://www.eea.europa.eu/publications/nec-directive-reporting-status-2019.

The Gothenburg Protocol was revised in May 2012 to set emission reduction commitments (ERCs) for 2020 (from the 2005 baseline) for the same four pollutants and $PM_{2.5}$. The European Commission published a proposal to revise the National Emission Ceilings Directive in December 2013, to implement the new 2020 ERCs in the Protocol, and to set further commitments for 2030.

The revised National Emission Ceilings Directive (Directive 2016/2284/EU)[11] came into force on 31st December 2016. The Directive was transposed into UK legislation in February 2018, and the new legislation came into force on 1st July 2018. Under the new Directive and the amended Gothenburg Protocol, the UK has ambitious targets in place to reduce emissions of five damaging air pollutants (ammonia, nitrogen oxides, non-methane volatile organic compounds, fine particulate matter and sulphur dioxide) by 2020 and 2030. Defra's Clean Air Strategy, published in January 2019, sets out how we will work towards these goals (see Section 2.2.2).

2.1.4 The Industrial Emissions Directive

The Industrial Emissions Directive (Directive 2010/75/EU) sets stringent provisions to reduce the emissions of pollutants from a diverse range of industrial sources - from intensive pig and poultry farms to chemical manufacturing sites and power stations – with the aim of achieving the environmental and human health benefits associated with a reduction in pollution. Under the Directive, industries must use best available techniques (BAT) to reduce their emissions. These techniques, and the emissions limits associated with the use of those techniques, are set out in best available technique reference documents (known as BREFs). BREFs are reviewed regularly, to ensure an ongoing process of improvement to EU air quality achieved through the continuous reduction of pollution. In addition, the Directive sets emission limits for the emission of pollutants from particular sectors. The revised NECD (2016/2284/EU), which entered into force on 31st December 2016, sets new emission reduction commitments (ERCs) for each Member State for the total emissions of NO_X, SO_X, NMVOC, NH_3 and $PM_{2.5}$ in 2020 and 2030.

2.2 The UK Perspective

Domestic, EU and internationally-driven environmental legislation introduced over the past seventy 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. Following the UK's Clean Air Act, the city smogs of the 1950s, caused by domestic and industrial coal burning, have now gone for good and significant progress has been made in improving air quality throughout recent decades. Between 1990 and 2017, UK estimated emissions of nitrogen oxides have fallen by 72%, and UK estimated emissions of PM_{10} particulate matter have fallen by 55% (data from the National Atmospheric Emissions Inventory at http://naei.beis.gov.uk/). Reductions in emissions have continued in recent years. Between 2010 and 2017, emissions of nitrogen oxides have fallen by 29%, and primary emissions of $PM_{2.5}$ have fallen by 10%.

Poor air quality is the greatest environmental risk to public health in the UK. It is known to exacerbate the impact of pre-existing health conditions, such as respiratory and cardio-vascular illnesses, especially for the elderly and infants.

Nitrogen dioxide (NO_2) is of particular concern because there is widespread exceedance in the UK, of limit values for this pollutant. NO_2 is associated with adverse effects on human health. Estimating the long-term impacts of NO_2 pollution is difficult, because of the challenge of separating its effects from those of other traffic-related pollutants[12]. Although it has been more difficult to estimate the level of impact, there is enough evidence of such health effects to support the need to take action now.

Particulate matter is also of concern, although the UK has been compliant with EU limit values in recent years. In 2010, the Committee on the Medical Effects of Air Pollutants (COMEAP) produced a report on the mortality effects of long-term exposure to particulate air pollution in the United Kingdom. COMEAP estimated that the long-term impact of particulate pollution in the UK equated to 340,000 years of life lost[13].

2.2.1 The UK Air Quality Strategy

The Environment Act 1995 required that a National Air Quality Strategy be published, containing policies for assessment and management of air quality. The Air Quality Strategy[14] 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[15] 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.

2.2.2 The Clean Air Strategy 2019

On 14th January 2019, Defra published the Clean Air Strategy[16] (CAS), following a consultation over the summer of 2018. The Strategy sets out a range of initiatives that will help reduce air pollution, providing healthier air to breathe, enhancing the economy and protecting nature.

Clean air is very important; it is crucial for life, health, the environment and the economy. The Strategy document begins by outlining our **understanding** of the problem, and the importance of a robust evidence base, backed by the most up to date science. It introduces the five damaging air pollutants which are the focus of the strategy, these are:

- Fine particulate matter (as $PM_{2.5}$).
- Ammonia (NH_3).
- Nitrogen oxides (NO_X).
- Sulphur dioxide (SO_2).
- Non-methane volatile organic compounds (NMVOCs).

The CAS also addresses ozone (O_3), as a pollutant which is not emitted but formed from chemical reactions in the air.

Next, it deals with **protecting the nation's health**. The health impacts (and their estimated costs to the UK) are summarised: actions are then set out for how public exposure to air pollution can be reduced.

Air pollution is not only a major risk to human health; it also has significant effects on the environment. It has damaging impacts on both plants and animal communities. The CAS devotes a chapter to **protecting the environment**.

The strategy highlights the importance of **securing clean growth and driving innovation**. Cleaning our air is about increasing productivity through improved air quality, effective use of resources and moving to a low carbon economy. Improving air quality is linked to tackling climate change, as the sources of 'greenhouse gases' implicated in climate change are in many cases also sources of air pollutants. It is acknowledged that there is a gap between our air quality now and what we would like our air quality to be in 10 years' time and beyond. This gap needs to be closed by a variety of actions.

Air pollution is a problem because of how we currently produce power, food, heat our homes, manufacture goods and services and power transport. The CAS contains subsequent chapters devoted to:

- Action to reduce emissions from **transport** (covering action already taken and action proposed for the future).
- Action to reduce emissions from **the home** (including domestic burning, and the use of products which release NMVOCs).
- Action to reduce emissions from **farming**: this focusses on reduction of emissions of ammonia (which reacts with nitrogen oxides and sulphur dioxide to form secondary particulate matter) and NMVOCs (which contribute to the formation of ozone).
- Action to reduce emissions from **industry** – setting out how we can build upon the existing strong framework, and support continuous improvement.

The Strategy also addresses the issue of **leadership at all levels**: international (acknowledging that air pollution is not stopped at national borders, and UK emissions can have an impact across our country, the continent and worldwide); national (including securing a green Brexit, and updating and improving the legislative framework); and local (giving local authorities new powers to lower emissions from a wider a range of sources than transport alone by means of Clean Air Zones). Focusing on the importance of cooperating with all parts of the UK, the document outlines the actions which are already underway throughout Northern Ireland, Scotland and Wales. These actions show how we can address the different sources of air pollution.

Finally, the Strategy summarises **progress -** there are several high-profile agreements which the UK has signed up to, to improve air quality. Currently the UK is compliant with EU ambient air quality legislation for most pollutants but NO_2 is an exception. However, an air quality plan has been created to help achieve compliance as swiftly as possible. It has been shown through analysis that the CAS can help meet the ambitious targets to reduce emissions.

In 2015, the Scottish Government published its air quality strategy 'Cleaner Air for Scotland – The Road to a Healthier Future'[17] (CAFS). CAFS brings together into a single framework a number of Government policies impacting on air quality and sets out a series of 40 actions intended to deliver further air improvements.

At the end of 2018, an independent review of CAFS was launched, with a remit to review progress to date and identify priorities for additional action. The review report was published in August 2019[18] and will be used as the basis for developing a revised and updated strategy.

2.2.3 National Air Quality Statistics and Indicators

For many years, the UK has reported the following two indicators as National Air Quality Statistics for ambient air:

- **Annual average concentrations of particles and ozone**. These two types of air pollution are believed to have a significant impact on public health.

- **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 Daily Air Quality Index (see Section 2.2.5). From the 1st January 2012, $PM_{2.5}$ particles replaced 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.

In 2018, new content was added, including the following:

- **Annual mean concentrations of fine particulate matter ($PM_{2.5}$)** at urban roadside and background monitoring sites. The inclusion of $PM_{2.5}$ reflects the increased interest in this size fraction.

- **Annual mean nitrogen dioxide (NO_2) concentrations** at urban roadside, urban background and rural background monitoring sites. The inclusion of NO_2 informs the public and scientific discussion regarding concentrations of this pollutant, particularly at the roadside.

- **Average hours per year in the 'Moderate' or higher categories** of the Daily Air Quality Index, for PM_{10}, $PM_{2.5}$, NO_2 and ozone. This is intended to highlight variation in short-term exposure per year to harmful levels of air pollution.

- **Variation in pollutant concentration by month of the year (for $PM_{2.5}$ and ozone), by day of the week (for NO_2), and by hour of the day - 'diurnal' variation – (for $PM_{2.5}$ and NO_2).** These are provided for the most recent year, and intended to aid understanding of the nature of variation in pollutant concentrations at different types of site.

The National Air Quality Statistics summary for 2018 was released on 25th April 2019 and is available from the Defra website[19].

In August 2016, Defra published a revised edition of the England Natural Environment Indicators[20]. Indicator 11 for Environmental Quality and Health relates to air quality. This is based on:

- The average number of days per site when air pollution is 'Moderate' or higher – for urban and for rural sites,

- Regional mortality due to anthropogenic particulate air pollution, compared to the England national average (5.6% in 2010, which is being taken as the baseline year for this indicator).

The UK Government's Public Health Outcomes Framework for England (published in 2012) recognises the burden of ill-health resulting from poor air quality as well as other public health concerns. This Framework sets out 60 health outcome indicators for England, and includes as an indicator:

- The fraction of annual all-cause adult mortality attributable to long-term exposure to current levels of anthropogenic particulate air pollution (measured as fine particulate matter, $PM_{2.5}$)[21].

This indicator is intended to enable Directors of Public Health to appropriately prioritise action on air quality in their local area. The indicator is calculated for each local authority in England based on modelled concentrations of fine particulate air pollution ($PM_{2.5}$). Estimates of the percentage of mortality attributable to long term exposure to particulate air pollution in local authority areas are available from the Public Health Outcomes Framework data tool at https://fingertips.phe.org.uk/profile/public-health-outcomes-framework. Current estimates at the time of writing, which are based on year 2017, range from 2.5% in the Isles of Scilly to around 7% in some areas of London.

The Defra document *'Air Quality: Public Health Impacts and Local Actions'* can be found at https://laqm.defra.gov.uk/documents/air_quality_note_v7a-(3).pdf. A toolkit aimed at helping public health professionals appropriately prioritise assessment and action on $PM_{2.5}$ on a local level is available here: http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=18580 .

Northern Ireland has a similar Public Health Strategy: *'Making Life Better – A Whole System Framework for Public Health 2013-2023'*. This document can be found at https://www.health-ni.gov.uk/topics/public-health-policy-and-advice/making-life-better-whole-system-strategic-framework-public, and also includes an air quality indicator.

Wales has a new national indicator under the Well-being of Future Generations (Wales) Act 2015 and the Welsh Public Health Outcomes Framework, which has now been published on StatsWales at (https://statswales.gov.wales/Catalogue/Environment-and-Countryside/Air-Quality).

2.2.4 National Emissions Statistics

The UK reports annual emissions of the following pollutants via an annual National Statistics Release[22], available at https://www.gov.uk/government/statistics/emissions-of-air-pollutants :

- Sulphur dioxide (SO_2).
- Oxides of nitrogen (NO_X).

- Non-methane volatile organic compounds (NMVOCs).
- Ammonia (NH_3).
- Particulate matter (as PM_{10} and $PM_{2.5}$).

The most recent National Statistics Release covers 1970 to 2017 (the most recent year for which emission statistics are available). The main conclusions are as follows:

- *‘There has been a long term decrease in the emissions of all of the air pollutants covered by this statistical release (ammonia, nitrogen oxides, non-methane volatile organic compounds, particulate matter (PM_{10}, $PM_{2.5}$) and sulphur dioxide).*
- *Emissions of sulphur dioxide decreased by 1.6 per cent from 2016 to 2017, dropping to the lowest level in the time series. This was driven by a decline in coal use in power stations, continuing a long-term decrease in emissions from this source.*
- *Emissions of nitrogen oxides decreased in 2017 compared to 2016 by 3.4 per cent, dropping to the lowest level in the time series. This was driven by a decline in coal use in power stations and modernisation of the road transport fleet, although this is partially offset by the large proportion of the transport fleet using diesel as a fuel. Road transport accounted for 32 per cent of emissions of nitrogen oxides in 2017.*
- *Emissions of non-methane volatile organic compounds increased by 1.0 per cent between 2016 and 2017 although the long-term trend has been a steady reduction in emissions. The rate of decline was most pronounced in the 1990s and early 2000s.*
- *PM_{10} emissions have remained relatively static in recent years but increased by 1.0 per cent from 2016 to 2017.*
- *$PM_{2.5}$ emissions decreased by 0.1 per cent between 2016 and 2017. 2017 emissions are the lowest level in the time series. The use of wood in domestic combustion activities accounted for 36 per cent of $PM_{2.5}$ emissions in 2017.*
- *There was an increase of 0.7 per cent in emissions of ammonia between 2016 and 2017. Increases since 2013 go against the trend of steady overall reduction observed from 1998 to 2013. Agriculture accounted for 87 per cent of emissions from ammonia in 2017.*
- *The UK continues to meet current international and EU ceilings for emissions of ammonia, nitrogen oxides, non-methane volatile organic compounds and sulphur dioxide. The Gothenburg Protocol under the UNECE Convention on Long-range Trans-boundary Air Pollution was revised in 2012 to set new emission ceilings to apply from 2020. These ceilings are indicated in the charts of the results.*
- *This latest data shows that the UK exceeded the current emission ceilings for nitrogen oxides, which apply from 2010 to 2019, for the years 2010 and 2012 only, but were in compliance with these ceilings in all other years. As permitted under the 2016 National Emission Ceilings Directive and the 2012 amendment to the Gothenburg Protocol, the UK successfully applied for an adjustment to total national emissions of nitrogen oxides which brought the 2010 total into*

compliance with the 2010 emissions ceiling, and this adjustment has been extended for the year 2012. Adjustments are allowed where non-compliance with the ceilings results from applying improved emission inventory methods updated in accordance with scientific knowledge. Compliance with national ceilings is then assessed by reference to the adjusted totals.'

New emission statistics for 2018 will be published in February 2020.

2.2.5 The UK Air Pollution Forecasting System

Daily UK air pollution forecasts are produced for five pollutants; nitrogen dioxide, sulphur dioxide, ozone, PM_{10} particles and $PM_{2.5}$ particles. The forecasts are communicated using the Daily Air Quality Index (http://uk-air.defra.gov.uk/air-pollution/daqi) which is a scale of one to ten divided into four bands. This allows the public to see at a glance whether the air pollution is low, moderate, high or very high and to look up any recommended actions to take.

The group of pollutants covered, and the thresholds between the various index bands, were updated by Defra as of 1st January 2012, in the light of recommendations by the Committee on the Medical Effects of Air Pollutants (COMEAP) in their 2011 review of the UK air quality index[23].

The daily forecast is provided by the Met Office and 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, Twitter and RSS feeds. Anyone may subscribe to the free air pollution bulletins at: http://uk-air.defra.gov.uk/subscribe Latest forecasts are issued daily, at: http://uk-air.defra.gov.uk/forecasting/. Defra also provide automated updates on current and forecast air quality via Twitter @DefraUKAIR– see http://uk-air.defra.gov.uk/twitter.

2.2.6 NO_2 Air Quality Plans

In July 2017, the Government published the UK Plan for Tackling Roadside Nitrogen Dioxide Concentrations, setting out how to achieve compliance in the shortest possible time, supported by a £3.5 billion investment into air quality and cleaner transport. This investment includes:

- £1.5 billion – to support the uptake of ultra-low emission vehicles to 2021.
- £1.2 billion – for the Cycling and Walking Investment Strategy.
- £495 million – to support local authorities in England to take action as part of the NO_2 Plan.
- £100 million – for air quality as part of the Road Investment Strategy.
- £156million – supporting cleaner buses through the Green Bus Fund and Clean Bus and Vehicle technology Funds
- £14 million – for the Air Quality Grant.

In addition, we published a Supplement to the NO_2 Plan on 5 October 2018 setting out work with a further 33 local authorities in England and therefore in total, 61 local authorities have been required to assess what action is needed to address the exceedances. This is supported by £495m to develop and implement required measures including a £220m Clean Air Fund to mitigate the impact of the plans on individuals and businesses. As a result of this work, a wide range of measures, including Charging Clean Air Zones, will be implemented from 2019 onwards in England.

The UK air quality plan for nitrogen dioxide, together with the supplement published in October 2018, is available at https://www.gov.uk/government/publications/air-quality-plan-for-nitrogen-dioxide-no2-in-uk-2017.

Scotland's first Low Emission Zone was established in Glasgow in December 2018. Further LEZs will be introduced in Aberdeen, Dundee and Edinburgh by the end of 2020. Other Scottish local authorities with Air Quality Management Areas are currently undertaking assessment to determine whether an LEZ would be an appropriate intervention in their areas.

In 2018/19, £10.8 million in capital funding was allocated to LEZs in Scotland, comprising £7.8 million for bus retrofitting and £2.2 million for local authorities. £0.8 million was also provided for development work. For 2019/20, an additional £19.6 million has been allocated for LEZ work.

The Scottish Government also provides a total of £4.5 million per year to support local authority air quality work, spends over £1 billion per year on public transport and doubled the active travel budget from 2018/19.

2.2.7 Measures to Address Target Value Exceedances of B[a]P and Nickel

EU Directive (2004/107/EC) sets target values for a number of metallic elements and for benzo[a]pyrene (B[a]P). During all years from 2013 to 2016 inclusive, the UK exceeded target values for B[a]P and nickel: in 2017, the UK exceeded the target value for B[a]P but not for nickel. These exceedances were reported in September of the following years as part of the UK's annual compliance assessment[24].

The UK published reports providing details of the assessment of the exceedances in years 2013 to 2016. These also reported the actions and measures already taken or planned, to help the UK meet the target values. An overview report was provided for each pollutant alongside more detailed information on any exceedances by zone. The reports are available at: https://uk-air.defra.gov.uk/library/bap-nickel-measures. At the time of writing, the 2016 report is the most recent in the series.

2.3 Local Authority Air Quality Management

Requirements for local air quality management (LAQM) are set out in Part IV of the Environment Act 1995, and the Environment (Northern Ireland) Order 2002[25]. Authorities are required to carry out regular 'Review and Assessments' of air quality in their area and take action to improve air quality in those areas where objectives set out in regulation have been shown to not be achieved.

Local Authorities in England, Scotland, Wales and Northern Ireland undertake Review and Assessment against the Strategy's objectives prescribed in the Air Quality (England) Regulations 2000[26], Air Quality (Scotland) Regulations 2000[27], Air Quality (Wales) Regulations 2000[28] and Air Quality (Northern Ireland) Regulations 2003[29], together with subsequent amendments[30,31,32,33,34].

With regards to LAQM statutory reporting requirements, in 2018 authorities in Wales[34] adopted reporting in the form of an Annual Progress Report in line with the streamlined LAQM regime. In England[35] and Scotland[36], reporting in the form of the adopted Annual Status / Progress Reports continued for a fourth year, whilst London authorities continued working against the revised London specific LLAQM policy guidance[37] through the preparation of Annual Status Reports. Authorities in Northern Ireland commenced Round 7 of the Review and Assessment process in 2018, with appraisal of local air quality via Updating and Screening Assessments in line with the Round based approach to LAQM.

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. Action Plans formally set out the measures the Local Authority proposes to take to work towards meeting the air quality objectives. They may include a variety of measures such as congestion charging, traffic management, planning and financial incentives. Advice for Local Authorities preparing an Action Plan is available from the Defra LAQM web pages at https://laqm.defra.gov.uk/action-planning/aqap-supporting-guidance.html.

Information on the UK's AQMAs is summarised in **Table 2-1** below. At the time of writing (July 2019), 263 Local Authorities – 67.6% of those in the UK – have one or more AQMAs. Some AQMAs are for more than one pollutant, and many Local Authorities have more than one AQMA.

Most Air Quality Management Areas in the UK are in urban areas and have been established to address the contribution to air pollution from traffic emissions of nitrogen dioxide or PM_{10}, or in some cases both. A small number are for SO_2. There are no longer any AQMAs for benzene. The number of AQMAs for PM_{10} in Scotland is relatively high because of the more stringent objective for PM_{10} adopted in Scotland.

Table 2-1 Current UK-wide status of Air Quality Management Areas (AQMAs) and Action Plans (as of July 2019.)

Region	Total LAs	LAs with AQMAs	AQMAs for NO_2	AQMAs for PM_{10}	AQMAs for SO_2
England (outside London)	291	195	521	42	6
London	33	33	34	29	0
Scotland	32	14	29	25	1
Wales	22	12	44	1	0
Northern Ireland	11	9	17	3	0
TOTAL	**389**	**263**	**645**	**100**	**7**

Figure 2-1, Figure 2-2 and **Figure 2-3** are pie charts illustrating the proportion of AQMAs declared as a result of various different emission sources, for the three pollutants NO_2, PM_{10} and SO_2.

Road transport is specified as the main source in 96.6% of the AQMAs declared for NO_2. A further 1.9% of NO_2 AQMAs result from road transport mixed with industrial sources, 0.9% from a combination of road transport, industry and domestic sources, and the remaining 0.6% from other or unspecified sources.

Road transport is also the main source in the majority (79%) of AQMAs declared for PM_{10}. Road transport together with industry accounts for a further 10%. Industry, domestic and other sources account for a larger proportion than is the case for NO_2.

Five of the seven AQMAs declared for SO_2 relate to industrial sources: the other two are from domestic and 'other' sources.

The locations of the UK's AQMAs are shown in **Figure 2-4**. Information on the UK's Air Quality Management Areas is published on the Defra LAQM web pages at https://laqm.defra.gov.uk/action-planning/aqap-supporting-guidance.html. Information is provided on each AQMA, together with a map of the area, where available.

Figure 2-1 Proportions of AQMAs Resulting from Various Sources: NO_2

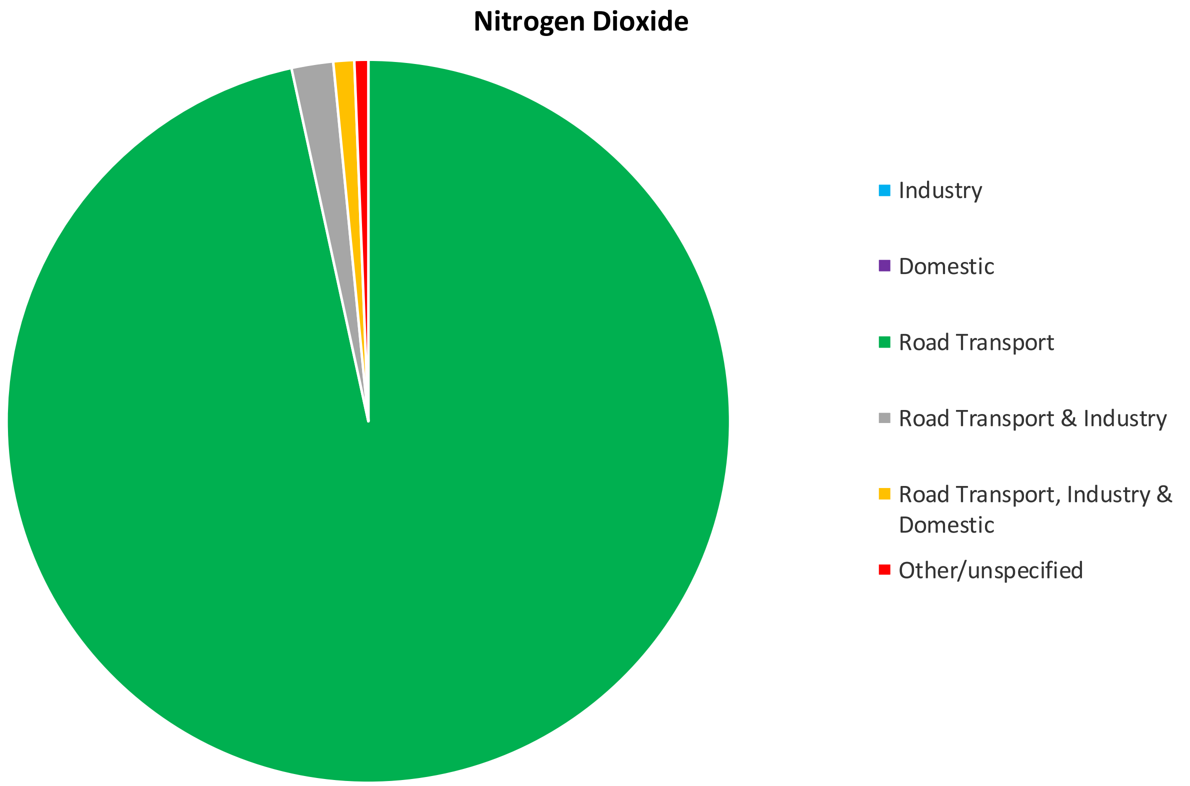


Figure 2-2 Proportions of AQMAs Resulting from Various Sources: PM_{10}

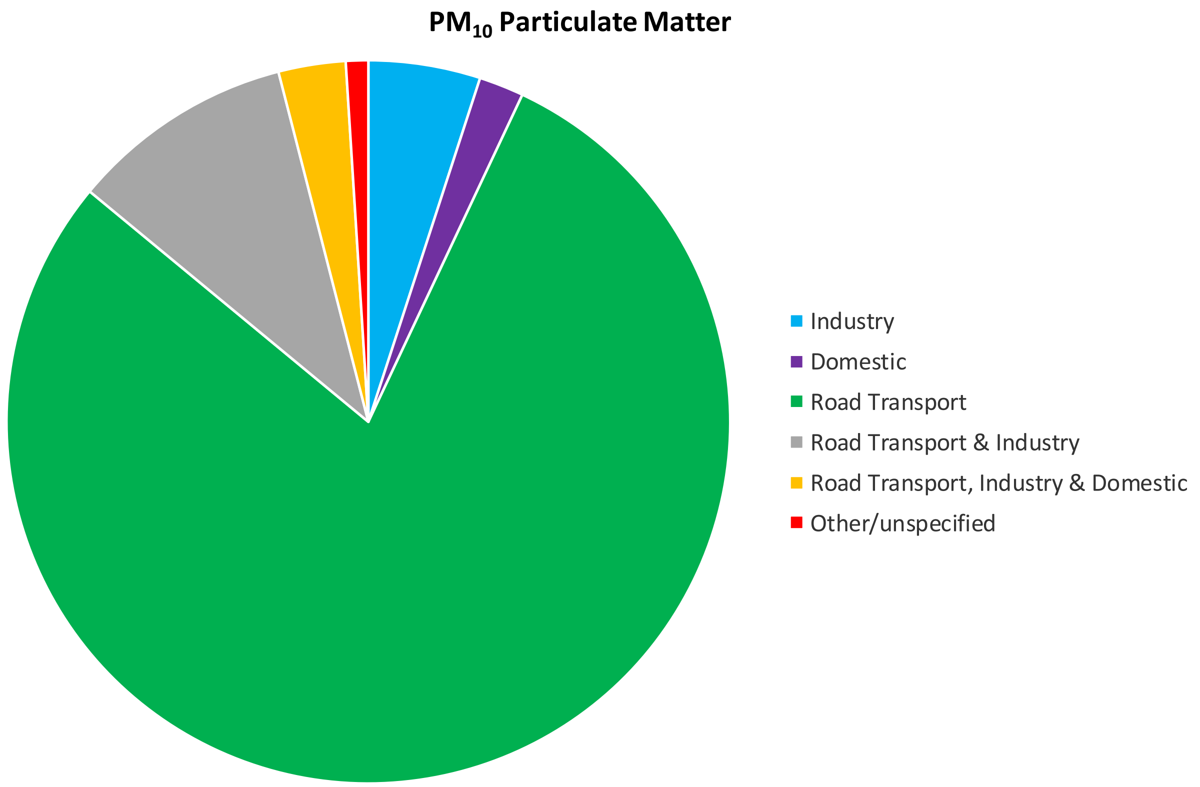


Figure 2-3 Proportions of AQMAs Resulting from Various Sources: SO_2

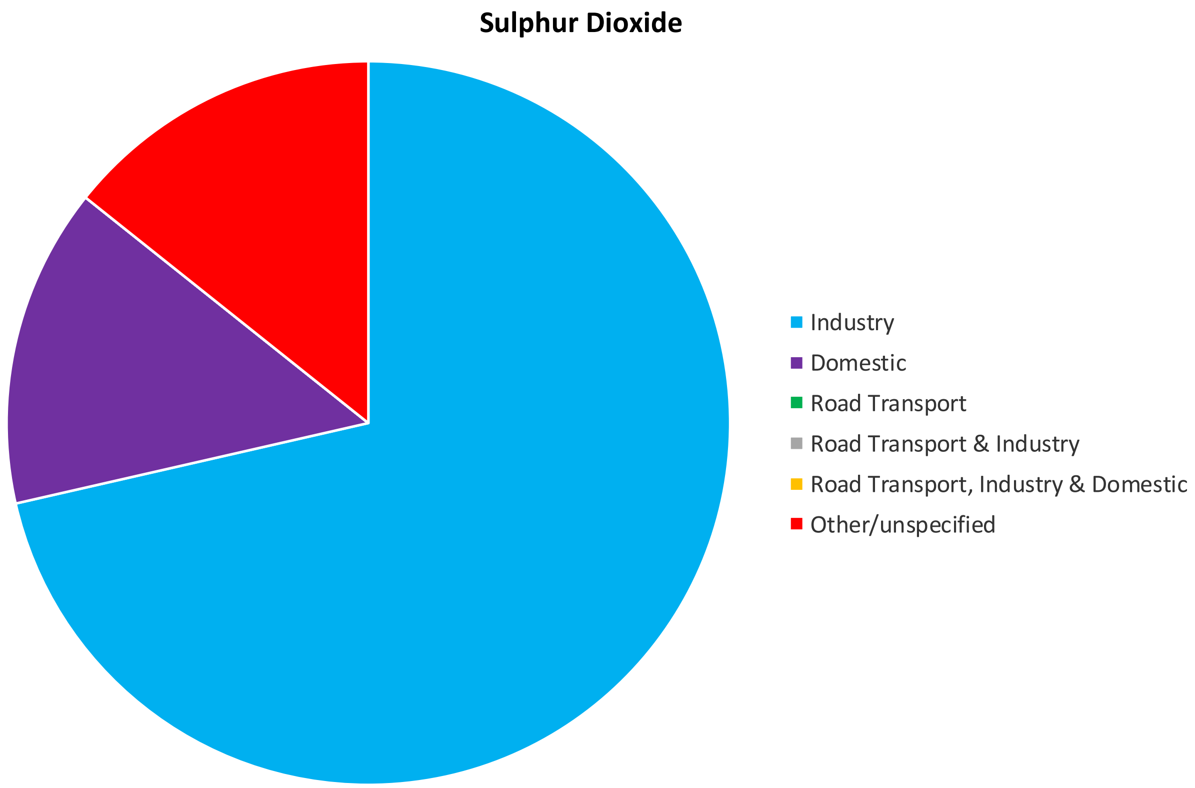
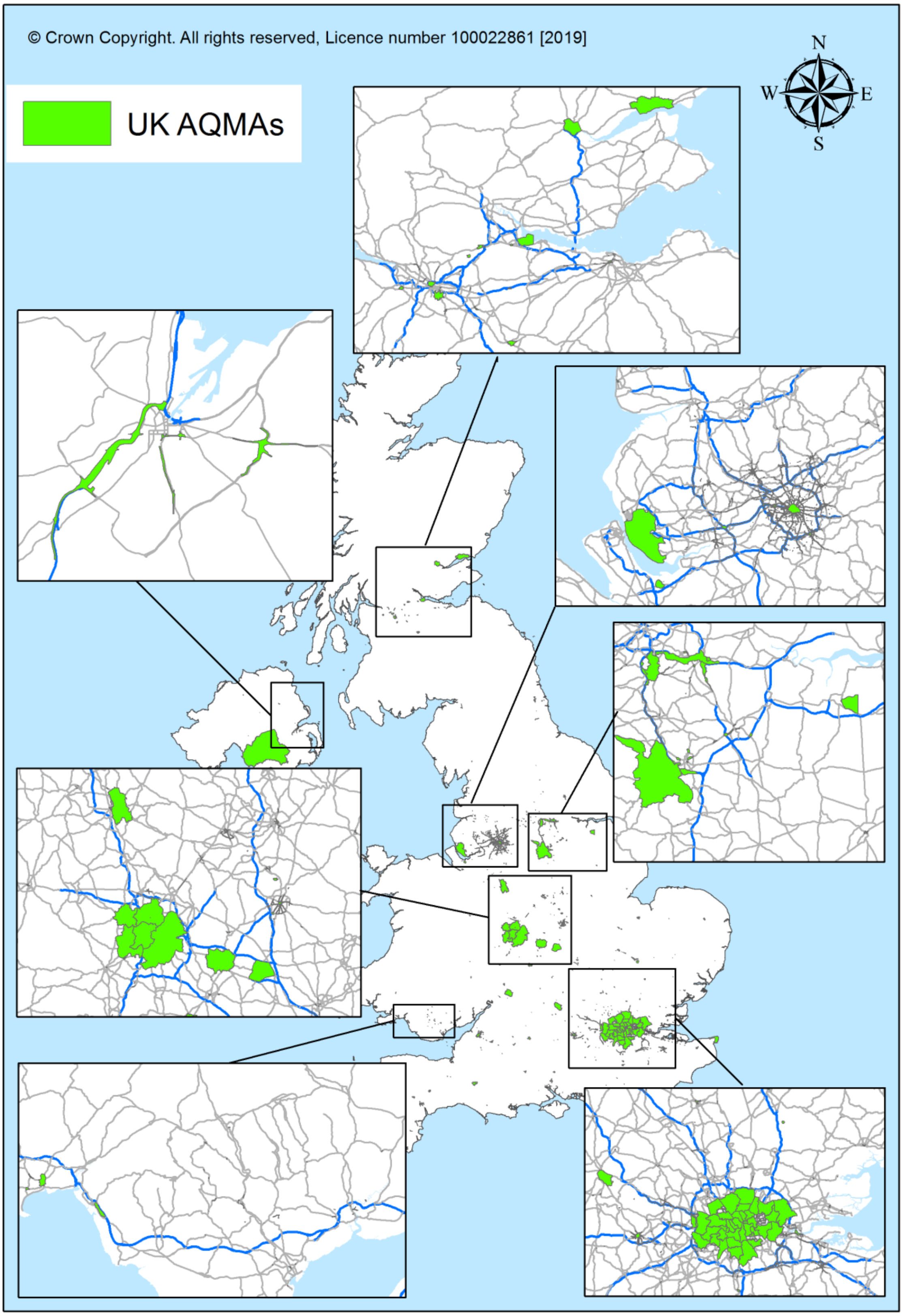


Figure 2-4 Air Quality Management Areas in the UK (at end of 2018). For details of AQMAs please see the interactive map at https://uk-.air.defra.gov.uk/aqma/maps



3 The Evidence Base

A programme of air quality assessment and research is in place in the UK which delivers the evidential needs of Defra, associated with compliance with a range of European Directives, as well as the means to assess the effectiveness of air pollution mitigation policies.

This section explains Defra and the Devolved Administrations' evidence base for the annual assessment of compliance with the EU Directives on ambient air quality. It describes the air pollutants which are of concern and how these are monitored and modelled in the UK.

3.1 Pollutants of Concern

Table 3-1 below summarises the sources, effects and typical UK concentrations of the pollutants being assessed in relation to the Air Quality Directive and 4th Daughter Directive.

The information on sources has largely been summarised from the National Atmospheric Emission Inventory (NAEI) pollutant information pages[38] together with Table 1 of the Air Quality Strategy[39].

Information on health effects is summarised (and further information can be sought) from the following sources:

- The World Health Organization's Air Quality Guidelines Global Update (2005)[40] (which covers particulate matter, sulphur dioxide, nitrogen dioxide and ozone).
- The World Health Organization's *'Air Quality and Health*' factsheet (factsheet 313) at http://www.who.int/mediacentre/factsheets/fs313/en/index.html.
- Committee on the Medical Effects of Air Pollution – COMEAP's "Statement on the Evidence for the Effects of Nitrogen Dioxide on Health" (COMEAP 2015)[41] (referred to in the table as COMEAP 2015a).
- Reports by the Committee on the Medical Effects of Air Pollution (COMEAP):
  - COMEAP's report of 22nd August 2018 on associations of long-term average concentrations of nitrogen dioxide with mortality[42],
  - COMEAP's report of July 2016 on the long-term exposure to air pollution and chronic bronchitis[43].
  - COMEAP's 2015 report on quantification of effects associated with ozone[44] (referred to in the table as COMEAP 2015b)
  - COMEAP's 2011 review of the air quality index[45],
  - COMEAP's 2010 report on the mortality effects of long-term exposure to particulate air pollution in the United Kingdom[46] (subsequently updated in 2018: referred to in the table as COMEAP 2010),

    - COMEAP's 2009 report on long-term exposure to air pollution and its effect on mortality[47] (subsequently updated in 2018: referred to in the table below as COMEAP 2009),
- Expert Panel on Air Quality Standards (EPAQS) report 'Metals and Metalloids[48] (referred to as EPAQS 2009 in the table below).
- Public Health England's Compendium of Chemical Hazards web pages at https://www.gov.uk/government/collections/chemical-hazards-compendium
- World Health Organization's 2013 'Review of Evidence on Health Aspects of Air Pollution' (REVIHAAP) report[49].
- The Air Quality Strategy.

Information on typical ambient concentrations in the UK has been summarised from the Defra online air information resource, UK-AIR at http://uk-air.defra.gov.uk/.

Table 3-1 Sources, Effects and Typical UK Concentrations

Pollutant and Sources	Health Effects	Environmental Effects	Typical Ambient Concentrations in the UK
Sulphur Dioxide (SO_2): an acid gas formed when fuels containing sulphur impurities are burned. The largest UK source is currently power generation. Other important sources include industry, commercial fuel use, and residential fuel use in some areas.	A respiratory irritant that can cause constriction of the airways. People with asthma are considered to be particularly sensitive. Health effects can occur very rapidly, making short-term exposure to peak concentrations important. (Source: WHO AQG 2005)	Harmful to plants at high concentrations. Contributes to acidification of terrestrial and aquatic ecosystems, damaging habitats and leading to biodiversity loss. SO_2 is also a precursor to the formation of secondary sulphate particles in the atmosphere.	Annual mean concentrations are typically less than 5 µg m^{-3} except at sites in industrial locations, or in residential areas with high use of solid fuel for heating.
Nitrogen Oxides (NO_X): NO_X, which comprises nitric oxide (NO) and nitrogen dioxide (NO_2), is emitted from combustion processes. Main sources include power generation, industrial combustion and road transport. According to the NAEI, road transport is now the largest single UK source of NO_X, accounting for almost one third of UK emissions.	Short-term exposure to concentrations of NO_2 higher than 200 µg m^{-3} can cause inflammation of the airways. NO_2 can also increase susceptibility to respiratory infections and to allergens. It has been difficult to identify the direct health effects of NO_2 at ambient concentrations because it is emitted from the same sources as other pollutants such as particulate matter (PM). Studies have found that both day-to-day variations and long-term exposure to NO_2 are associated with mortality and morbidity. Evidence from studies that have corrected for the effects of PM is suggestive of a causal relationship, particularly for respiratory outcomes (Source: WHO 2013 REVIHAAP report, COMEAP 2015).	In the presence of sunlight, nitrogen oxides can react with Volatile Organic Compounds to produce photochemical pollutants including ozone. NO_X contributes to the formation of secondary nitrate particles in the atmosphere. High levels of NO_X can harm plants. NO_X also contributes to acidification and eutrophication of terrestrial and aquatic ecosystems, damaging habitats and leading to biodiversity loss.	Annual mean concentrations of NO_2 beside busy roads frequently exceed 40 µg m^{-3}. This is not a UK-specific problem and is common in many other European countries. The main reasons why roadside NO_2 concentrations have not decreased as expected is believed to be the failure of Euro vehicle emission standards for diesel vehicles to deliver the anticipated reductions in NO_X emissions in real world driving conditions. At urban background locations, annual mean NO_2 concentrations are lower, typically 10-40 µg m^{-3}. Peak hourly mean concentrations exceed 100 µg m^{-3}

Pollutant and Sources	Health Effects	Environmental Effects	Typical Ambient Concentrations in the UK
			at most urban locations, and occasionally exceed 300 µg m^{-3} at congested urban roadside sites.
Particulate Matter: PM_{10}. This 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). The main source is combustion, e.g. vehicles, domestic burning and power stations. Other man-made sources include quarrying and mining, industrial processes and tyre and brake wear. Natural sources include wind-blown dust, sea salt, pollens and soil particles.	Research shows a range of health effects (including respiratory and cardiovascular illness and mortality) associated with PM_{10}. No threshold has been identified below which no adverse health effects occur. (Source: WHO AQG 2000)	Black carbon in PM is implicated in climate change. Secondary PM includes sulphate, nitrate and ammonium, formed from SO_2, NO_X and NH_3 which are the main drivers for acidification and eutrophication.	Annual mean PM_{10} concentrations for urban AURN monitoring sites have been typically in the range 10-20 µg m^{-3} in recent years.
Particulate Matter: $PM_{2.5}$. Like PM_{10}, the finer size fraction $PM_{2.5}$ can be primary or secondary, and has the same sources. Road transport becomes an increasingly important sector as the particle size decreases.	Fine particulate matter can penetrate deep into the lungs and research in recent years has strengthened the evidence that both short-term and long-term exposure to $PM_{2.5}$ are linked with a range of health outcomes including (but not restricted to) respiratory and cardiovascular effects. COMEAP estimated that the burden of anthropogenic particulate air pollution in the UK in 2008 was an effect on mortality equivalent to nearly 29,000 deaths at typical ages and an associated loss of life across the population of 340,000 years. The	Secondary PM includes sulphate, nitrate and ammonium, formed from SO_2, NO_X and NH_3 which are the main drivers for acidification and eutrophication.	Annual mean urban $PM_{2.5}$ concentrations in the UK are typically in the range 5-15 µg m^{-3} in recent years. It has been several years since any AURN site measured an annual mean exceeding 20 µg m^{-3}, even at urban roadside locations.

Pollutant and Sources	Health Effects	Environmental Effects	Typical Ambient Concentrations in the UK
	burden can also be represented as a loss of life expectancy from birth of approximately six months. (Source: COMEAP 2010.) In 2016, COMEAP estimated that 722,660 cases of chronic bronchitis could be attributed to anthropogenic particulate pollution (source: COMEAP 2016).		
Benzene: (C_6H_6) is an organic chemical compound. Ambient benzene concentrations arise from domestic and industrial combustion processes, in addition to road transport. (Source: Air Quality Strategy).	Benzene is a recognised human carcinogen which causes changes in the genetic material (mutagenic effect) of the circulatory and immune systems. No absolutely safe level can be specified in ambient air. Acute exposure to high concentrations affects the central nervous system. (Source: WHO AQG 2000, PHE Compendium of Chemical Hazards)	Can also pollute soil and water, leading to exposure via these routes.	Annual mean concentrations of benzene are now low (consistently below 2 µg m^{-3}) due to the introduction of catalytic converters on car exhausts. The UK meets the benzene limit value of 5 µg m^{-3}.
Carbon Monoxide (CO) is produced when fuels containing carbon are burned with insufficient oxygen to convert all carbon inputs to carbon dioxide (CO_2). Although CO emissions from petrol-engine road vehicles have been greatly reduced by the introduction of catalytic converters, road transport is still the most significant source of this pollutant (Source: NAEI).	CO affects the ability of the blood to take up oxygen from the lungs, and can lead to a range of symptoms. People are more likely to be exposed to dangerous concentrations of CO indoors, due to faulty or poorly ventilated cooking and heating appliances. Cigarette smoke is also a major source of exposure. (Source: NAEI, PHE Compendium of Chemical Hazards.)	Can contribute to the formation of ground-level ozone.	The UK is compliant with the European limit value for CO, with the 8-hour running mean concentration consistently below 10 mg m^{-3} at all monitoring sites in recent years.

Pollutant and Sources	Health Effects	Environmental Effects	Typical Ambient Concentrations in the UK
Ozone (O_3) is a secondary pollutant produced by the effect of sunlight on NO_X and VOCs from vehicles and industry. Ozone concentrations are greatest in the summer on hot, sunny, windless days. O_3 can travel long distances, accumulate and reach high concentrations far away from the original sources.	A respiratory irritant: short-term exposure to high ambient concentrations can cause inflammation of the respiratory tract and irritation of the eyes, nose, and throat. High levels may exacerbate asthma or trigger asthma attacks in susceptible people and some non-asthmatic individuals may also experience chest discomfort whilst breathing. Evidence is also emerging of effects due to long-term exposure (WHO AQG 2000, WHO 2013 - REVIHAAP).	Ground level ozone can also cause damage to many plant species leading to loss of yield and quality of crops, damage to forests and impacts on biodiversity. Ozone is also a greenhouse gas implicated in climate change. In the upper atmosphere the ozone layer has a beneficial effect, absorbing harmful ultraviolet radiation from the sun.	In recent years, the annual mean daily maximum 8-hour running mean measured at AURN sites has been typically in the range 30-80 µg m^{-3}. NO_X emitted in cities reduces local O_3 concentrations as NO reacts with O_3 to form NO_2 and levels of O_3 are often higher in rural areas than urban areas.
Lead (Pb): a very toxic metallic element. Historically, lead was used as an additive in petrol, and road vehicles were the main source Lead's use in petrol was phased out in 1999, resulting in a 98% reduction of pre-1999 UK emissions. Today, the main sources are metal production and industrial combustion of lubricants containing small amounts of lead. (Source: NAEI.)	Lead inhalation can affect red blood cell formation and have effects on the kidneys, circulatory system, gastrointestinal tract, the joints, reproductive systems, and can cause acute or chronic damage to the central nervous system (CNS). Long term low level exposure has been shown to affect intellectual development in young children (Source: EPAQS 2009). A threshold, below which the adverse effects of lead are not anticipated, has not been established (source: WHO AQG 2000, PHE Compendium of Chemical Hazards).	Can also pollute soil and surface waters. Exposure to contaminated soil and water may then become a health risk. Lead may accumulate in other organisms such as fish, and be passed up the food chain.	In recent years, UK annual mean concentrations of lead have typically ranged from less than 5 ng m^{-3} at rural monitoring sites, to around 60 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.
Nickel (Ni) is a toxic metallic element found in ambient air as a result of releases from oil and coal combustion,	Nickel compounds are human carcinogens by inhalation exposure. Can cause irritation to the nose and sinuses and allergic responses	Can also pollute soil and water, leading to exposure via these routes.	Annual mean ambient particulate phase concentrations in the urban environment are typically of the

Pollutant and Sources	Health Effects	Environmental Effects	Typical Ambient Concentrations in the UK
metal processes, manufacturing and other sources. Currently the main source is the combustion of heavy fuel oil, the use of coal having declined. (Source: NAEI.)	and can lead to the loss of the sense of smell. Long-term exposure may lead to respiratory diseases and cancers. (Source: WHO AQG 2000, EPAQS 2009, PHE Compendium of Chemical Hazards.)		order of 1 ng m^{-3} with the exception of a few industrial areas, where higher annual means may occur, in some locations exceeding the 4th Daughter Directive target value of 20 ng m^{-3}.
Arsenic (As) is a toxic element emitted into the atmosphere in the form of particulate matter. Historically the largest source was coal combustion, but as this has declined, the use of wood treated with preservatives containing As has become the most significant component of As emissions. (Source: NAEI.)	Acute inhalation exposure to high levels of arsenic primarily affects the respiratory system and can cause coughs, sore throat, breathlessness and wheezing. Long term inhalation exposure is associated with toxic effects on the respiratory tract and can cause lung cancer. (Source: WHO AQG 2000, EPAQS 2009, PHE Compendium of Chemical Hazards.)	Can also pollute soil and water, leading to exposure via these routes. Arsenic in water or soil can be taken up by plants or fish.	Measured UK annual mean concentrations in the particulate phase are now typically less than 1 ng m^{-3}, meeting the 4th Daughter Directive target value of 6 ng m^{-3}.
Cadmium (Cd): a toxic metallic element whose main sources are energy production, non-ferrous metal production, iron and steel manufacture (as well as other forms of industrial combustion). (Source: NAEI.)	Acute inhalation exposure to cadmium causes effects on the lung such as pulmonary irritation. Chronic effects via inhalation can cause a build-up of cadmium in the kidneys that can lead to kidney disease and long-term inhalation can lead to lung cancer. (Source: WHO AQG 2000, EPAQS 2009, PHE Compendium of Chemical Hazards.)	Can also pollute soil and water, leading to exposure via these routes.	Annual mean particulate phase concentrations in the UK in recent years are now typically < 2 ng m^{-3} and meet the 4th Daughter Directive target value of 5 ng m^{-3}.
Mercury (Hg): released to the air by human activities, such as fossil fuel combustion, iron and steel production	Acute exposure to high levels of Hg can cause chest pain and shortness of breath, and affect the central nervous system (CNS) and	Can also pollute soil, fresh water and sea water. Exposure to contaminated soil and water may then become a	There is no target value for mercury. Annual mean ambient concentrations (total of vapour

Pollutant and Sources	Health Effects	Environmental Effects	Typical Ambient Concentrations in the UK
processes, waste incineration, the manufacture of chlorine in mercury cells, and coal combustion. Emissions have declined in recent years as a result of improved controls on mercury cells, the reduction in coal use, and improved controls on waste incineration processes from 1997 onwards. (Source: NAEI.)	kidneys. Chronic exposure leads to CNS disorders, kidney damage and stomach upsets. (Source: WHO AQG 2000, PHE Compendium of Chemical Hazards.)	health risk. Mercury may accumulate in other organisms such as fish, and be passed up the food chain.	and particulate phases) are typically in the range 1-3 ng m^{-3}, although higher concentrations (over 20 ng m^{-3}) have been measured at industrial sites in recent years.
Benzo[a]pyrene (B[a]P) is used as a 'marker' for a group of compounds known as polycyclic aromatic hydrocarbons (PAHs). The main sources of B[a]P in the UK are domestic coal and wood burning, fires (e.g. accidental fires, bonfires, forest fires, etc.), and industrial processes such as coke production. (Source: Air Quality Strategy).	PAHs are a large group of persistent, bio-accumulative, organic compounds with toxic and carcinogenic effects. Lung cancer is most obviously linked to exposure to PAHs through inhaled air. (Source: WHO AQG 2000, PHE Compendium of Chemical Hazards)	PAHs can bio-accumulate and be passed up the food chain.	Annual mean concentrations in most urban areas are below the EU target value of 1 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. The use of models reduces the number of monitoring stations required. It has the added benefit 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.

UK compliance assessment modelling is undertaken using national models known as the Pollution Climate Mapping (PCM) models. The PCM models have been designed to assess compliance with the limit values at locations defined within the Directives. Modelled compliance assessments are undertaken for 11 air pollutants each year. This assessment needs to be completed each year in the relatively short period between the time when the input data (including ratified monitoring data and emission inventories) become available and the reporting deadline at the end of September.

It is important to understand the differences between modelling carried out for compliance assessment purposes, and that carried out for Local Air Quality Management. National air quality modelling for the UK focuses on two components: pollutant concentrations at background locations, on a 1x1 km grid square basis, and roadside pollutant concentrations, at four metres from the kerb of urban major road links. By contrast, 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. 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 the modelling carried out for compliance assessment.

3.3 Current UK Air Quality Monitoring

During 2018 there were 270 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 3-2** (the number of sites shown in this table amounts to considerably more than 270 because some sites belong to more than one network). This table shows the number of sites in operation during part or all of 2018.

Table 3-2 The UK's Air Quality Monitoring Networks in 2018

Network	Pollutants	Number of Sites operating in 2018
Automatic Urban and Rural Network (AURN)	CO, NO_X, NO_2, SO_2, O_3, PM_{10}, $PM_{2.5}$.	**169**
UK Heavy Metals Network	Metals in PM_{10}. Including: As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Se, V, Zn. Measured deposition. Including: 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. Hg deposition Total gaseous mercury	**25**
Non-Automatic Hydrocarbon	Benzene	**34**
Automatic Hydrocarbon	Range of volatile organic compounds (VOCs)	**4**
Polycyclic Aromatic Hydrocarbons (PAH).	23 PAH species including benzo[a]pyrene	**32**
European Monitoring and Evaluation Programme (EMEP)	Wide range of parameters relating to air quality, precipitation, meteorology and composition of aerosol in PM_{10} and $PM_{2.5}$.	**2**
Particle Numbers and Concentrations Network	Total particle number, concentration, size distribution, anions, EC/OC, speciation of PM_{10}, $PM_{2.5}$ and PM_1.	**4**
Toxic Organic Micropollutants	Range of toxic organics including dioxins and dibenzofurans.	**6**
UK Eutrophying and Acidifying Pollutants: NO_2Net (rural diffusion tubes)	NO_2 (rural)	**24**
UK Eutrophying and Acidifying Pollutants: AGANet	HNO_3, HONO, SO_2, Ca, Cl, Mg, Na, NO_2, NO_3 and SO_4	**27**
UK Eutrophying and Acidifying Pollutants: NAMN	NH_3 and/or NH_4	**71**
UK Eutrophying and Acidifying Pollutants: PrecipNet	Major ions in rain water	**41**
Black Carbon	Black Carbon	**14**
Upland Waters Monitoring Network	Chemical and biological species in water	**10**
Rural Mercury Network	Tekran analyser used to measure mercury in $PM_{2.5}$, reactive mercury and elemental mercury at Auchencorth Moss, and total gaseous mercury at Chilbolton Observatory.	**2**

3.3.1 The Automatic Urban and Rural Network (AURN)

The AURN is currently the largest automatic monitoring network in the UK and forms a key part 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 gaseous pollutants within the AURN are the reference measurement methods defined in the relevant EU Directives. 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 3-3**.

Table 3-3 AURN Measurement Techniques

Pollutant	Method used, including details of CEN Standard Methods
O_3	EN 14625:2012 'Ambient air quality – standard method for the measurement of the concentration of ozone by ultraviolet photometry'[50]
NO_2/NO_X	EN 14211:2012 'Ambient air quality - Standard method for the measurement of the concentration of nitrogen dioxide and nitrogen monoxide by chemiluminescence'[51]
SO_2	EN 14212:2012 'Ambient air quality – Standard method for the measurement of the concentration of sulphur dioxide by UV fluorescence'[52]
CO	EN 14626:2012 'Ambient air quality - Standard method for the measurement of the concentration of carbon monoxide by non-dispersive infrared spectroscopy'[53]
PM_{10} and $PM_{2.5}$	EN 12341:2014 'Ambient air quality - Standard gravimetric measurement method for the determination of the PM_{10} or $PM_{2.5}$ mass fraction of suspended particulate matter'[54] The AURN uses four methods which are equivalent for one or both metrics: 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, the Fidas, which uses an optical technique, and the Partisol – a gravimetric sampler that collects daily samples onto a filter for subsequent weighing.

3.3.2 The UK Heavy Metals Network

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

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

At the end of 2013 Defra merged the existing Urban and Industrial Network with the Rural Network to form the UK Heavy Metals Network. The merged network monitors a range of elements (not all of which are classified as heavy metals) at urban, industrial and rural sites, using a method equivalent to the CEN standard method[55]. Metals (As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Se, V and Zn) in PM_{10} are measured at 25 sites. (The network stopped measuring mercury in PM_{10} as of 2014.)

Metal deposition (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 and Zn) is measured at the following sites: Auchencorth Moss, Chilbolton Observatory, Heigham Holmes, Lough Navar and Yarner Wood.

Mercury deposition is measured at Auchencorth Moss, Chilbolton Observatory, Heigham Holmes and Yarner Wood.

Within the Heavy Metals Network total gaseous mercury was measured at London Westminster and Runcorn Weston Point until August 2018.

3.3.3 Non-Automatic Hydrocarbon Network

In this network, ambient concentrations of benzene are measured by the CEN standard method[56]. This 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 at four sites using automated pumped sampling with *in-situ* gas chromatography. The VOCs monitored include benzene, which is covered by the Air Quality Directive as a pollutant in its own right.

3.3.5 PAH 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. Samples are collected on filters using the PM_{10} ‘Digitel’ sampler. Samples are subsequently analysed in a laboratory. During 2018, there were 32 sites in this network, measuring 23 PAH compounds.

3.3.6 EMEP

EMEP (European Monitoring and Evaluation Programme) is a programme set up to provide governments with qualified scientific information on air pollutants, under the UNECE Convention on Long-range Transboundary Air Pollution. There are currently two EMEP ‘supersites’, at Auchencorth Moss in Lothian (representing the north of the UK) and at Chilbolton Observatory in Hampshire (representing the south). The site at Chilbolton replaced the long running site at Harwell at the start of 2016. A representativeness analysis showed that both sites were similar in their rural background nature. A very wide range of measurements are taken at EMEP 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,
- Major ions in $PM_{2.5}$ and PM_{10}, as well as HCl, HNO_2, HNO_3, NH_3 and SO_2,
- Trace gases (ozone, NO_X and SO_2),
- Black carbon, organic carbon (OC) and elemental carbon (EC),
- Ammonia (monthly),
- Daily and hourly PM_{10} and $PM_{2.5}$ mass,
- Volatile Organic Compounds,
- Carbonyls,
- CH_4 and N_2O fluxes.

3.3.7 Particle Numbers and Concentrations Network

The Air Quality Directive requires that the chemical composition of $PM_{2.5}$ is characterised at background locations in the United Kingdom. The Particle Numbers and Concentrations Network sites contribute to this statutory requirement. During 2018, the network consisted of four measurement sites; two rural sites (Auchencorth Moss and Chilbolton Observatory), and two in London (London Marylebone Road and London Honor Oak Park; this latter site replaced London North Kensington in November 2018).

Among the parameters measured are:

- Total particle numbers per cubic centimetre of ambient air,
- Particle numbers in different particle size fractions,
- Major ions in PM_{10},
- Cl, NH_4, NO_3, OC, SO_4 and organic carbon (OC) in $PM_{1,}$

- Organic carbon (OC) and elemental carbon (EC) concentrations in $PM_{2.5}$.

As well as its statutory function, this network provides data on the chemical composition of particulate matter, primarily for the use of researchers of atmospheric processes, epidemiology and toxicology.

Measurements of elemental carbon (EC) and organic carbon (OC) began at Auchencorth Moss at the start of 2011 and Chilbolton Observatory at the start of 2016. EC and OC measurements are also made using a thermal/optical method involving both reflectance and transmission correction methods. Comparing both correction methods aims to provide valuable understanding of the measurement process for EC and OC.

3.3.8 TOMPs Network

This research-based 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: Auchencorth Moss, Hazelrigg, High Muffles, London Nobel House, Manchester Law Courts and Weybourne.

The purpose of the TOMPs Network is to provide data on these air pollutants, and to support the development of policy to protect the environment and human health. Further information on the TOMPs Network can be found on UK-AIR at http://uk-air.defra.gov.uk/networks/network-info?view=tomps. However, this network is not used for compliance monitoring and will not be discussed further in subsequent sections of the report.

3.3.9 UK Eutrophying and Acidifying Pollutants Network

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. The UKEAP network is an 'umbrella' project covering four groups of sites:

- The UKEAP rural NO_2 diffusion tube network (NO_2Net). This measures NO_2 concentrations as required as input to the rural NO_X concentration field in the Pollution Climate Model.
- In 2018, the Acid Gas and Aerosol Network (AGANet) comprised a total of 27 sites (sampling stopped at London Cromwell Road on 1st February 2018). The network measures a range of gases and aerosol components. Samples are collected monthly and are analysed by either inductive coupled plasma optical emission spectrometry (ICP-OES) or ion chromatography.

- The National Ammonia Monitoring Network (NAMN) which characterizes ammonia and ammonium concentrations using both passive samplers (Alpha Samplers) and low volume denuders (Delta Samplers) at 71 locations in 2018.
- The Precipitation Network (PrecipNet), measuring major ions in precipitation at 41 rural sites. Samples are collected fortnightly at all sites and daily at two sites.

The UKEAP network allows estimates of sulphur and nitrogen deposition.

3.3.10 Black Carbon Network

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 2018, the Black Carbon Network measured black carbon at 14 sites using the Aethalometer™ automated instrument. The Aethalometer™ measures black carbon directly, using a real-time optical transmission technique. The objectives of the network are as follows:

- To maintain coverage of black carbon 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.

3.3.11 UK Upland Waters Monitoring Network (UKUWMN)

The UK Upland Waters Monitoring Network (UWMN) was set up in 1988 (then called the Acid Waters Network) 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 10 primary monitoring sites including a mix of lakes and rivers across the UK, and a series of secondary sites, monitoring a range of parameters including water chemistry, algae and higher aquatic plants, invertebrates, fish, water temperature and sediment biology and chemistry.

3.3.12 Rural Mercury Monitoring

During 2018, in addition to the weekly monitoring of total gaseous mercury carried out at London Westminster and Runcorn Weston Point, and the monthly mercury deposition measurements at Auchencorth Moss, Chilbolton Observatory, Heigham Holmes and Yarner Wood as described in Section 3.3.2, speciated mercury monitoring was carried out using the Tekran™ automated instrument. The Tekran instrument at Auchencorth Moss measures the mercury composition of $PM_{2.5}$ as well as mercury in its elemental and reactive forms, whereas at Chilbolton Observatory it measured just total gaseous mercury.

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. An allowance of 5% is made in some cases for down-time due to planned maintenance.
- Consistent with Data Quality Objectives[57]. 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 (in the case of NO_X analysers) response time, flow rate etc.

Data verification is the process of checking and validating the data. (The term 'ratification' is used in some networks). Data uploaded to 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 verification process. The verified 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 'Verified' could be subject to further revision. This may be for example where:

- A QA/QC audit has detected a problem which affects data from earlier verification periods.
- Long-term analysis has detected an anomaly between expected and measured trends which requires further investigation and possible data correction.
- 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 verified 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 relevant monitoring networks, and from the report '*Quality Assurance and Quality Control (QA/QC) Procedures for UK Air Quality Monitoring under 2008/50/EC and 2004/107/EC)*'[58] available from Defra's UK-AIR website.

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:

- A reduction in the number of fixed continuous monitoring locations required 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 a technical report[59] (the latest versions of these can be found in the Library section of Defra's UK-AIR website[60]).

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 10,000 of these urban major road links.

Roadside concentrations are not modelled for CO, SO_2, ozone, benzo[a]pyrene 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 and oil refineries),
- Small point sources (e.g. boilers in town halls, schools or hospitals and crematoria),
- Distant sources (characterised by the rural background concentration),
- Local area sources (e.g. road traffic, domestic and commercial combustion and 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 area source components are added together to provide the final background map.

3.5.4 Roadside Air Quality

Roadside concentrations are determined 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 emission estimates from the National Atmospheric Emissions Inventory (NAEI)[61] for each pollutant and road traffic counts. A measured roadside increment concentration is calculated for road links with a roadside monitoring station on them by subtracting the link's modelled background concentration (from the 1x1 km modelled maps) from the relevant measured roadside concentration. A roads kernel model (RKM) is used to calculate a modelled roadside increment concentration for each road by applying the NAEI emissions and road traffic counts (annual average daily traffic flow) in a dispersion model. The RKM is calibrated by comparing the measured roadside increment concentrations at roadside monitoring stations with the modelled roadside increment concentrations on these road links. The application of the roads kernel model ensures that a process-based modelling approach is used to determine the local component of roadside concentrations, including factors influencing dispersion at the roadside e.g. road orientation, width, and additional vehicle induced turbulence.

3.6 Access to Assessment Data

Data from the UK's air quality monitoring networks and annual compliance modelling is available under the Open Government Licence[62] from UK-AIR.

Defra has produced a searchable online catalogue of air quality and emissions datasets which allows people to browse the extent of data available and access key metadata. This is available at http://uk-air.defra.gov.uk/data/data-catalogue.

Historical monitoring data can be accessed through the data selector tools in UK-AIR, at http://uk-air.defra.gov.uk/data/. Modelled data from the Pollution Climate Mapping model are available as .csv files for download from the modelled air quality data pages at http://uk-air.defra.gov.uk/data/modelling-data or can be accessed through the Ambient Air Quality Interactive Map at http://uk-air.defra.gov.uk/data/gis-mapping - a GIS (geographical information system) based tool which provides enhanced visualisation capability and access to roadside concentration data.

4 Assessment of Compliance

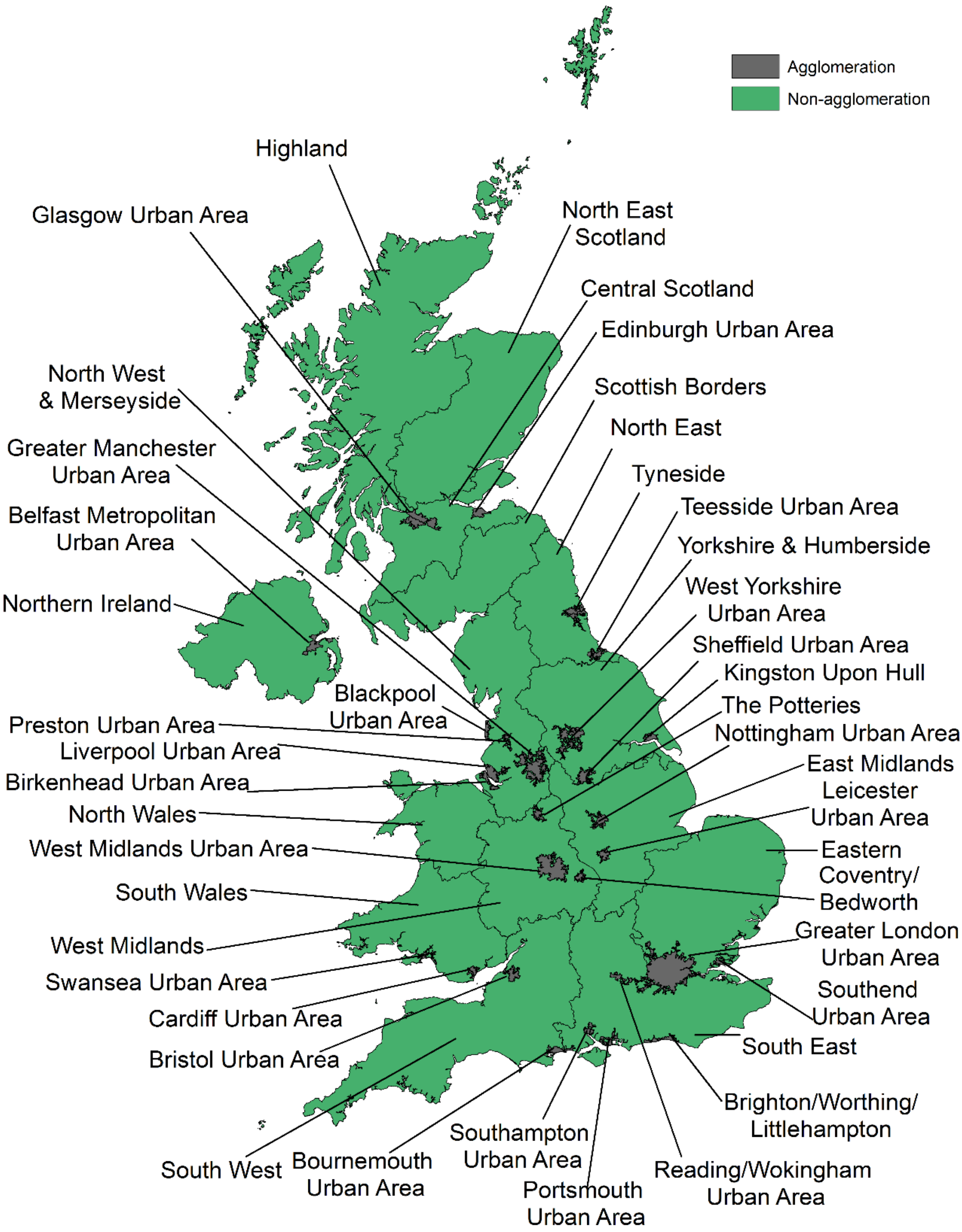
4.1 Definition of Zones

The UK is divided into 43 zones for air quality assessment. There are 28 agglomeration zones (large urban areas) and 15 non-agglomeration zones. Each zone has an identification code (**Table 4-1**). Zones are shown in **Figure 4-1**.

Table 4-1 UK Zones for Ambient Air Quality Reporting 2018

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

Figure 4-1 UK Zones for Ambient Air Quality Reporting 2018



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4.2 Air Quality Assessment for 2018

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 air quality compliance assessment is submitted to the European Commission via an e-Reporting system. All the compliance results come under ‘Information on the Attainment of Environmental Objectives’ in e-Reporting Data Flow G.

The results of the air quality assessment submitted to the European Commission for 2018 are summarised in the tables below. The tables have been completed as follows:

- Where all measurements were within the relevant limit values in 2018, the table shows this as ‘OK’.
- In the above cases, where compliance was determined by modelling or supplementary assessment, this is indicated by ‘(m)’ – i.e. ‘OK (m)’.
- Where locations were identified as exceeding a limit value, target value or long-term objective, this is identified as ‘>LV’, '>TV’ or ‘>LTO’ as applicable.
- Where a non-compliance was determined by modelling or supplementary assessment, this is indicated by (m), as above.
- 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.
- Zones that complied with the relevant limit values, targets or long-term objectives are shaded blue, while those that did not are shaded red. For ozone, zones that met the relevant target value but not the long-term objective are shaded purple.

There are no longer any zones where margins of tolerance apply.

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

Sulphur dioxide (SO_2): in 2018, 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).

Carbon monoxide (CO), benzene and lead: all zones and agglomerations were compliant with the limit values for these three pollutants in 2018. The 2018 compliance assessment for CO has been based on objective estimation (explained in Defra's technical report on UK air quality assessment[63]), underpinned by NAEI emission trends, AURN measurement trends and historical modelling assessments.

Nitrogen dioxide (NO_2): in 2018 not all zones and agglomerations were compliant with the limit values. The results of the air quality assessment for nitrogen dioxide for each zone are summarised in **Table 4-2**.

Two zones had locations where the 1-hour limit value (200 µg m^{-3}) was exceeded on more than the permitted 18 occasions during 2018: Greater London Urban Area (UK0001) and South Wales (UK0041). The remaining 41 zones and agglomerations complied with the 1-hour mean NO_2 limit value.

Seven zones ***met*** the annual mean limit value for NO_2 in 2018:

- Brighton/Worthing/Littlehampton (UK0010)
- Birkenhead Urban Area (UK0020)
- Blackpool Urban Area (UK0022)
- Preston Urban Area (UK0023)
- Highland (UK0039)
- Scottish Borders (UK0040)
- Northern Ireland (UK0043).

The remaining 36 zones had locations with measured or modelled annual mean NO_2 concentrations higher than the annual mean limit value (40 µg m^{-3}). In 25 of these zones the maximum measured or modelled annual mean NO_2 concentration had decreased compared to 2017.

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

As part of the 2017 UK plan for tackling roadside nitrogen dioxide concentrations, local authorities with exceedances of the annual mean nitrogen dioxide limit value have been required to develop local plans or studies to consider measures to achieve the statutory limit value within the shortest possible time. These studies or plans may include local scale modelling and/or monitoring data, and in some cases this local data and the national PCM modelling present different results. This local data is not reflected within this assessment; however, we are working to develop our approach to assessing national NO_2 compliance with a view to better reflecting local level NO_2 concentrations.

Table 4-2 Results of Air Quality Assessment for Nitrogen Dioxide in 2018

Zone	Zone code	NO_2 LV for health (1hr mean)	NO_2 LV for health (annual mean)	NO_x critical level for vegetation (ann. mean)
Greater London Urban Area	UK0001	> LV	> LV	n/a
West Midlands Urban Area	UK0002	OK	> LV (m)	n/a
Greater Manchester Urban Area	UK0003	OK	> LV (m)	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 (m)	n/a
Bristol Urban Area	UK0009	OK	> LV	n/a
Brighton/Worthing/Littlehampton	UK0010	OK	OK	n/a
Leicester Urban Area	UK0011	OK	> LV (m)	n/a
Portsmouth Urban Area	UK0012	OK	> LV (m)	n/a
Teesside Urban Area	UK0013	OK	> LV (m)	n/a
The Potteries	UK0014	OK	> LV	n/a
Bournemouth Urban Area	UK0015	OK	> LV (m)	n/a
Reading/Wokingham Urban Area	UK0016	OK	> LV (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	OK	n/a
Southend Urban Area	UK0021	OK	> LV (m)	n/a
Blackpool Urban Area	UK0022	OK	OK	n/a
Preston Urban Area	UK0023	OK	OK	n/a
Glasgow Urban Area	UK0024	OK	> LV	n/a
Edinburgh Urban Area	UK0025	OK	> LV	n/a
Cardiff Urban Area	UK0026	OK (m)	> LV (m)	n/a
Swansea Urban Area	UK0027	OK	> LV (m)	n/a
Belfast Urban Area	UK0028	OK	> LV	n/a
Eastern	UK0029	OK	> LV	OK
South West	UK0030	OK	> LV (m)	OK
South East	UK0031	OK	> LV (m)	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 (m)	OK (m)
North East Scotland	UK0038	OK	> LV (m)	OK (m)
Highland	UK0039	OK	OK	OK (m)
Scottish Borders	UK0040	OK	OK	OK
South Wales	UK0041	> LV	> LV	OK
North Wales	UK0042	OK	> LV (m)	OK
Northern Ireland	UK0043	OK	OK	OK (m)

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

Particulate Matter as PM_{10}: all zones and agglomerations were compliant with the annual mean limit value of 40 µg m^{-3} for PM_{10}. All zones and agglomerations were compliant with the daily mean limit value. The results of the air quality assessment for PM_{10} for each zone, with respect to the daily mean and annual mean limit values, are summarised in **Table 4-3**.

Under Section 20 of the Air Quality Directive, Member States are required to inform the Commission where exceedances of PM_{10} limit values are due to natural sources (for example sea salt), and where this is the case, the exceedance does not count as non-compliance. Particulate matter from sea salt is modelled and has been used in the past to determine whether compliance with the limit values has been achieved after contribution from natural sources has been subtracted. However, in 2018 there were no modelled exceedances of either the 24-hr or annual mean limit values, so no subtraction of contribution from natural sources has been carried out.

Particulate Matter as $PM_{2.5}$: all zones met the Stage 1 limit value (25 µg m^{-3} to be achieved by 1st Jan 2015) which came into force on 1st January 2015, and the Stage 2 indicative limit value (20 µg m^{-3} to be achieved by 1st Jan 2020). Both limit values apply to the calendar year mean.

The results of the air quality assessment for $PM_{2.5}$ for each zone are summarised in **Table 4-4**. Subtraction of $PM_{2.5}$ contributions due to natural sources was not necessary for any zone.

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 (AEI) statistic. The AEI for the UK is calculated as follows: the arithmetic mean $PM_{2.5}$ concentration at appropriate UK urban background sites only is calculated for three consecutive calendar years, and the mean of these values taken as the AEI.

The AEI for the reference year (2010) was used to determine the National Exposure Reduction Target (NERT), to be achieved by 2020 (see Annex XIV of the Air Quality Directive). The UK's reference year AEI was 13 µg m^{-3}; on this basis, the Air Quality Directive sets an exposure reduction target of 15%. This equates to reducing the AEI to 11 µg m^{-3} by 2020. (The detailed methodology and results of this calculation are presented in Defra's technical report on UK air quality assessment.)

Table 4-3 Results of Air Quality Assessment for PM_{10} in 2018

Zone	Zone code	PM_{10} LV (daily mean)	PM_{10} LV (annual mean)
Greater London Urban Area	UK0001	OK	OK
West Midlands Urban Area	UK0002	OK	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	OK
Brighton/Worthing/Littlehampton	UK0010	OK (m)	OK (m)
Leicester Urban Area	UK0011	OK	OK
Portsmouth Urban Area	UK0012	OK	OK
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	OK
Kingston upon Hull	UK0018	OK	OK
Southampton Urban Area	UK0019	OK (m)	OK (m)
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	OK
Swansea Urban Area	UK0027	OK	OK
Belfast Metropolitan Urban Area	UK0028	OK	OK
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	OK
North East	UK0036	OK	OK
Central Scotland	UK0037	OK	OK
North East Scotland	UK0038	OK	OK
Highland	UK0039	OK (m)	OK (m)
Scottish Borders	UK0040	OK (m)	OK (m)
South Wales	UK0041	OK	OK
North Wales	UK0042	OK (m)	OK (m)
Northern Ireland	UK0043	OK	OK

In Table 4-3, 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 2018.

Zone	Zone code	$PM_{2.5}$ 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
West Midlands Urban Area	UK0002	OK	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	OK
Brighton/Worthing/Littlehampton	UK0010	OK	OK
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	OK
Reading/Wokingham Urban Area	UK0016	OK	OK
Coventry/Bedworth	UK0017	OK	OK
Kingston upon Hull	UK0018	OK	OK
Southampton Urban Area	UK0019	OK	OK
Birkenhead Urban Area	UK0020	OK	OK
Southend Urban Area	UK0021	OK (m)	OK (m)
Blackpool Urban Area	UK0022	OK	OK
Preston Urban Area	UK0023	OK	OK
Glasgow Urban Area	UK0024	OK	OK
Edinburgh Urban Area	UK0025	OK	OK
Cardiff Urban Area	UK0026	OK	OK
Swansea Urban Area	UK0027	OK	OK
Belfast Metropolitan Urban Area	UK0028	OK	OK
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	OK
North East	UK0036	OK	OK
Central Scotland	UK0037	OK	OK
North East Scotland	UK0038	OK	OK
Highland	UK0039	OK (m)	OK (m)
Scottish Borders	UK0040	OK (m)	OK (m)
South Wales	UK0041	OK	OK
North Wales	UK0042	OK (m)	OK (m)
Northern Ireland	UK0043	OK	OK

Subtraction of natural source contribution was not carried out for any zones in 2018.

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

The AEI for the reference year 2015 is set at 20 µg m^{-3} as an Exposure Concentration Obligation (ECO) in the Air Quality Directive. The UK already meets this obligation. There are no obligations or target values for the years *between* 2010, 2015 and 2020, but the running AEIs for these intervening years give an indication of progress towards the 2020 target. The running year AEI for 2018 was calculated as follows:

- 2016: 10 µg m^{-3}
- 2017: 10 µg m^{-3}
- 2018: 10 µg m^{-3}

The mean of these three values (to the nearest integer) is 10 µg m^{-3}. Thus, the running AEI for 2018 is below the 2020 exposure reduction target.

Ozone: all zones and agglomerations met the target values for health and for protection of vegetation. The results of the air quality assessment for ozone are summarised in **Table 4-5**.

For ozone, there is a target value based on the maximum daily 8-hour mean. All 43 zones and agglomerations were compliant with this target value. There is also a long-term objective for protection of human health, based on the maximum daily 8-hour mean. None of the 43 zones and agglomerations were compliant with the long-term objective (LTO) for health in 2018.

There is also a target value based on the AOT40 statistic. 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 hourly mean values measured between 08:00 and 20:00 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; five zones and agglomerations also met this long-term objective for vegetation in 2018. These were: Preston Urban Area, Glasgow Urban Area, Belfast Metropolitan Urban Area, Central Scotland and North East Scotland.

Ozone concentrations – and hence the number of zones exceeding the LTOs - fluctuate from year to year as ozone is a transboundary pollutant and its formation is influenced by meteorological factors.

Table 4-5 Results of Air Quality Assessment for Ozone in 2018

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

Footnote to Table 4-5: TV = target value, LTO = long-term objective, (m) indicates that the compliance or exceedance was determined by modelling.

In 2018 there were 42 measured exceedances of the ozone population information threshold of 180 µg m^{-3} (at 12 sites), but no exceedances of the population warning threshold of 240 µg m^{-3}. The population information threshold exceedances are detailed in **Table 4-6**. All occurred on the following dates: 5th May, 26th June, 1st July, 2nd July, 26th July and 27th July, in the late afternoon or early evening of those dates.

Table 4-6 Measured Exceedances of the Ozone Information Threshold Value in 2018

Site name	Zone code	Number of 1-hour exceedances of information threshold	Maximum 1-hour concentration (µg m^{-3})
Wicken Fen	UK0029	8	196
Norwich Lakenfields	UK0029	6	192
Sibton	UK0029	6	202
Bournemouth	UK0015	4	203
Wigan Centre	UK0033	4	205
Chilbolton Observatory	UK0031	3	191
Reading New Town	UK0016	3	188
Canterbury	UK0031	2	191
Glazebury	UK0033	2	182
Rochester Stoke	UK0031	2	185
Hull Freetown	UK0018	1	190
Yarner Wood	UK0030	1	186

Table 4-6 shows the exceedances of the ozone information threshold in the verified dataset.

Fourth Daughter Directive 2004/107/EC

All zones met target values for arsenic and cadmium, but some zones exceeded the target value for nickel and benzo[a]pyrene. 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 summarised in **Table 4-7**.

Concentrations of nickel were above the target value in four zones; Sheffield Urban Area, Swansea Urban Area, Yorkshire & Humberside, and South Wales. Three of these (Swansea Urban Area, Yorkshire & Humberside, and South Wales) also had concentrations of B[a]P above the target value. These Ni and B[a]P exceedances are attributed to emissions from industrial sources. The remaining 39 zones were compliant with the target values for nickel and B[a]P, as shown in **Table 4-7**.

Table 4-7 Results of Air Quality Assessment for As, Cd, Ni and B[a]P in 2018

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 (m)	OK (m)	OK (m)	OK (m)
Greater Manchester Urban Area	UK0003	OK (m)	OK (m)	OK (m)	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	> TV (m)	OK
Nottingham Urban Area	UK0008	OK (m)	OK (m)	OK (m)	OK
Bristol Urban Area	UK0009	OK (m)	OK (m)	OK (m)	OK (m)
Brighton/Worthing/Littlehampton	UK0010	OK (m)	OK (m)	OK (m)	OK (m)
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 (m)	OK (m)	OK (m)	OK
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 (m)	OK (m)	OK (m)	OK
Edinburgh Urban Area	UK0025	OK (m)	OK (m)	OK (m)	OK
Cardiff Urban Area	UK0026	OK (m)	OK (m)	OK (m)	OK
Swansea Urban Area	UK0027	OK	OK	> TV	> TV (m)
Belfast Urban Area	UK0028	OK	OK	OK	OK
Eastern	UK0029	OK	OK	OK	OK
South West	UK0030	OK	OK	OK	OK
South East	UK0031	OK	OK	OK	OK
East Midlands	UK0032	OK	OK	OK	OK
North West & Merseyside	UK0033	OK	OK	OK	OK
Yorkshire & Humberside	UK0034	OK	OK	> TV (m)	> TV
West Midlands	UK0035	OK	OK	OK	OK (m)
North East	UK0036	OK (m)	OK (m)	OK (m)	OK
Central Scotland	UK0037	OK	OK	OK	OK
North East Scotland	UK0038	OK (m)	OK (m)	OK (m)	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)	OK

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

4.3 Comparison with Previous Years

This section provides information on non-compliances in previous years from 2008 onwards.

For **SO_2, $PM_{2.5}$, lead, benzene and CO**, the UK has been compliant with Air Quality Directive limit values (apart from the $PM_{2.5}$ Stage 2 indicative limit value) in all years since 2008 (the year the Air Quality Directive came into force). For information on compliance with the 1st and 2nd Daughter Directives for all pollutants in earlier years, please see the 2012 or earlier reports in this series.

The UK has been compliant with the limit values for both **lead** and **CO** since 2003, and for **benzene** since 2007: these limit values are the same as those contained in the 1st and 2nd Daughter Directives, which the Air Quality Directive superseded.

For oxides of nitrogen, **Table 4-8** summarises the results of the air quality assessment in years from 2008 to 2018. This table shows the numbers of zones exceeding the limit value (plus any agreed margin of tolerance, in cases where a time extension had been granted). The right-hand column contains notes on the effects of any time extensions. As of 1st January 2015, there have been no margins of tolerance in force for any pollutant.

All non-agglomeration zones within the UK have complied with the critical level for annual mean NO_X concentration, set for protection of vegetation, in years 2008 onwards.

For PM_{10}, **Table 4-9** summarises the results of the air quality assessment in years from 2008 to 2018. Again, there are notes in the right-hand column explaining the effects of the time extensions which were in place up to the end of 2011 for some zones.

For ozone, **Table 4-10** summarises annual exceedances of the limit value for human health (based on the maximum daily 8-hour mean), the limit value for protection of vegetation (based on the AOT40 statistic), and the two long-term objectives (LTOs) based on these two metrics.

Finally, for the pollutants covered by the Fourth Daughter Directive - arsenic (As), cadmium (Cd), nickel (Ni) and benzo[a]pyrene (B[a]P), **Table 4-11** summarises the numbers of zones with exceedances of target values in previous years.

Table 4-8 Non-Compliances with the Limit Values of the Air Quality Directive for Nitrogen Dioxide, 2008-2018

Year	Zones Exceeding NO_2 LV for health (1hr mean)	Zones Exceeding NO_2 LV for health (annual mean)	Notes on Time Extensions
2008	3 zones (London, Glasgow, N.E. Scotland)	40 zones	-
2009	2 zones (London, Glasgow)	40 zones	-
2010	3 zones (London, Teesside, Glasgow)	40 zones	-
2011	3 zones (London, Glasgow, South East)	35 zones	*A further 5 zones exceeded the annual mean NO_2 LV in 2011 but were covered by time extensions and within the LV+ Margin of Tolerance (MOT), therefore compliant.*
2012	2 zones (London, South East)	34 zones	*A further 4 zones exceeded the annual mean NO_2 LV in 2012 but were covered by time extensions and within the LV+ MOT, therefore compliant.*
2013	1 zone (London)	31 zones	*A further 7 zones exceeded the annual mean NO_2 LV in 2013 but were covered by time extensions and within the LV+ MOT, therefore compliant.*
2014	2 zones (London, South Wales)	30 zones	*A further 8 zones exceeded the annual mean NO_2 LV in 2014 but were covered by time extensions and within the LV+ MOT, therefore compliant.*
2015	2 zones (London, South Wales)	37 zones	*2015 was the first year with no time extensions for NO_2: this is the reason for the apparent increase in zones exceeding between 2014 and 2015.*
2016	2 zones (London, South Wales)	37 zones	*No time extensions in place.*
2017	2 zones (London, South Wales)	37 zones	*No time extensions in place.*
2018	2 zones (London, South Wales)	36 zones	*No time extensions in place.*

Table 4-9 Non-Compliances with the Limit Values of the Air Quality Directive for PM_{10}, 2008-2018

Year	PM_{10} LV (annual mean)	PM_{10} LV (daily mean)	Notes on Time Extensions and Subtraction of Natural contribution
2008	None	2 zones (1 zone after subtraction of natural contribution)	-
2009	None	3 zones (1 zone after subtraction of natural contribution)	-
2010	None	None (after subtraction of natural contribution)	*One zone exceeded the daily mean PM_{10} limit value more than the permitted 35 times in 2010, after subtraction of natural contribution. This zone was covered by a time extension and was within the LV+MOT so was therefore compliant.*
2011	None	None (after subtraction of natural contribution)	*One zone exceeded the daily mean PM_{10} limit value more than the permitted 35 times in 2011, after subtraction of natural contribution. This zone was covered by a time extension and was within the LV+MOT so was therefore compliant.*
2012	None	None (after subtraction of natural contribution. No time extension.)	-
2013	None	None (after subtraction of natural contribution. No time extension.)	-
2014	None	None (after subtraction of natural contribution. No time extension.)	-
2015	None	None (after subtraction of natural contribution. No time extension.)	-
2016	None	None	-
2017	None	None	-
2018	None	None	-

Table 4-10 Exceedances of Air Quality Directive Target Values for Ozone (Health) and Long-Term Objectives, 2008-2018

Year	8-Hour Mean Target Value	AOT40 Target Value	8-Hour Mean LTO	AOT40 LTO
2008	1 zone measured (Eastern)	None	43 zones	41 zones
2009	None	None	39 zones	10 zones
2010	None	None	41 zones	6 zones
2011	None	None	43 zones	3 zones
2012	None	None	41 zones	3 zones
2013	None	None	33 zones	8 zones
2014	None	None	32 zones	3 zones
2015	None	None	43 zones	1 zone
2016	None	None	42 zones	5 zones
2017	None	None	34 zones	None
2018	None	None	43 zones	38 zones

Table 4-11 Exceedances of 4th Daughter Directive Target Values for As, Cd, Ni and B[a]P, 2008-2018

Year	As	Cd	Ni	B[a]P
2008	None	None	2 zones (Swansea, South Wales)	6 zones (Yorkshire & Humberside, Teesside, Northern Ireland, Swansea, South Wales, Belfast)
2009	None	None	2 zones (Swansea, South Wales)	6 zones (Yorkshire & Humberside, Northern Ireland, Teesside, Swansea, North East, South Wales)
2010	None	None	2 zones (Swansea, South Wales)	8 zones, (Yorkshire & Humberside, Northern Ireland, Teesside, Belfast, W Midlands, North East, South Wales, North Wales.)
2011	None	None	2 zones, (Swansea, South Wales)	7 zones (Yorkshire & Humberside, Northern Ireland, Teesside, Swansea, Belfast, North East, South Wales)
2012	None	None	2 zones, (Swansea, South Wales)	8 zones (Yorkshire & Humberside, Teesside, Swansea, Belfast, the North East, South Wales, North Wales, Northern Ireland.)
2013	None	None	2 zones, (Swansea, South Wales)	6 zones (Yorkshire & Humberside, Teesside, Swansea, the East Midlands, the North East, South Wales.)
2014	None	None	3 zones, (Sheffield, Swansea, South Wales)	6 zones (Yorkshire & Humberside, Teesside, Swansea, the East Midlands, the North East and South Wales).
2015	None	None	2 zones, (Swansea, South Wales)	5 zones (Yorks. & Humberside, Teesside, Swansea, the North East and South Wales).
2016	None	None	3 zones, (Sheffield, Swansea, South Wales)	4 zones (Yorks. & Humberside, Swansea, South Wales and Northern Ireland).
2017	None	None	None	3 zones, (Yorks. & Humberside, Swansea and South Wales)
2018	None	None	4 zones, (Sheffield, Yorks. & Humberside, Swansea and South Wales)	3 zones, (Yorks. & Humberside, Swansea and South Wales)

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, roadside and background concentrations are discussed separately.

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 Heavy Metals Network, and the PAH Network.

The AURN has been in operation since 1992. Since that time, it has grown considerably in size, and the proportion of urban traffic (‘roadside’) monitoring sites has increased. Therefore, in most cases, we have based our investigation of trends on data from sub-sets of long-running AURN monitoring sites, rather than the whole network. This is intended to show changes over time, without introducing any spurious effects due to changes in the number and distribution of the sites.

For pollutants monitored using continuous automatic techniques, trend analysis has been carried out using Openair: a free, open-source software package of tools for analysis of air pollution data. Openair was developed by King’s College London with the University of Leeds. The Openair project is currently led by Dr David Carslaw, of Ricardo Energy & Environment and the University of York. A range of Openair functions are available on UK-AIR: for more information on the functions and how to use them, please refer to: https://uk-air.defra.gov.uk/data/openair.

The Openair ‘TheilSen’ function has been used here. This uses the Theil-Sen statistical method to determine trends in pollutant concentrations over several years. The trend analysis is based on monthly mean pollutant concentrations. (At least 75% data capture is required for a valid monthly mean.) The ‘TheilSen’ function includes an option to ‘de-seasonalise’ the data (i.e. statistically modify the plotted data to remove the influence of seasonal cycles, thus providing a clearer indication of the overall trend). The de-seasonalise option has been used for most pollutants, particularly those that show a seasonal pattern; SO_2, NO_2, particulate matter, CO and ozone - but not 1,3-butadiene. Where the ‘de-seasonalise’ option has been used here, this is indicated in the graph title. In these trend graphs, the trend line is shown by a solid red line, with 95% confidence intervals for the trend shown by dotted red lines. The trend is given at the top of the graph in green, with confidence intervals shown in square brackets. The trend is given as units (e.g. $\mu g\ m^{-3}$) per year, over the period shown. This may be followed by a number of symbols, with + indicating that the trend is significant at the 0.1 level, * indicating that the trend is statistically significant at the 0.05 level, ** indicating significance at the 0.01 level and *** indicating significance at the 0.001 level. It should also be noted that the 'de-seasonalise' option fills in any gaps in the dataset using an interpolation method, so the datasets shown in these trend plots appear uninterrupted, though this is not necessarily the case.

These changes over time are compared to changes in estimated total UK emissions where appropriate. Estimated UK emissions data are taken from the National Atmospheric Emissions Inventory (NAEI) website at http://naei.beis.gov.uk/. (The most recent year for which NAEI emission estimates are available is 2017.) For some pollutants, the NAEI website allows bar charts to be created, showing emissions over a selected period of years, split between various emission source categories.

Please note that this section only aims to provide a general indication of changes in pollutant concentration over time, based in most cases on averages from groups of long-running sites. Patterns for specific regions or individual sites may be different.

5.1 Sulphur Dioxide

5.1.1 SO_2: Spatial Distribution in the UK

Figure 5-1shows how the modelled 99.73rd percentile[a] of hourly mean sulphur dioxide concentration varied across the UK during 2018. 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 5-2 shows the modelled 99.18th percentile of 24-hour means (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 would indicate 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 2018.

5.1.2 SO_2: Changes Over Time

Figure 5-3 shows how ambient concentrations have changed over the period 1992 to 2018, at the six AURN monitoring stations that have monitored this pollutant for the longest time and remained in operation in 2018. All six stations show a downward trend that is statistically significant at the 0.001 level - highly significant – as denoted by the three asterisks (***) on the plots.

[a] 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 per year), percentiles are used to illustrate this. These are simply the xth highest hourly mean divided by the number of hours in a year, or yth highest daily mean divided by the days in a year, expressed as a percentage.

However, the decrease has not been linear. At most of these sites, the downward trend is steepest for the 1990s and early 2000s: there is a clear flattening-off in more recent years from around 2010.

The pattern observed in ambient SO_2 concentrations appears to reflect changes in national emissions. **Figure 5-4** is taken from the NAEI and shows the UK's estimated annual emissions of sulphur dioxide from 1992 (the first year of operation of the AURN) to 2017 (the most recent year for which data are available). The decrease in emissions over time shown here is the continuation of an on-going trend observed by the NAEI throughout the 1970s and 1980s, partly due to the decline of the UK's heavy industry. The main source of this pollutant is fossil fuel combustion: SO_2 emissions in the UK have decreased substantially since 1992, due to reductions in the use of coal, gas and oil. More stringent legislation restricting the sulphur content of fuel oils and diesel fuel used in road vehicles has also helped to reduce emissions of SO_2.

Around 2009, the graph flattens off, and shows a slight upturn in total SO_2 emissions in 2012. The NAEI pollutant information page for SO_2 (at http://naei.beis.gov.uk/overview/pollutants?pollutant_id=8) explains this as follows: "*As a result of the economic downturn the drive to cut energy costs has resulted in an increase in solid fuel use, particularly in 2012 some coal-sensitive pollutants have seen a significant rise in coal burning emissions*." Following 2012, the downward trend in SO_2 emissions continues.

The UK's total estimated emissions of SO_2 in 2017 were 45% below the UK's targets for 2020, set by the National Emission Ceilings Directive and the Gothenburg Protocol.

Figure 5-1 99.73rd Percentile of 1-hour Mean SO_2 Concentration, 2018 (µg m^{-3})

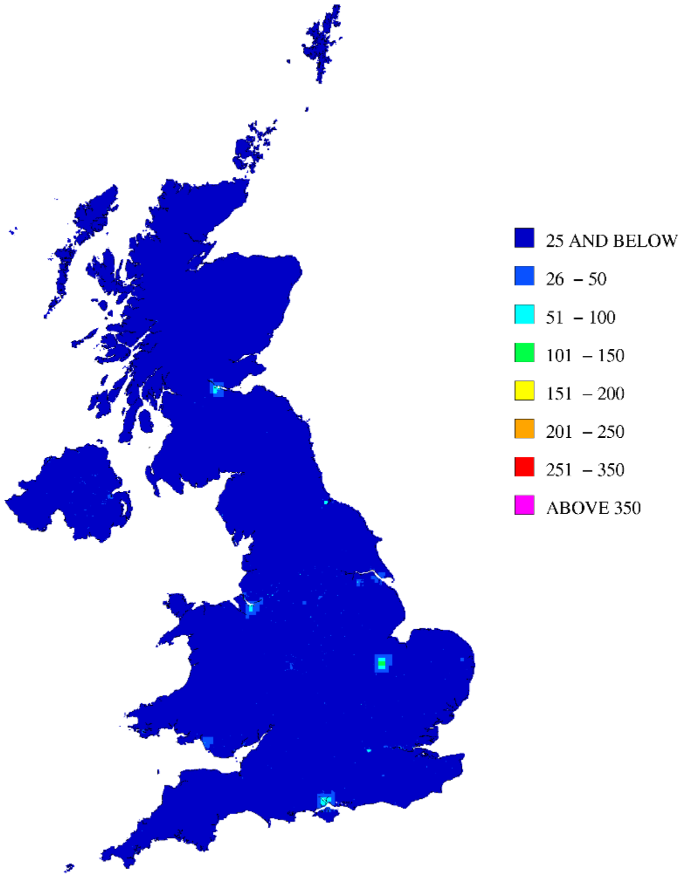


Figure 5-2 99.18th Percentile of 24-hour Mean SO_2 Concentration, 2018 (µg m^{-3})

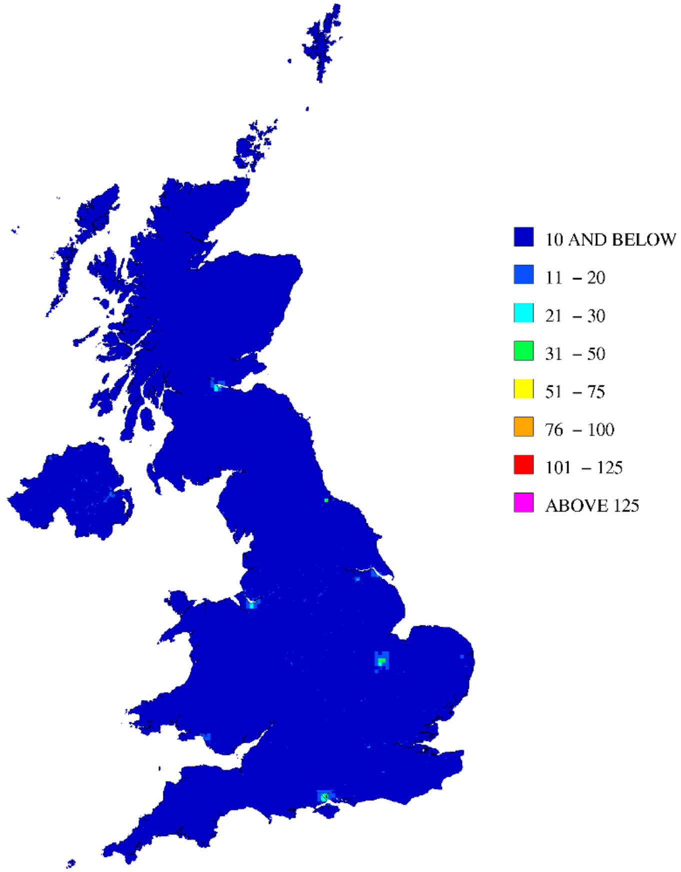


Figure 5-3 De-seasonalised Trends in SO_2 Concentration, 1992-2018 at 6 Long-running AURN Sites

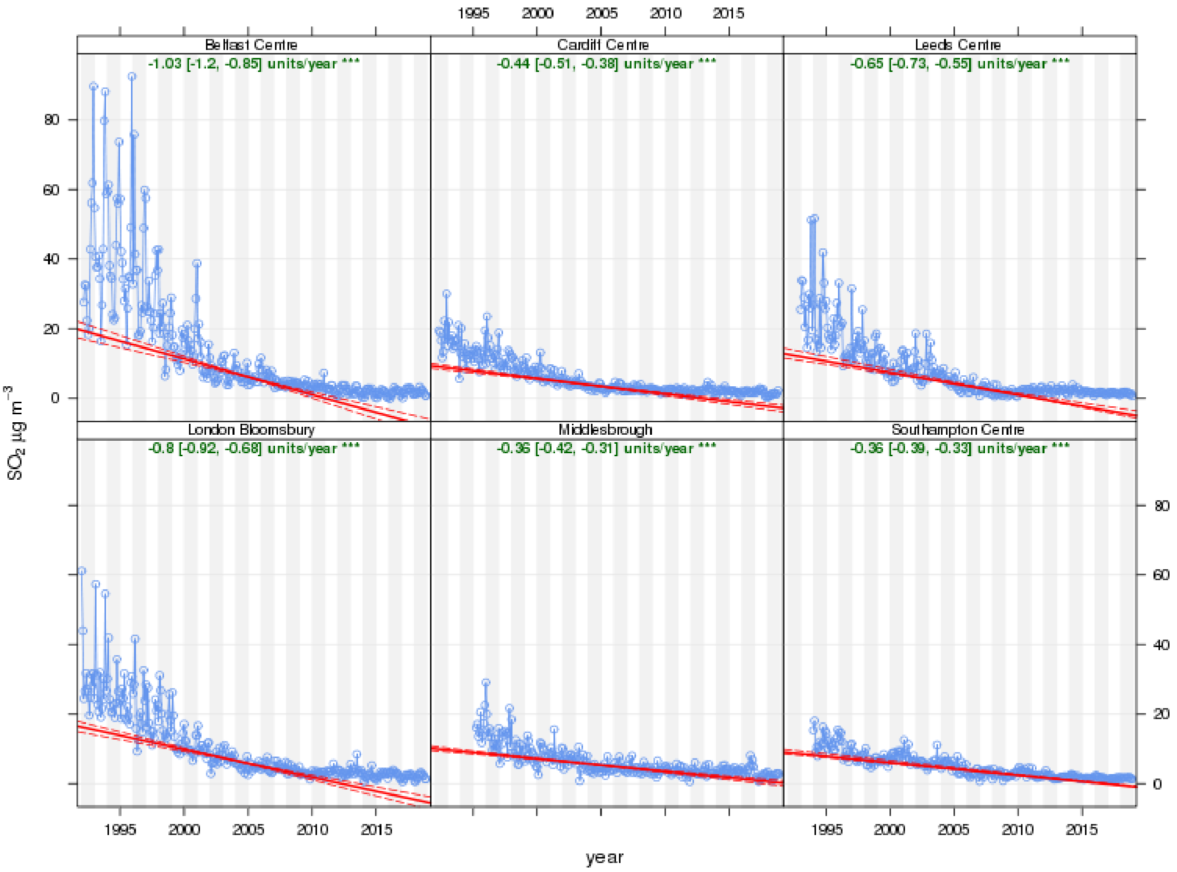
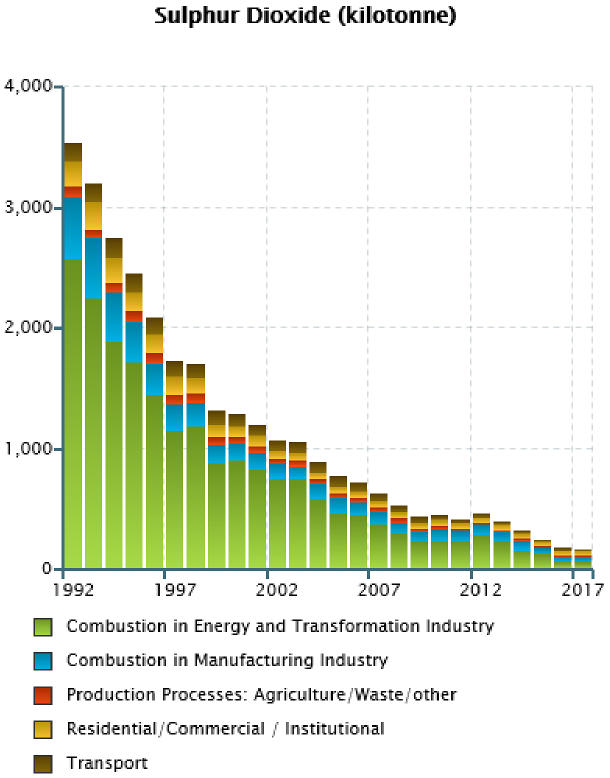


Figure 5-4 Estimated Annual UK Emissions of SO_2 (kt), 1992 – 2017 (from NAEI)



5.2 Nitrogen Dioxide

5.2.1 NO_2: Spatial Distribution in the UK

Figure 5-5 shows the modelled annual mean NO_2 concentrations for 2018, at *urban roadside* locations only. Although not every road link is clearly visible, it is possible to see that some are shaded yellow, orange or (in London) 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; there are also some in urban areas elsewhere in the UK.

Figure 5-6 shows the modelled annual mean *background* NO_2 concentrations for 2018. Most background locations were within the limit value of 40 µg m^{-3}, with the exception of some small areas within London, which are shaded yellow and orange.

5.2.2 NO_2: Changes Over Time

Figure 5-7 and **Figure 5-8** show how ambient concentrations of nitrogen dioxide (as measured by the AURN) have decreased since 1992 (the Network's first year of operation). Time series charts of annual mean NO_2 concentration are shown for the following sub-sets of long-running sites:

- Eight urban non-roadside sites operating since 1995 or earlier (**Figure 5-7**); Belfast Centre, Cardiff Centre, Leeds Centre, London Bloomsbury, Middlesbrough, Newcastle Centre, Sheffield Tinsley and Southampton Centre. (These are all urban background, except Middlesbrough which is urban industrial).
- Eight urban traffic sites operating since 1998 or earlier (**Figure 5-8**); Bath Roadside, Camden Kerbside, Exeter Roadside, Glasgow Kerbside, Haringey Roadside, London Marylebone Road, Oxford Centre Roadside and Tower Hamlets Roadside.

(As explained above, the use of sub-sets of long-running monitoring sites is intended to show changes over time, without introducing any spurious effects due to changes in the number and distribution of the sites.)

Figure 5-5 Urban Major Roads, Annual Mean Roadside NO_2 Concentration, 2018 (µg m^{-3})

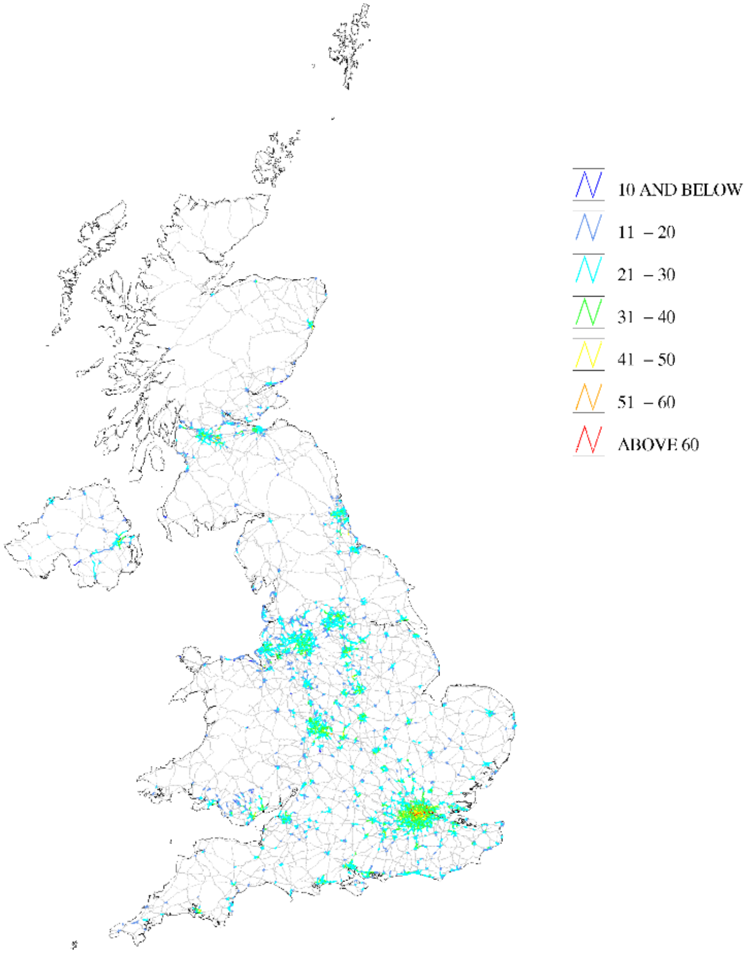


Figure 5-6 Annual Mean Background NO_2 Concentration, 2018 (µg m^{-3})

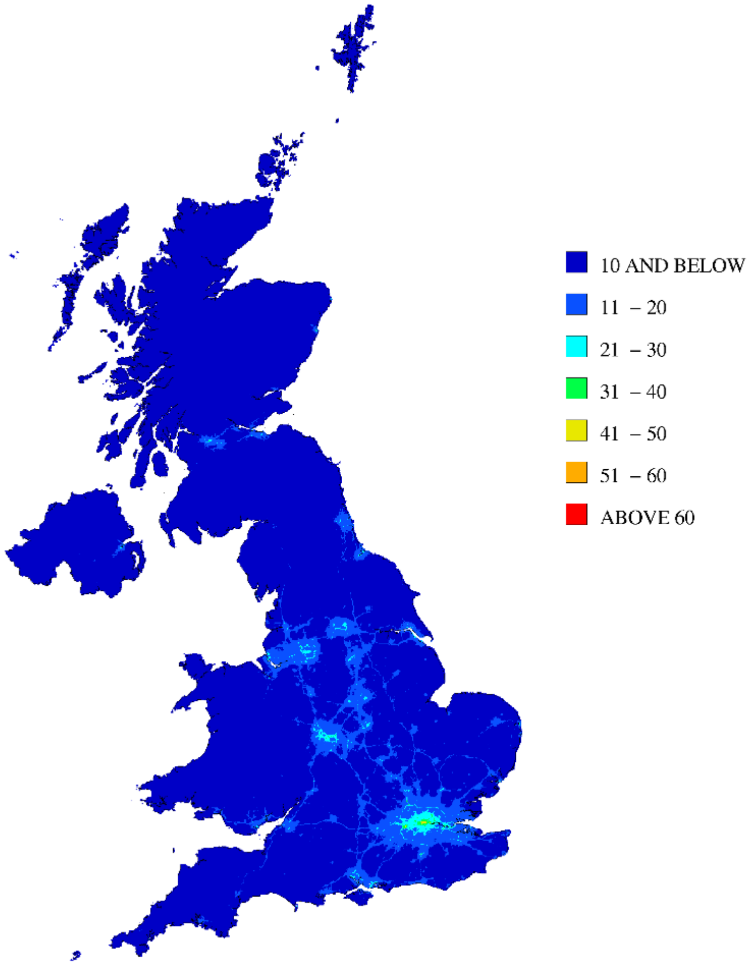
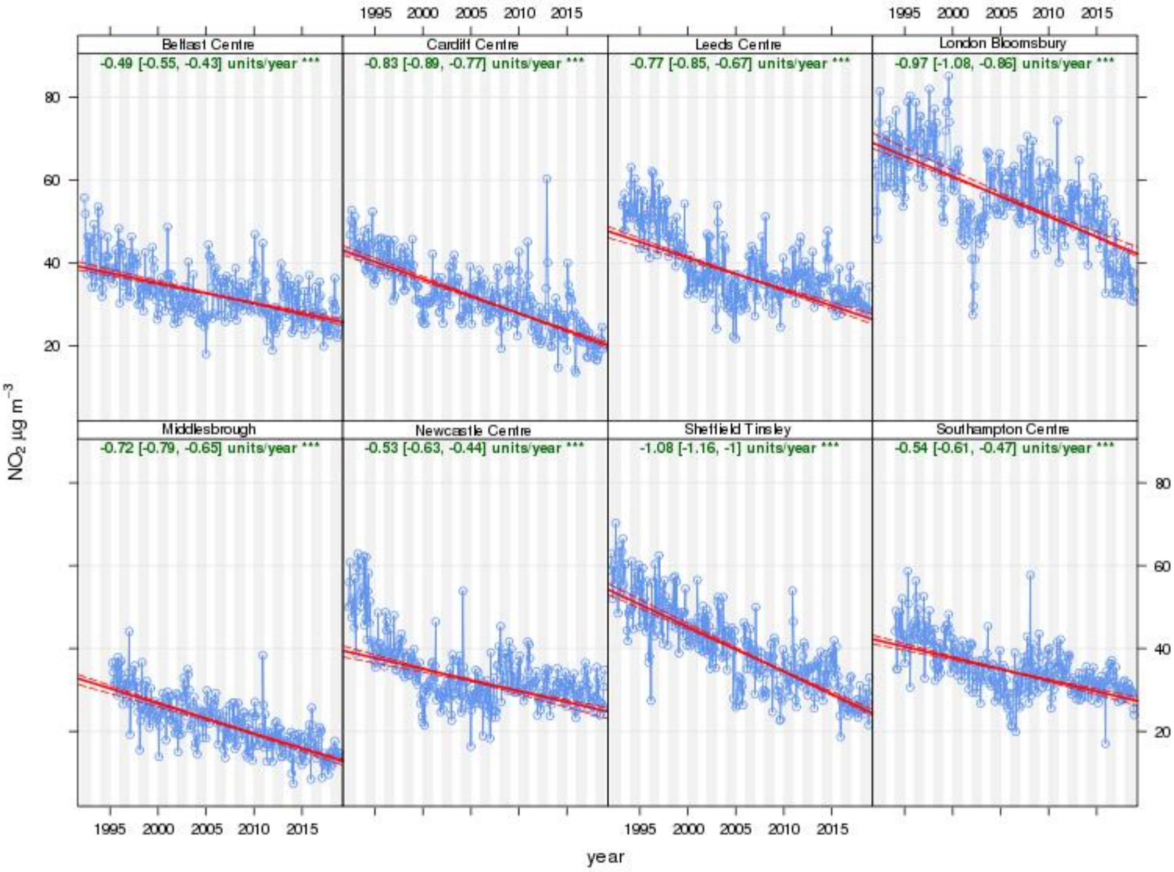


Figure 5-7 De-seasonalised Trends in NO_2 Concentration, at 8 Long-Running AURN Urban Non-Roadside* Sites, 1992-2018



**Urban Background, except for Middlesbrough which is urban industrial.*

All eight long-running urban non-roadside sites in **Figure 5-7** above show a decreasing trend in NO_2. While the magnitude of the year-on-year decrease varies (ranging from -1.08 µg m^{-3} to -0.49 µg m^{-3} per year), the trend is statistically significant at the 0.001 level for all eight sites, as indicated by the three asterisks.

For the urban traffic sites in **Figure 5-8** below, (for which the dataset is slightly shorter), the pattern of trends is less consistent, as highlighted in previous reports in this series. However, seven of the eight sites now show a downward trend statistically significant at the 0.001 level (compared to six last year), and the remaining site (Camden Kerbside) now shows no significant trend (compared with showing an increasing trend in last year's report).

Figure 5-8 De-seasonalised Trends in NO_2 Concentration at 8 Long-Running AURN Urban Traffic Sites, 1998-2018

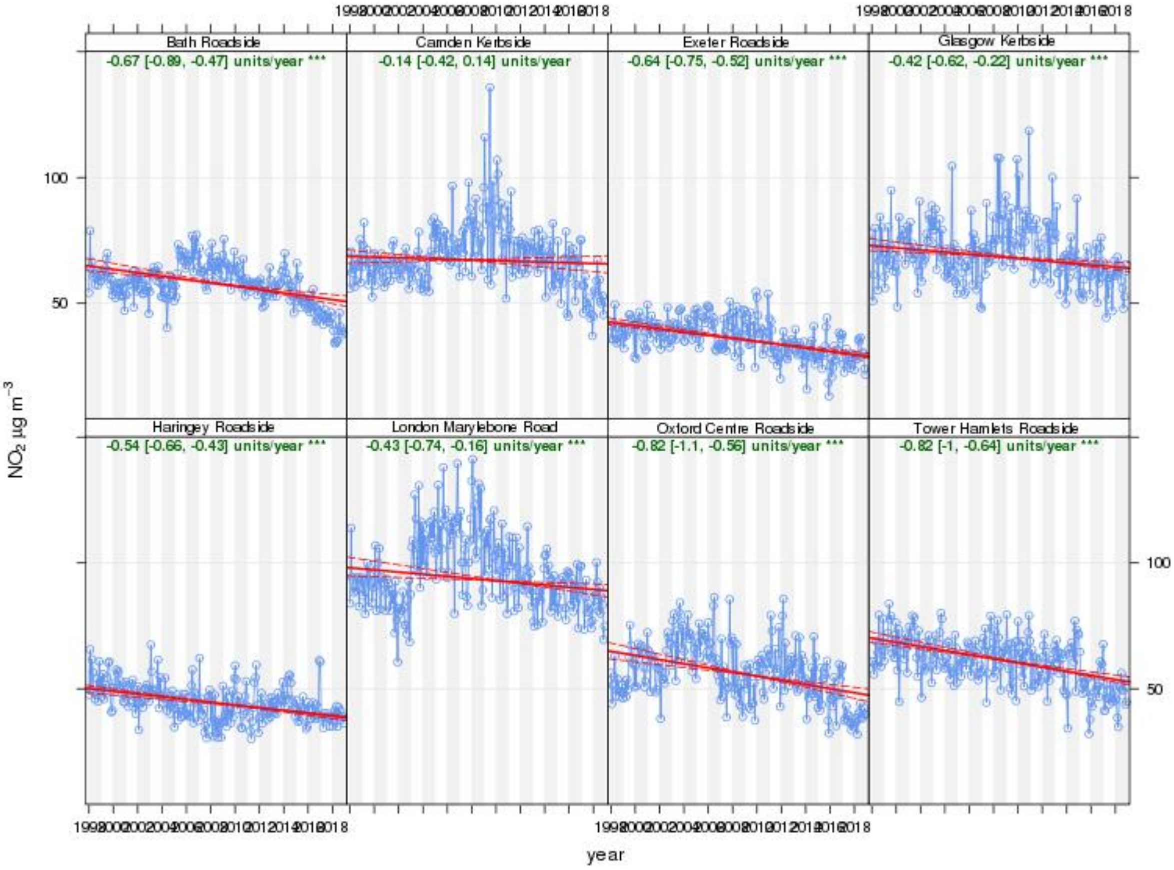
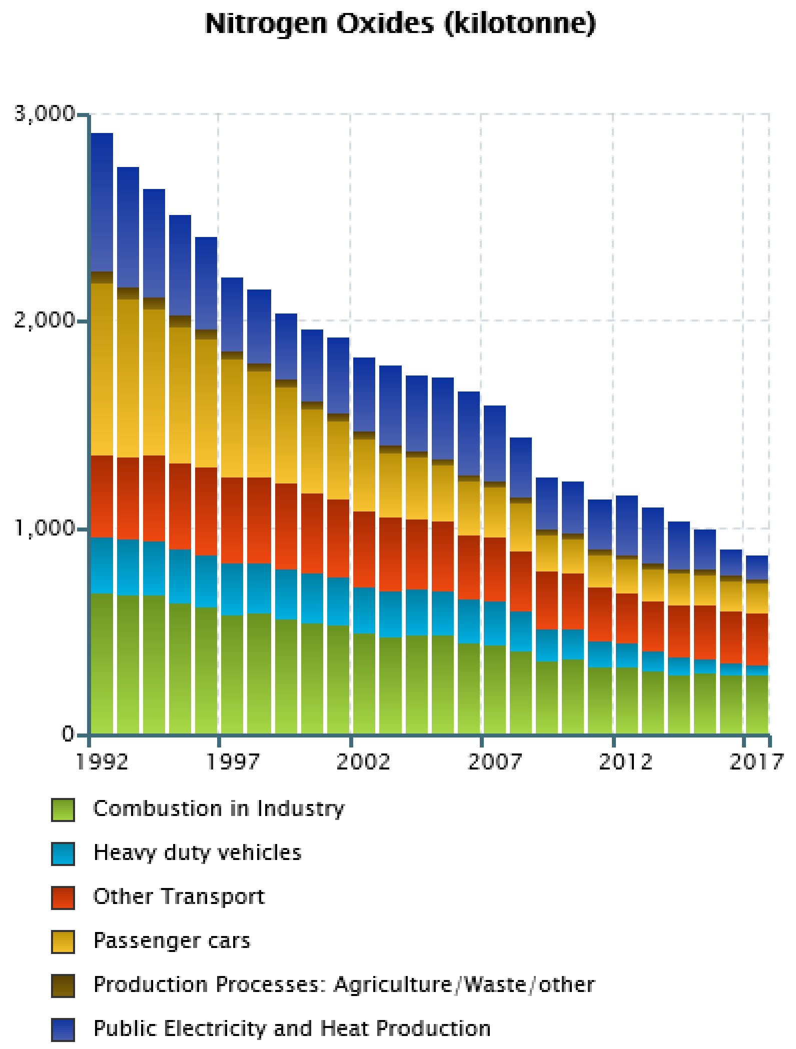


Figure 5-9 shows NAEI estimates of total UK annual emission of oxides of nitrogen, in kilotonnes. Total NO_X emissions have decreased substantially over the period shown. While long-running urban background sites show a general decrease in NO_2 concentration as might be expected from the national emissions estimates, the same is not consistently true of urban traffic sites. It is likely that the trend in ambient NO_2 concentration at each individual site depends, at least in part, on the quantity and type of traffic on the adjacent road.

In July 2017, the Government launched its UK Plan for Tackling Roadside Nitrogen Dioxide Concentrations (see section 2.2.6 for more information on this). The national air quality plan is available at https://www.gov.uk/government/publications/air-quality-plan-for-nitrogen-dioxide-no2-in-uk-2017.

Figure 5-9 Estimated Annual UK Emissions of Nitrogen Oxides (kt), 1992 – 2017 Source: NAEI



5.3 PM_{10} Particulate Matter

5.3.1 PM_{10}: Spatial Distribution

Figure 5-10 shows modelled annual mean urban roadside PM_{10} concentrations in 2018. No roadside locations had an annual mean concentration greater than 40 µg m^{-3}. This is consistent with the compliance assessment reported in **Section 4**.

Figure 5-11 shows modelled annual mean background PM_{10} concentrations in 2018. Background concentrations were higher in the southern and eastern parts of the country; this is a typical pattern, because these regions receive a larger transboundary contribution of particulate pollution from mainland Europe. The elevated levels of PM_{10} associated with urban areas – particularly London, and some of the cities of the East Midlands - can also be seen. Also, the routes of some major roads are just visible, particularly in the east of England.

The concentration bands used in the figures below include the ranges > 30.1 - 31.5 µg m^{-3}, and > 31.6 - 40 µg m^{-3}. The significance of the division at 31.5 µg m^{-3} is that where the annual mean PM_{10} concentration exceeds this value, 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. (Note: this threshold is calculated each year on the basis of the measured data. It may therefore change from year to year.) Road links with annual mean concentrations greater than 31.5 µg m^{-3} would be shaded red in **Figure 5-10**. No red shaded road links are visible on the map; in 2018 there were no modelled or measured exceedances of the 24-hour limit value.

Figure 5-10 Urban Major Roads, Annual Mean Roadside PM_{10} Concentration, 2018 (µg m^{-3})

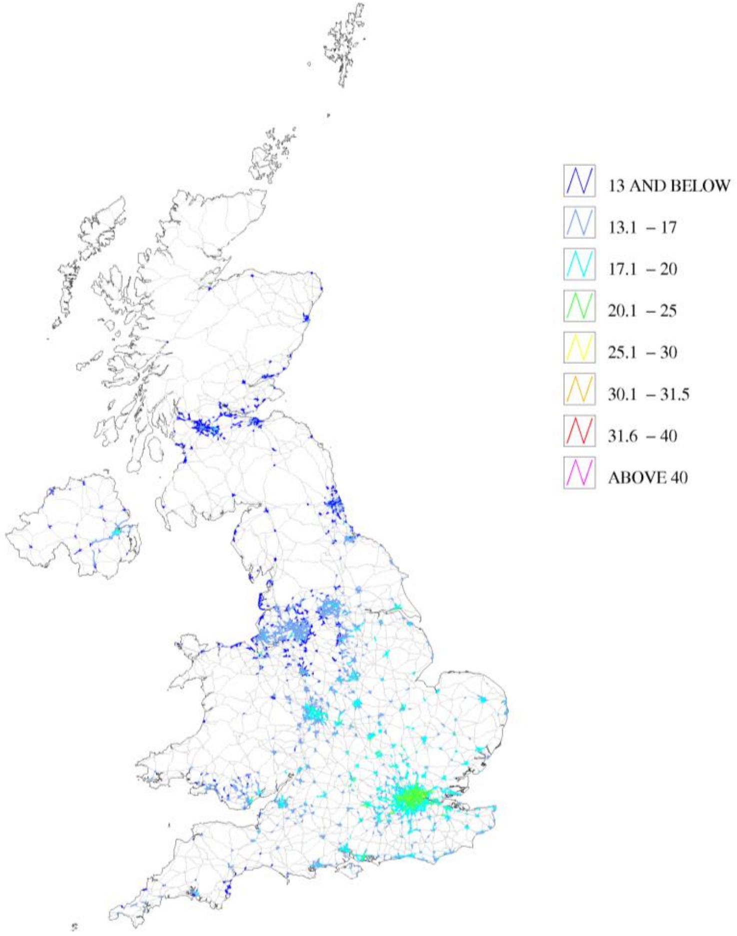
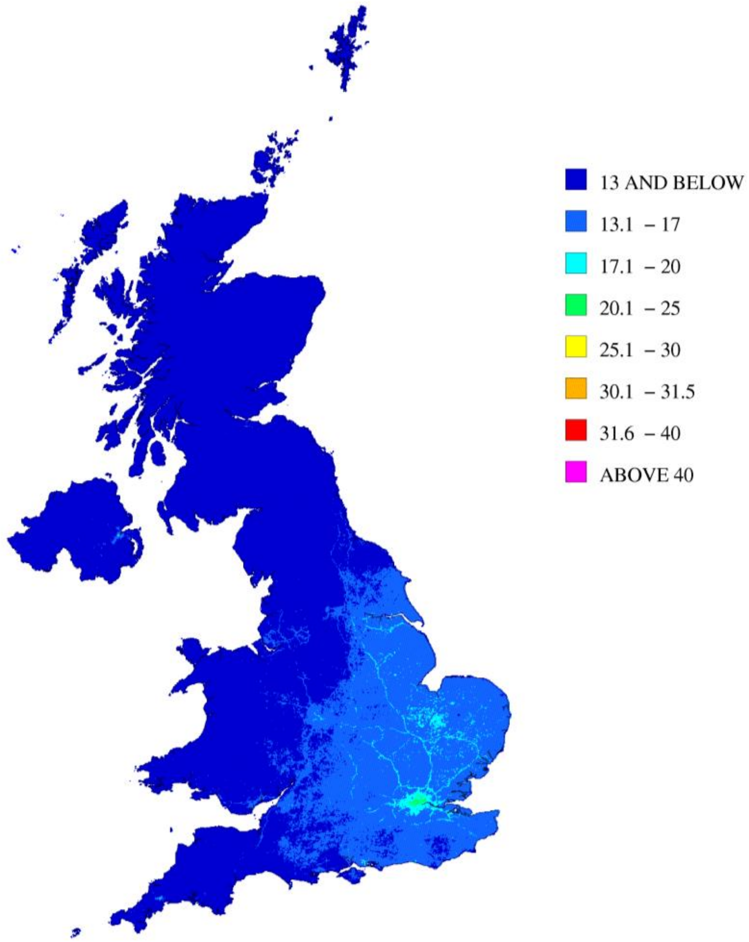


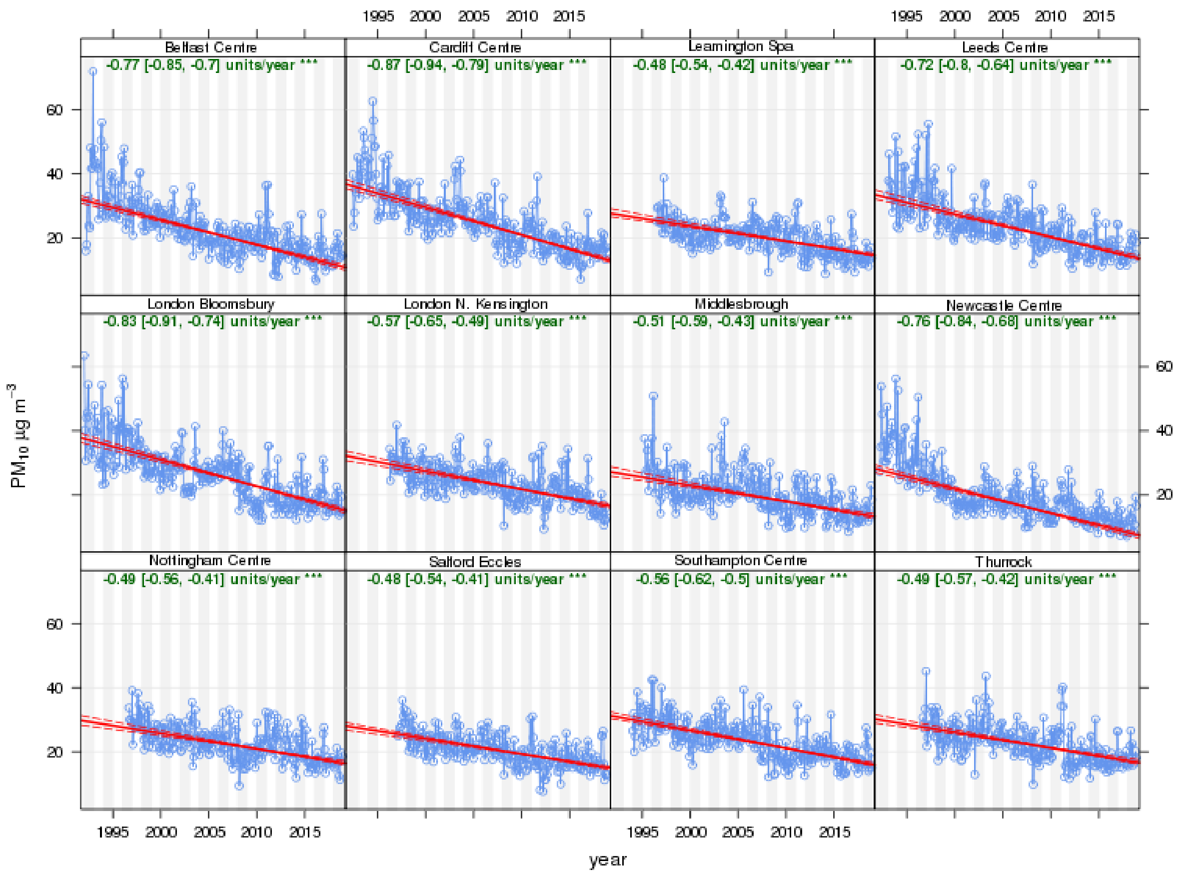
Figure 5-11 Annual Mean Background PM_{10} Concentration, 2018 (µg m^{-3})



5.3.2 PM_{10} Changes Over Time

Figure 5-12 shows de-seasonalised trends in ambient PM_{10} concentration, based on 12 urban non-roadside AURN sites, all of which have been operating since at least 1997. The sites are; Belfast Centre, Cardiff Centre, Leamington Spa, Leeds Centre, London Bloomsbury, London North Kensington, Middlesbrough, Newcastle Centre, Nottingham Centre, Salford Eccles, Southampton Centre and Thurrock. (Middlesbrough is urban industrial, the others are urban background). All 12 sites show a downward trend for PM_{10} over their period of operation, highly statistically significant (at the 0.001 confidence level).

Figure 5-12 De-seasonalised Trends in Ambient PM_{10}, 12 Long-Running Urban Non-Roadside* AURN Sites 1992 – 2018



**Middlesbrough is urban industrial, the others are urban background.*

Figure 5-13 shows de-seasonalised trends in ambient PM_{10} concentration, based on 12 urban traffic AURN sites. There are few very long-running urban traffic PM_{10} sites: only three began monitoring PM_{10} before 2008. The sites shown here have been operating since the start of 2009 or earlier. The sites are; Armagh Roadside, Camden Kerbside, Carlisle Roadside, Chepstow A48, Chesterfield Roadside, Leeds Headingley Kerbside, London Marylebone Road, Sandy Roadside, Stanford-le-Hope Roadside, Stockton-on-Tees Eaglescliffe, Swansea Roadside and York Fishergate.

Most of these sites show a statistically significant downward trend in PM_{10} concentration over this period (with varying degrees of significance). However, this is not the case for all: Stockton-on-Tees Eaglescliffe shows no significant trend and Swansea Roadside shows a statistically significant increase. As in the case of NO_2, it is possible that trends at urban traffic sites are influenced by changes in the volume and type of traffic on the adjacent road.

Figure 5-13 De-seasonalised Trends in Ambient PM_{10}, 12 Long-Running Urban Traffic AURN Sites 2009 – 2018

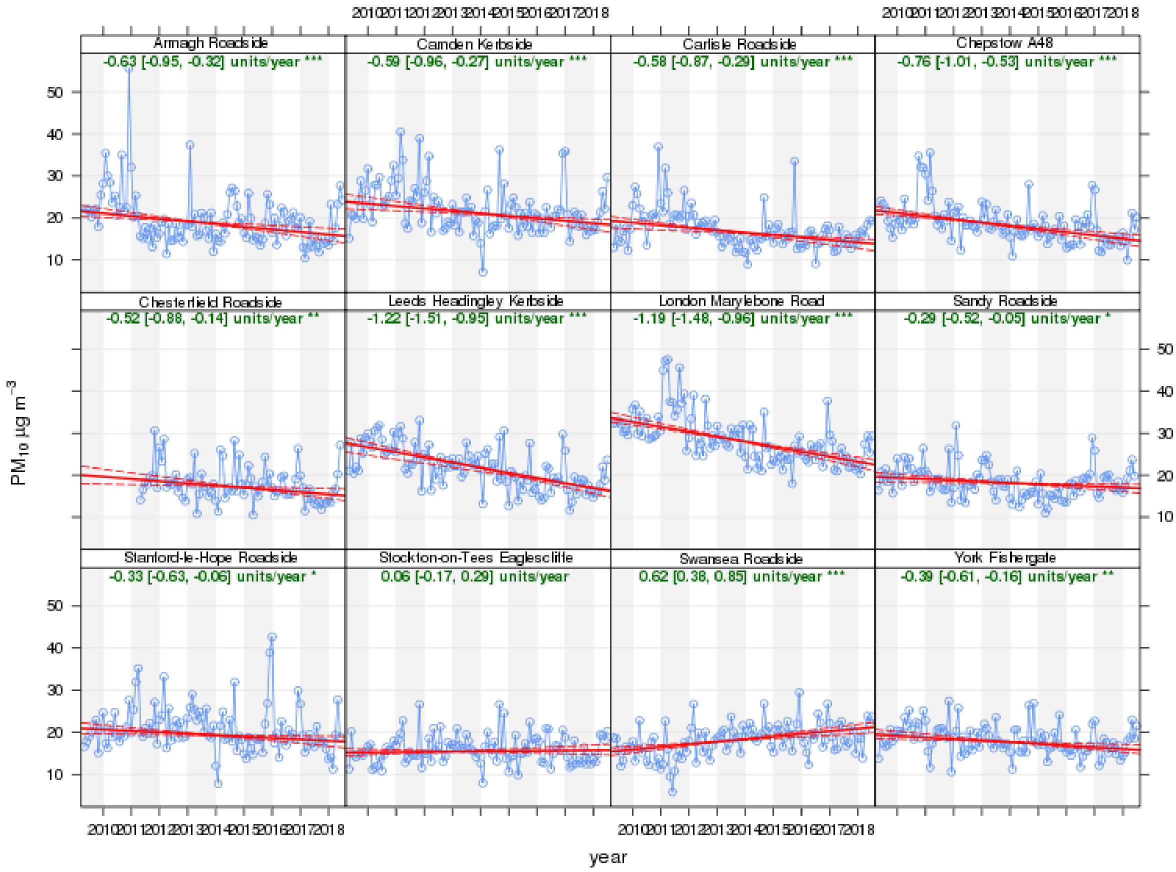


Figure 5-14 shows how the UK's total emissions of PM_{10} have decreased over the years in which the AURN has been in operation. Total PM_{10} emissions have steadily decreased over all this period, although in more recent years the rate of decrease has slowed, flattening off after around 2009. However, estimated emissions from road traffic alone have continued to decrease (**Figure 5-15**).

Figure 5-14 Estimated Annual UK Emissions of PM_{10} (kt), 1992 – 2017 Source: NAEI

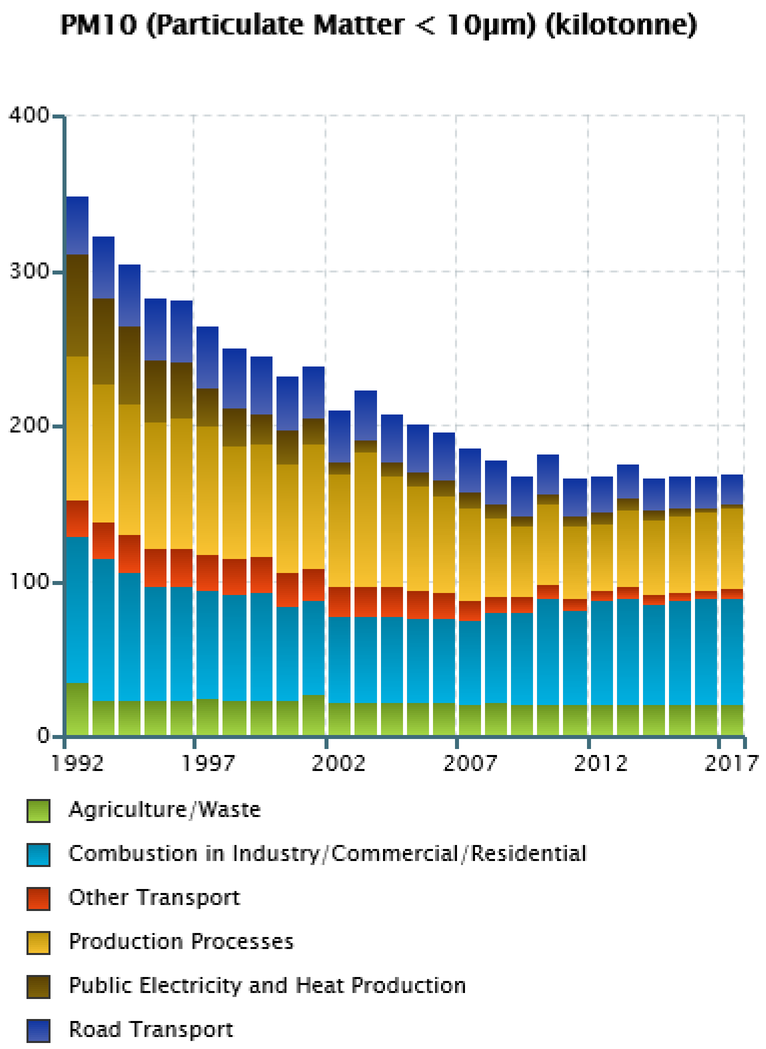
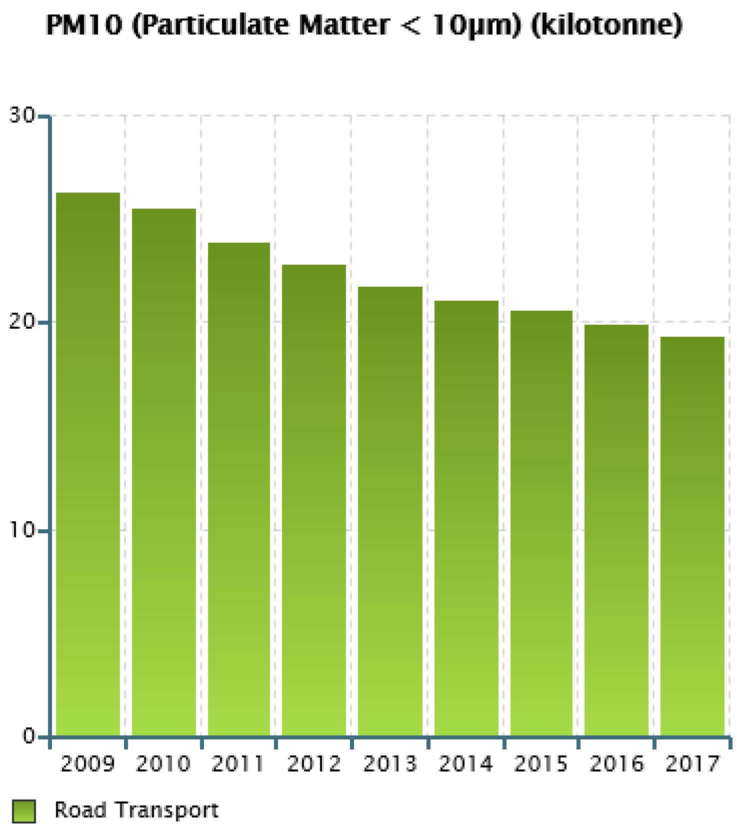


Figure 5-15 Estimated Annual UK Emissions of PM_{10} from Road Transport (kt), 2009 – 2017 Source: NAEI



(Please note, the colours used in these bar charts are selected automatically and the colour used for road transport here is different from that in the previous graph).

5.4 $PM_{2.5}$ Particulate Matter

5.4.1 $PM_{2.5}$: Spatial Distribution

Figure 5-16 shows the modelled annual mean urban roadside $PM_{2.5}$ concentrations in 2018. No roadside locations had annual means greater than the Stage 1 limit value of 25 µg m^{-3}; even in London, the highest were in the range 16 - 20 µg m^{-3}.

Figure 5-17 shows modelled annual mean background $PM_{2.5}$ concentrations in 2018. Modelled concentrations were in the range 6-10 µg m^{-3} throughout most of England and Wales; concentrations were lower in most parts of Scotland, Cumbria and parts of the North East of England, also the west of Northern Ireland. The areas with the highest modelled concentrations for 2018 were in London and the cities of the Midlands and south; some locations had modelled concentrations in the range 13 - 15 µg m^{-3}, but none exceeded the limit value of 25 µg m^{-3}.

Figure 5-16 Urban Major Roads, Annual Mean Roadside $PM_{2.5}$ Concentration, 2018 (µg m^{-3})

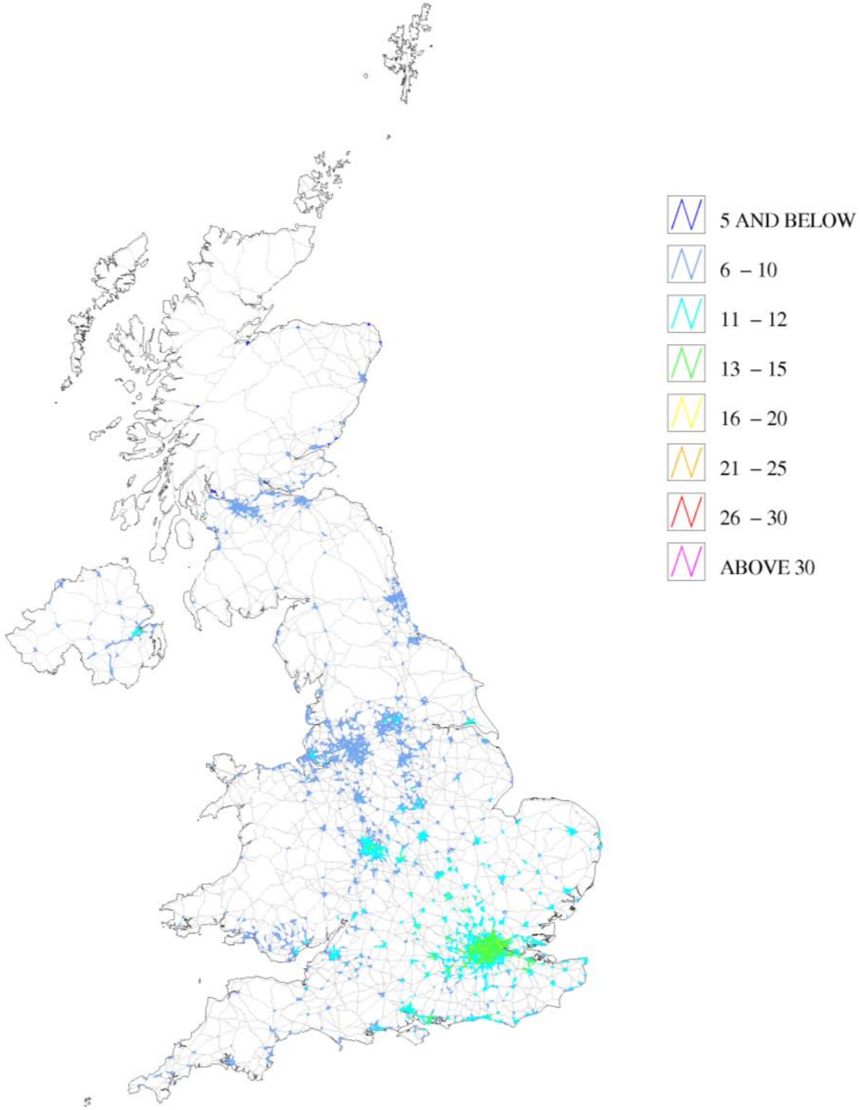
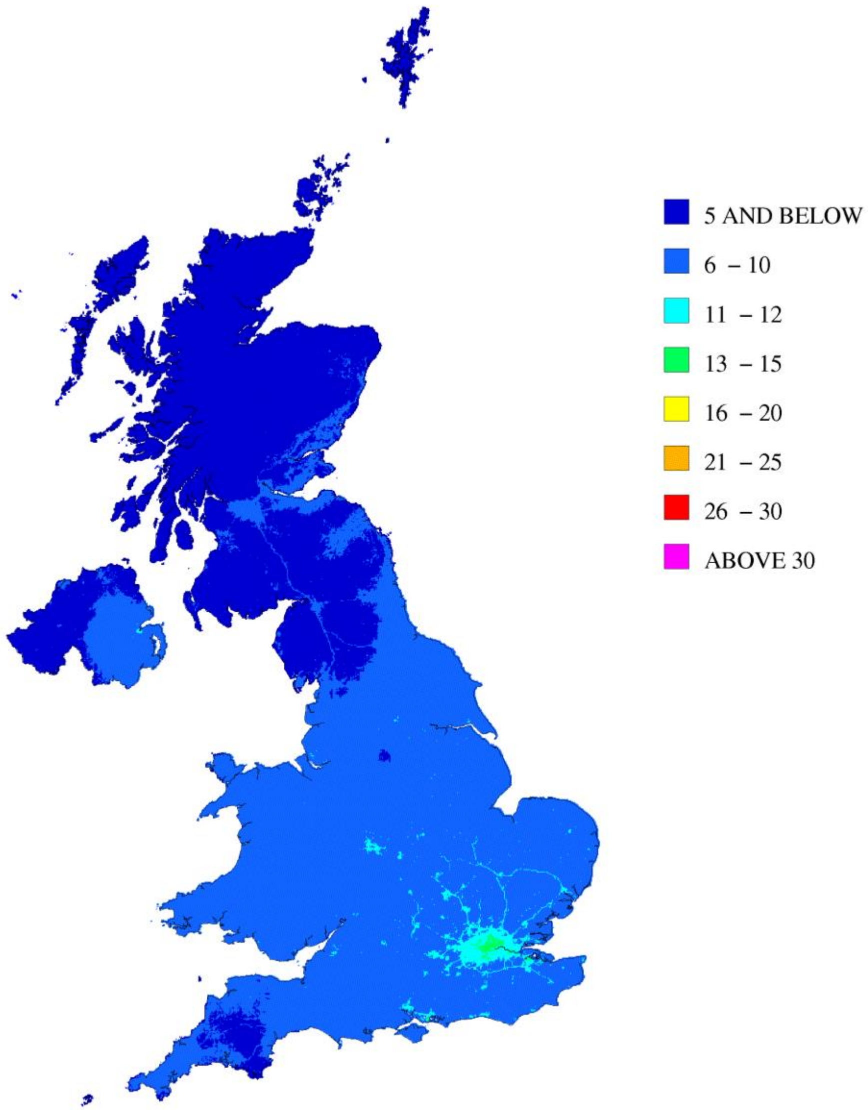


Figure 5-17 Annual Mean Background $PM_{2.5}$ Concentration, 2018 (µg m^{-3})



5.4.2 PM2.5: Changes Over Time

Until 2008, routine monitoring of $PM_{2.5}$ within the AURN was confined to a small number of sites in London. Therefore, in this report, trend analysis for $PM_{2.5}$ concentrates on years 2009 onwards, during which $PM_{2.5}$ monitoring has been widespread.

Figure 5-18 shows trends in $PM_{2.5}$ concentration at 12 long-running urban background AURN sites, 2009-2018. All 12 sites show a statistically significant downward trend in $PM_{2.5}$ concentration, though the magnitude of the trends, and their level of significance, varies.

Figure 5-18 De-seasonalised Trends in Ambient $PM_{2.5}$ Concentration, 12 Long-Running Urban Background AURN Sites 2009-2018

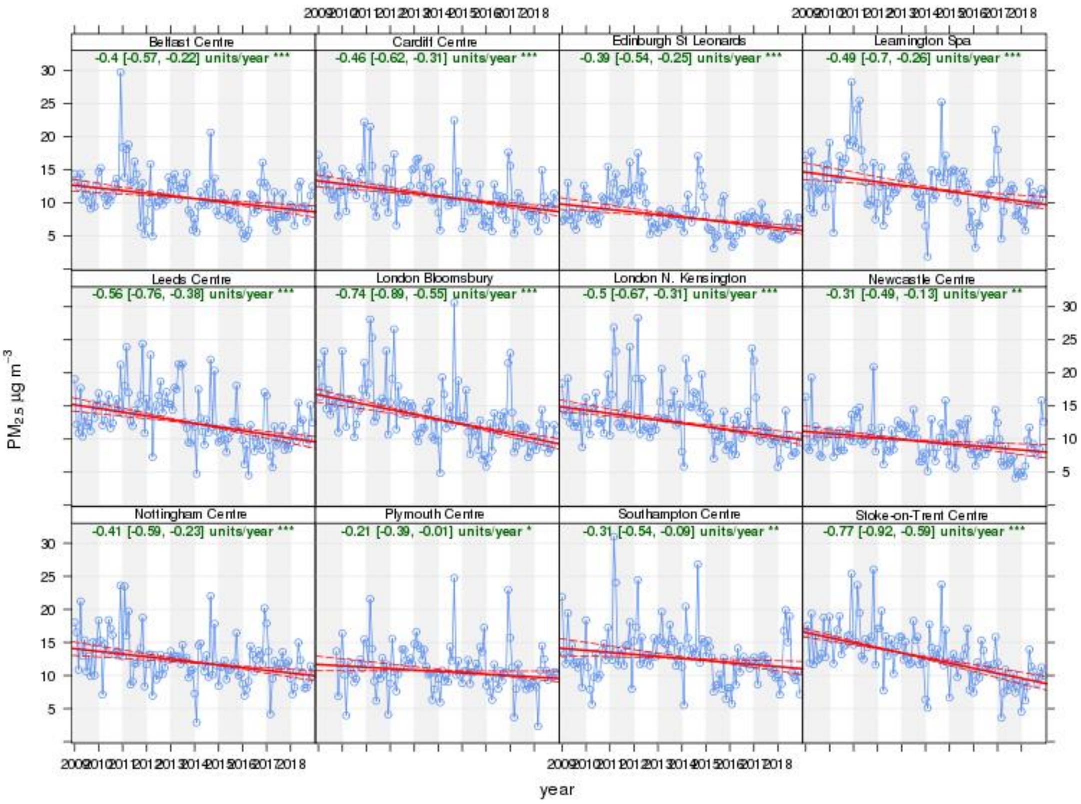
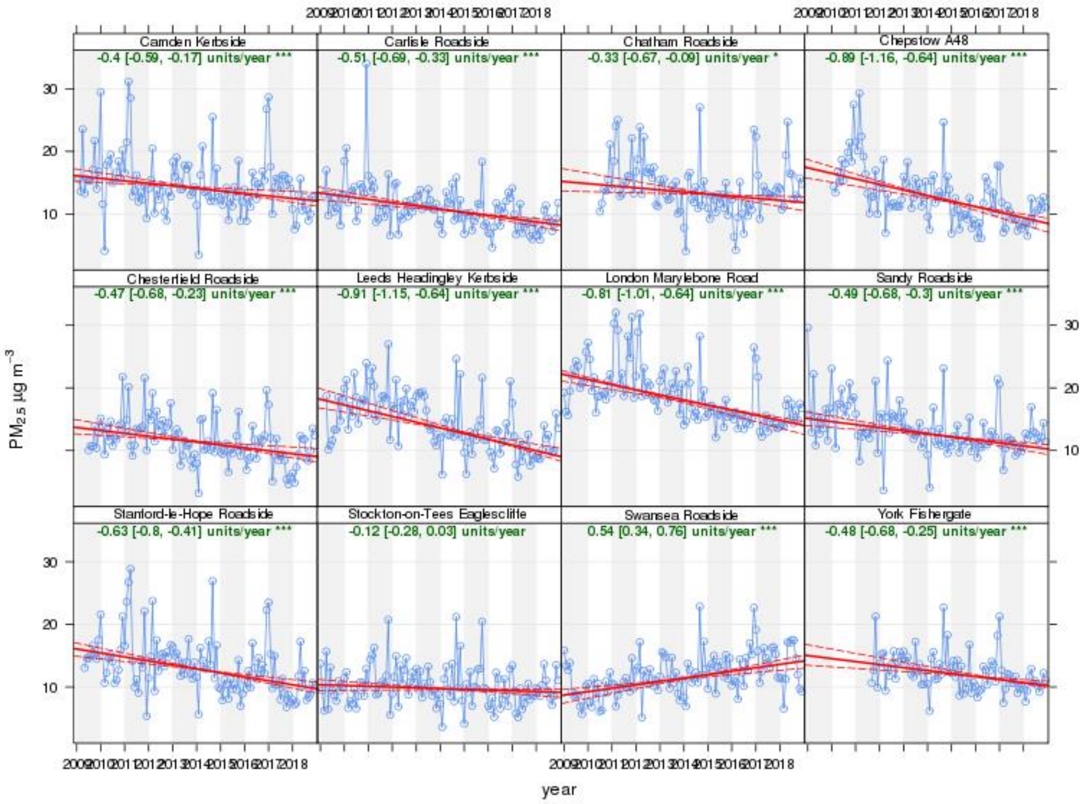


Figure 5-19 shows trends over the same period for $PM_{2.5}$ at 12 urban traffic AURN sites. (There has been a change to the original subset of sites used in the 2016 and earlier reports; Birmingham Tyburn Roadside has closed and Haringey Roadside no longer measures $PM_{2.5}$. Chatham Roadside and York Fishergate have been included instead, although they do not have $PM_{2.5}$ data going back to 2009).

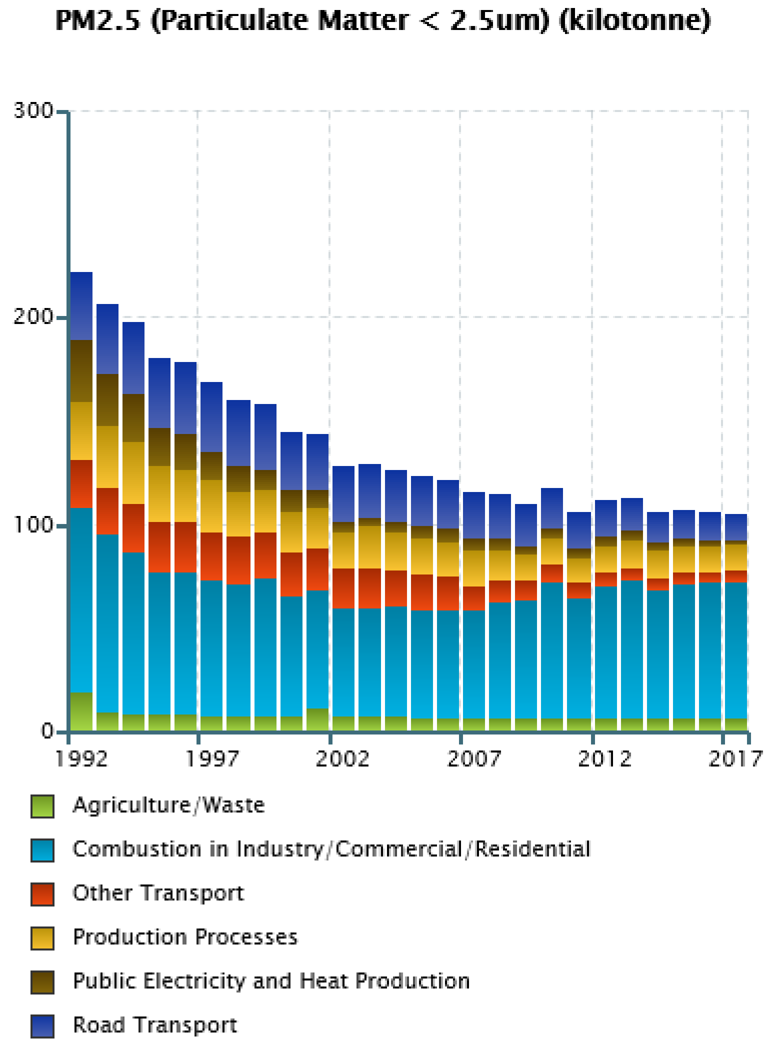
The majority (10 out of the 12 sites) show decreasing trends, of varying magnitude and level of significance, over this period. This includes Camden Kerbside, which until 2017 showed no significant trend. One site (Stockton-on-Tees Eaglescliffe) shows no significant trend, and one (Swansea Roadside) shows a highly significant *increasing* trend in $PM_{2.5}$ concentration, as previously highlighted in recent reports in this series. Swansea Roadside also shows a highly significant increasing trend in PM_{10} concentration, as discussed earlier in this section.

Figure 5-19 De-seasonalised Trends in Ambient $PM_{2.5}$ Concentration, 12 Long-Running Urban Traffic AURN Sites 2009-2018



Finally, **Figure 5-20** shows the estimated annual emission of $PM_{2.5}$, from 1992 to 2017. The graph shows that emissions have decreased in a similar manner to emissions of PM_{10}, with a steady decrease from the early 1990s, a clear levelling off, and no further consistent decrease after around 2009. The largest source category for $PM_{2.5}$ is combustion in industry, residential and commercial premises: this appears to have increased over the past decade.

Figure 5-20 Estimated Annual UK Emissions of $PM_{2.5}$ (kt), 1992 – 2017. Source: NAEI



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 5-21 shows modelled annual mean benzene concentrations at roadside locations in 2018. **Figure 5-22** shows the modelled annual mean background concentrations of benzene in 2018. Modelled background concentrations were below 0.5 µg m^{-3} over most of the UK, with marginally higher concentrations for most urban areas. A few very small areas, for example in Humberside, Portsmouth and the Grangemouth area, had concentrations in excess of 1 µg m^{-3}. These are too small to be clearly seen on the map. Background concentrations everywhere were well below the limit value of 5 µg m^{-3} for benzene.

Figure 5-21 Urban Major Roads, Annual Mean Roadside Benzene Concentration, 2018 (µg m^{-3})

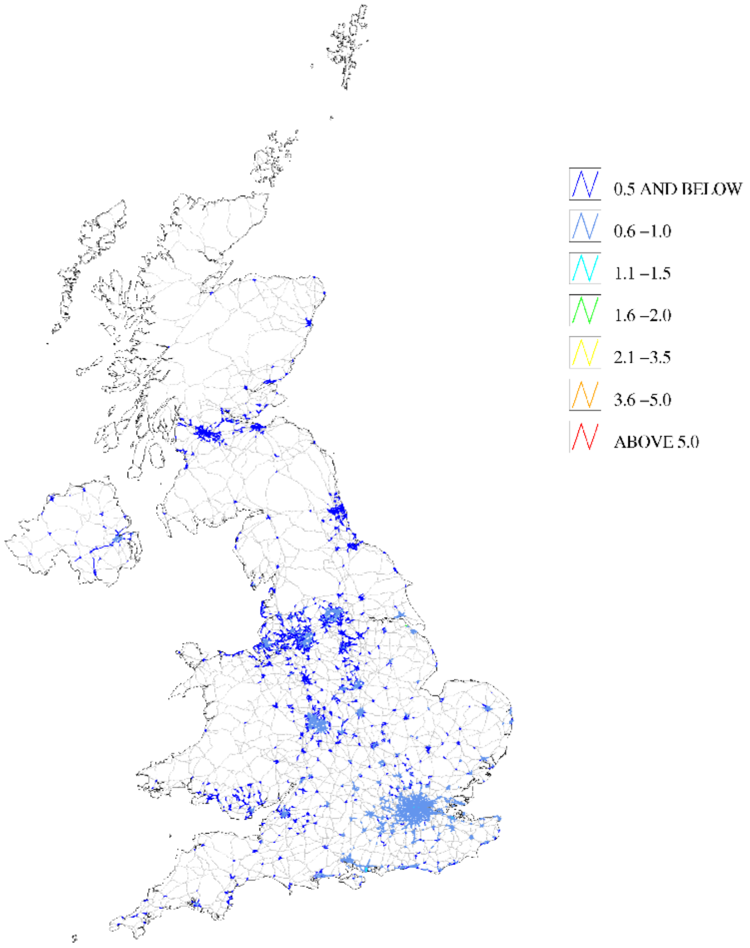
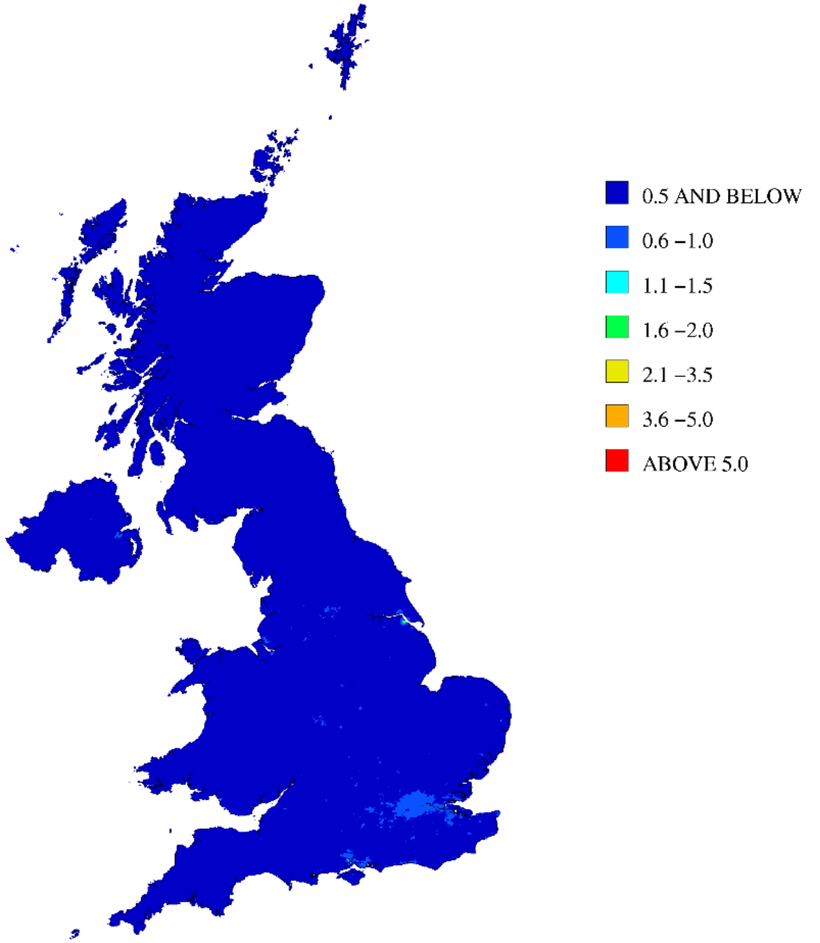


Figure 5-22 Annual Mean Background Benzene Concentration, 2018 (µg m^{-3})



5.5.2 Benzene: Changes Over Time

Figure 5-23 shows a smoothed trend plot based on the combined dataset from 14 long-running sites in the Non-Automatic Hydrocarbon Network, which have operated since 2002. These are: Barnsley Gawber, Belfast Centre, Haringey Roadside, Leamington Spa, Leeds Centre, Liverpool Speke, London Bloomsbury, Manchester Piccadilly, Middlesbrough, Newcastle Centre, Nottingham Centre, Oxford Centre Roadside, Southampton Centre and Stoke-on-Trent Centre.

The smoothed trend plot for these 14 sites shows a slight increase from 2002 to 2004, followed by a steep decrease between 2004 and 2008. From then on, the graph is much flatter, showing little further fall in ambient concentrations of benzene until 2012-2014 when there is a slight rise, followed by a further decrease in subsequent years.

Figure 5-23 Smoothed Trend Plot of Ambient Benzene Concentration, 14 Long-Running Non-Automatic Sites, 2002-2018

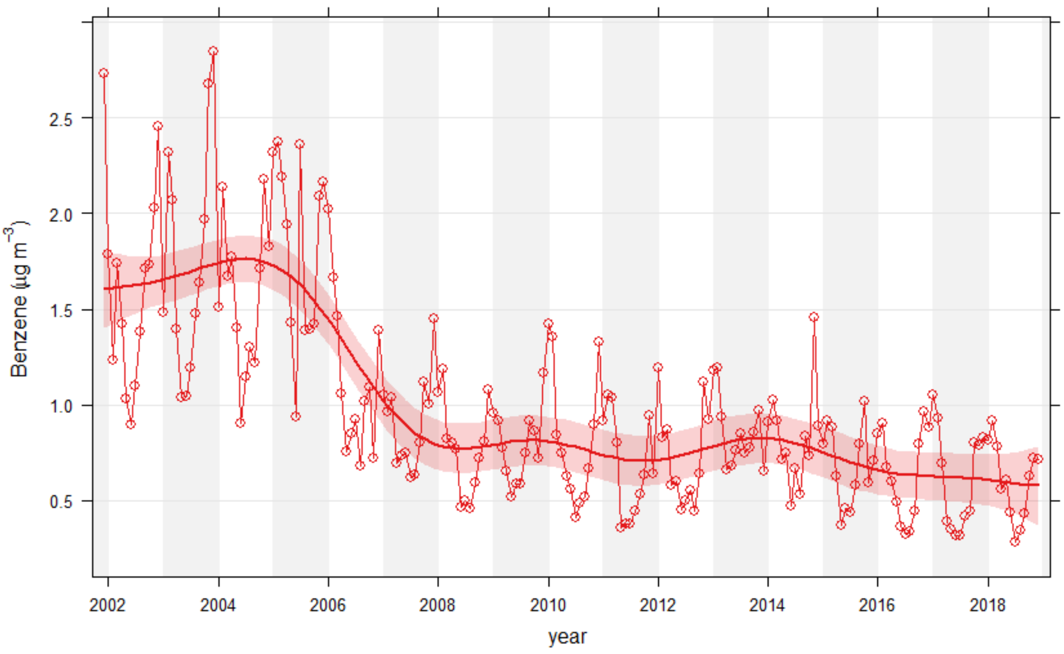
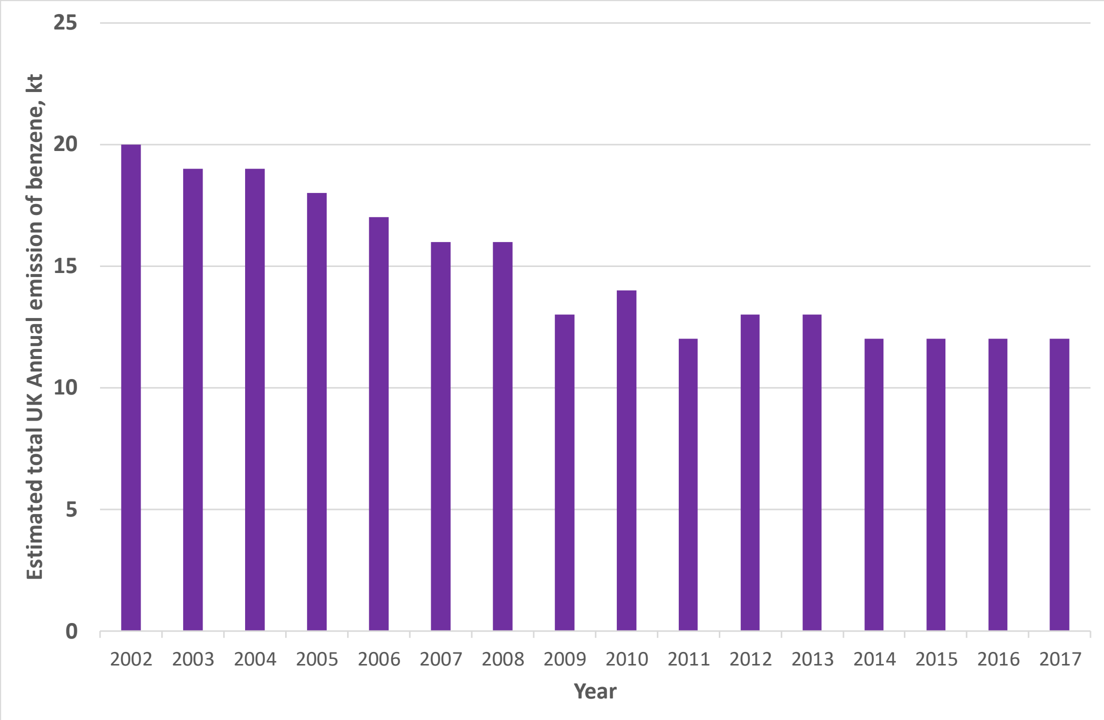


Figure 5-24 shows the estimated total annual UK emission of benzene (in kilotonnes). The data have been taken from the NAEI (which does not provide a bar chart for benzene). Like the ambient concentrations, the estimated annual emissions also appear to have decreased over the period shown – although more steadily than the average ambient concentration.

Figure 5-24 Estimated Annual UK Emissions of Benzene (kt), 2002 – 2017 (data from NAEI)



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 so modelled maps are not routinely produced for this pollutant. However, there is a UK Air Quality Strategy objective for 1,3-butadiene: 2.25 µg m^{-3}, as a maximum running annual mean. This objective was met throughout the UK by the due date of 31st December 2003.

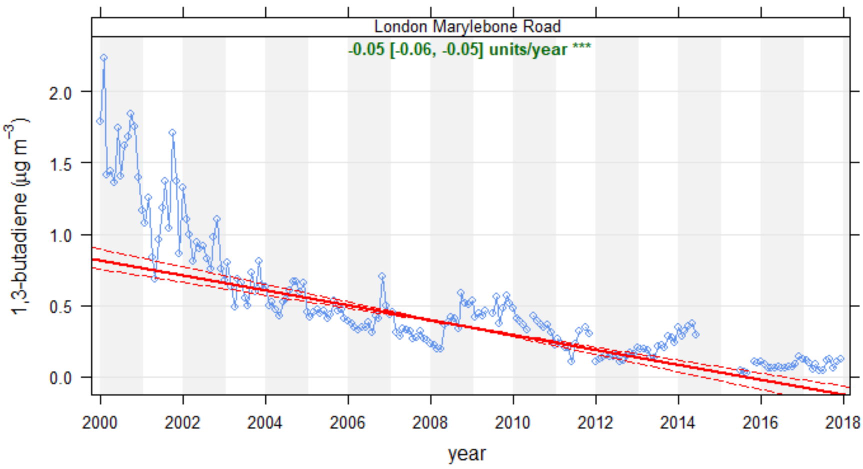
The Automatic Hydrocarbon Network monitors 1,3-butadiene at four sites: London Marylebone Road (urban traffic), London Eltham (urban background), Auchencorth Moss in Lothian (rural background), and Chilbolton Observatory in Hampshire (also rural background). Chilbolton Observatory replaced a previous rural site in Harwell (Oxfordshire) at the beginning of 2016. Measured concentrations of 1,3-butadiene at London Eltham and the two rural sites were well within the AQS objective in 2018. (The 2018 data from London Marylebone Road were rejected due to data quality issues, but this site too has been well within the AQS Objective in recent years.)

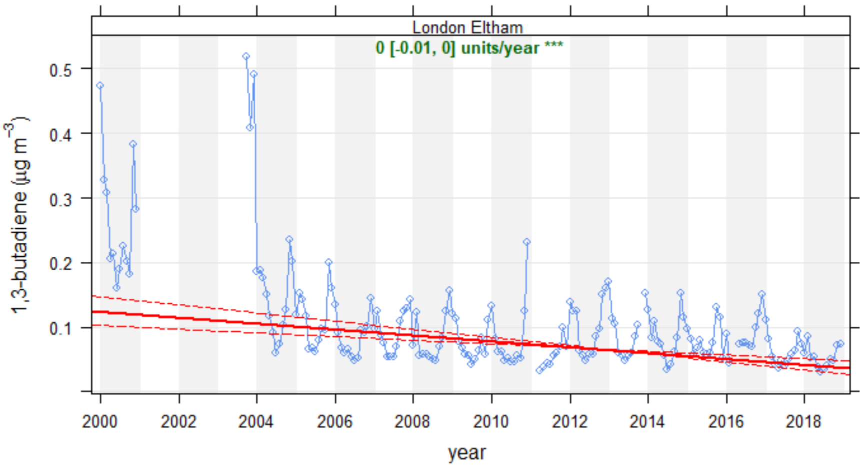
5.6.2 1,3-Butadiene: Changes Over Time

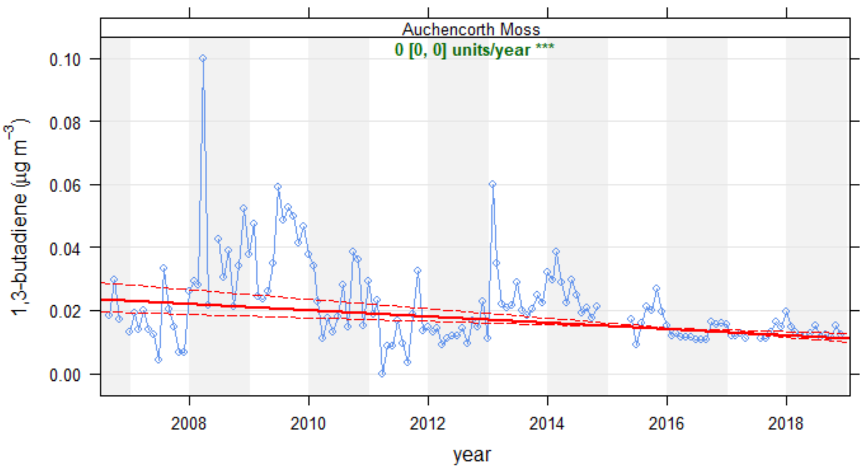
Figure 5-25 shows trends in ambient 1,3-butadiene concentration between 2000 and 2018 at the two London sites, and between 2000 and 2018 at

Auchencorth Moss. Chilbolton Observatory has not been in operation long enough for trends to be evaluated.

Figure 5-25 Trends in Urban 1,3-Butadiene Concentration, 2000-2018
(Note: the axes used for these three graphs are different).



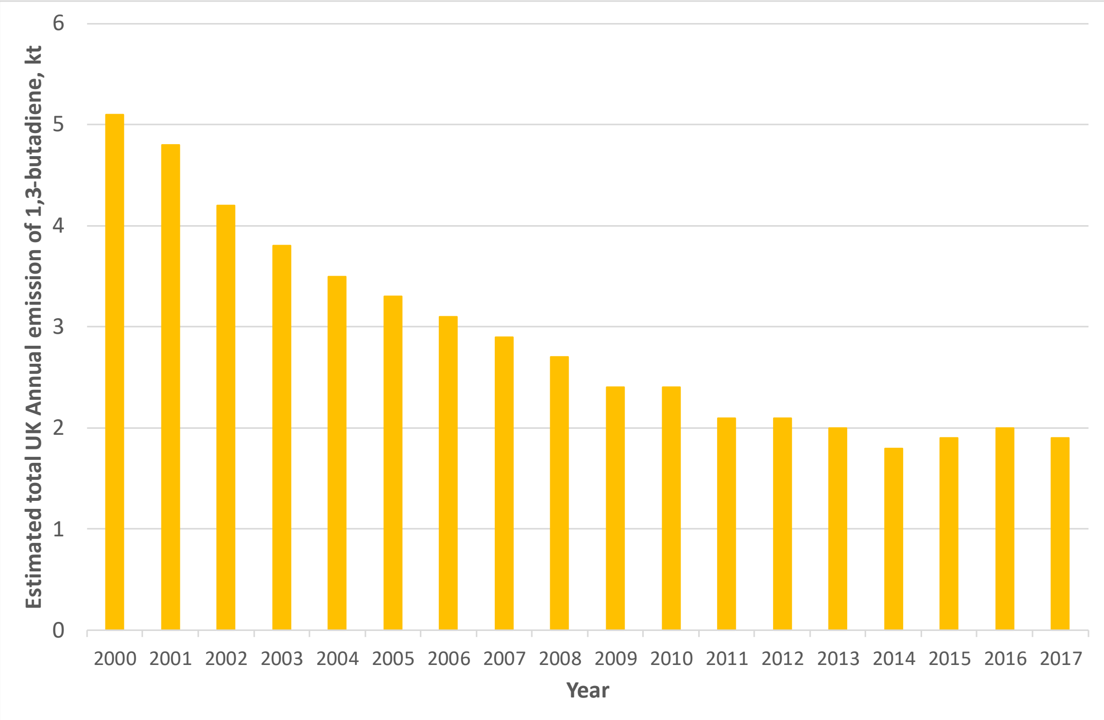




The three sites' data have been plotted on separate axes, because the magnitude of the measured 1,3-butadiene concentrations differs considerably between them. All three sites show a highly significant downward trend in concentrations of this pollutant; however, at London Eltham and Auchencorth Moss it is extremely small (less than 0.01 units per year in magnitude).

Figure 5-26 shows the total estimated UK annual emission of this compound, in kilotonnes. This appears to have decreased steadily since 2000, though flattening off after 2014. The main source of 1,3-butadiene is vehicle emissions, and the use of catalytic converters since the early 1990s has substantially reduced emissions from this source.

Figure 5-26 Estimated Annual UK Emissions of 1,3-Butadiene (kt), 2000 – 2017 (data from NAEI)



5.7 Carbon Monoxide

5.7.1 CO: Spatial Distribution

Ambient concentrations of CO throughout the UK have been well within the limit value for many years, Therefore, since 2010, maps of modelled concentration have no longer been routinely produced for CO.

5.7.2 CO: Changes over time

Because concentrations of CO are well within the limit value, relatively few monitoring sites are required. Seven urban AURN sites currently monitor this pollutant, of which six (Belfast Centre, Cardiff Centre, Edinburgh St Leonards, Leeds Centre, London Marylebone Road and London North Kensington) have operated for at least 10 years.

Figure 5-27 shows de-seasonalised trends at these six long-running AURN sites, from 1992 to 2018. All six show a highly significant downward trend over the period. **Figure 5-28** shows the estimated annual emissions of CO over the same period: a steady, almost linear year-on-year decrease to 2011 is followed by two years in which estimated emissions remained stable, before decreasing further. The decreasing ambient concentrations reflect declining emissions over the last 25 years. The NAEI attributes the decrease in CO emissions to factors including EU-wide emission standards for road vehicles, a decline in industrial use of solid fuels, and a decline in the production of steel and non-ferrous metals.[64]

Figure 5-27 De-seasonalised Trends in CO Concentration, 6 Long-Running AURN Sites 1992-2018, mg m^{-3}

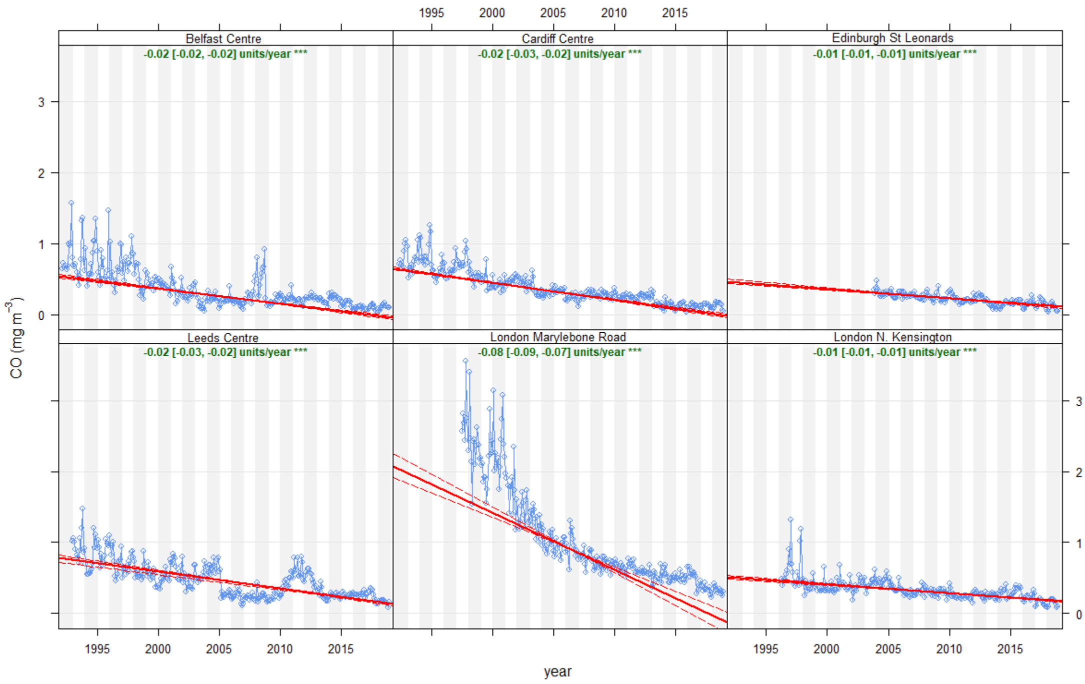
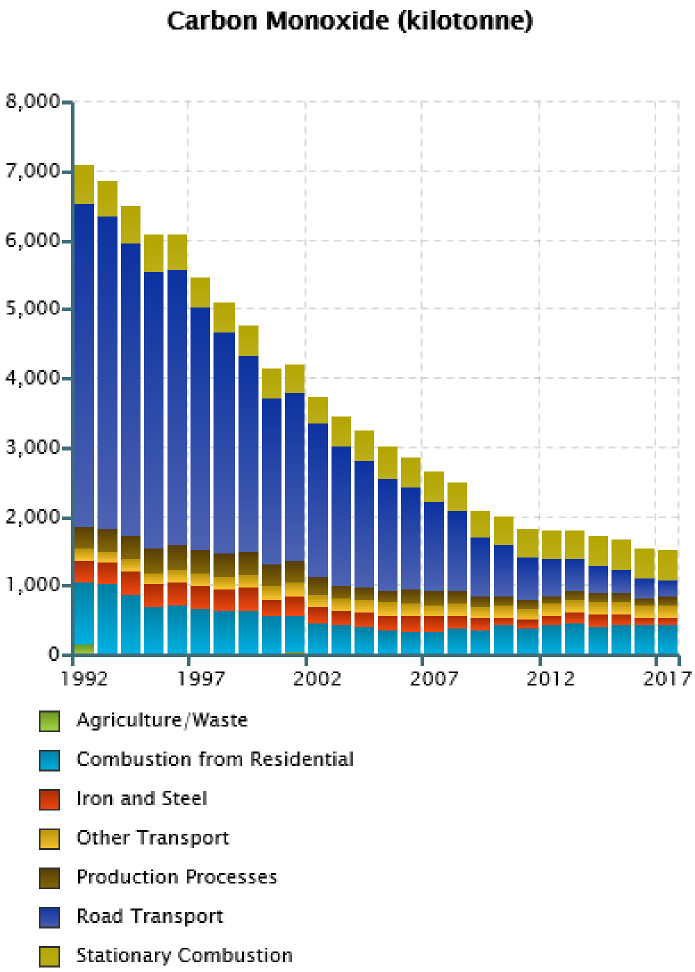


Figure 5-28 Estimated Annual UK Emissions of CO (kt), 1992 – 2017 Source: NAEI



5.8 Ozone

5.8.1 O_3: Spatial Distribution

Figure 5-29 shows the average number of days per year with ozone concentration > 120 µg m^{-3}, over the **three** years 2016-2018. The average number of days was highest (in the range 6-10 days) in southern and eastern England and mid-Wales, apart from urban areas. This is in contrast to the 2015-2017 map (featured in last year's report), where the average was less than six days throughout the UK. **Figure 5-30** shows the average number of days per year for 2018 only. The map illustrates the fact that ozone concentrations in 2018 were the highest the UK has experienced for some years. The south of England, East Anglia and the middle of Wales had 11-15 days with ozone concentrations above 120 µg m^{-3} in 2018. The rest of England and Wales, Northern Ireland and Scotland had 10 days or fewer with ozone above 120 µg m^{-3} in 2018.

Figure 5-31 shows the AOT40 statistic, averaged over the past **five** complete years, 2014-2018. 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. Highest average AOT40 values can be seen in parts of East Anglia. Within the UK generally, small lines of lower concentration can be seen following some major traffic routes. This is because vehicle emissions (nitric oxide and other pollutants) react with ozone and thereby remove it from the air.

Figure 5-32 shows the same statistic, for 2018 only. This clearly illustrates the relatively high ozone concentrations that occurred in the UK in 2018, and the main areas affected. Large parts of the south and east of England had AOT0 values in excess of 12,000: in one small area of central southern England, this statistic exceeded 15,000. Again, the paths of major roads are visible, running through areas of otherwise higher ozone concentration.

Figure 5-29 Average no. of days with O_3 Concentration > 120 µg m^{-3} 2016-2018

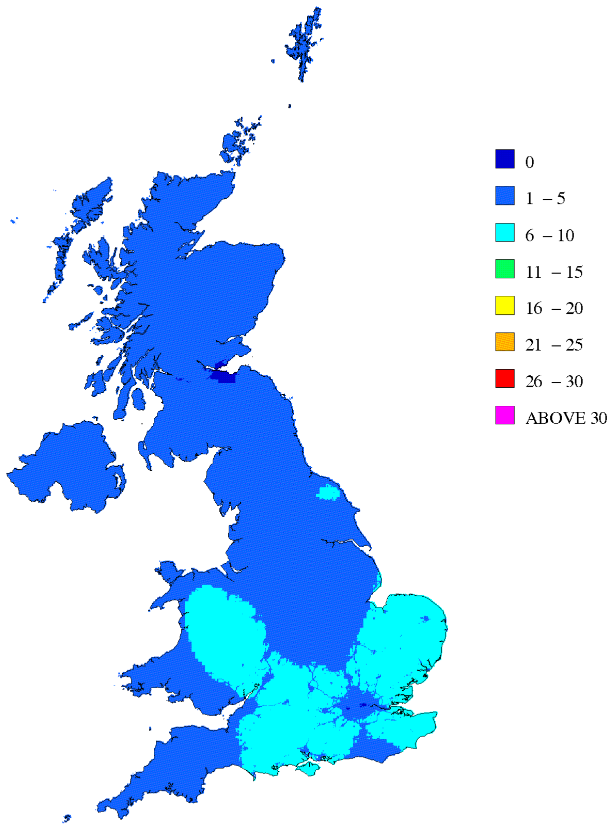


Figure 5-30 Days with O_3 Concentration > 120 µg m^{-3}, 2018

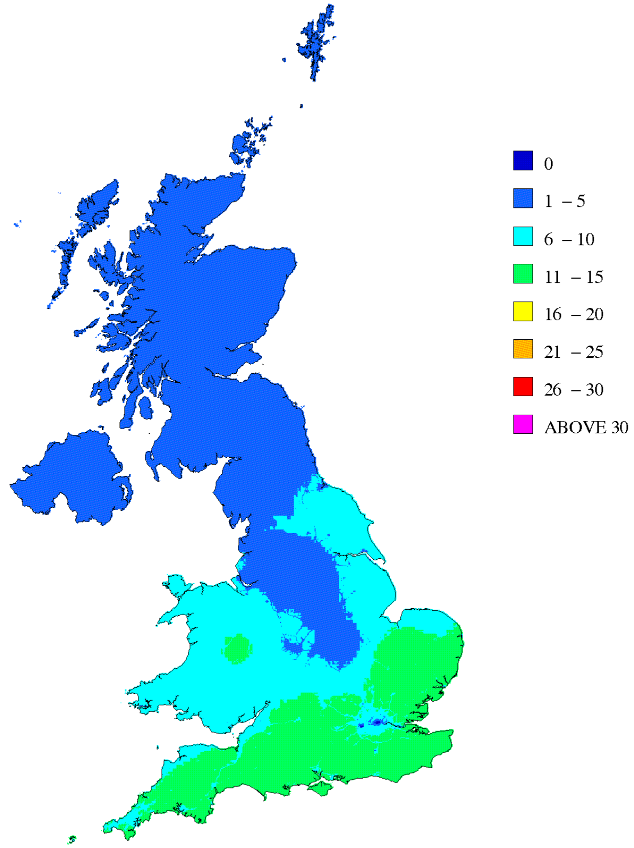


Figure 5-31 Average AOT40, 2014-2018 (µg m^{-3}.hours)

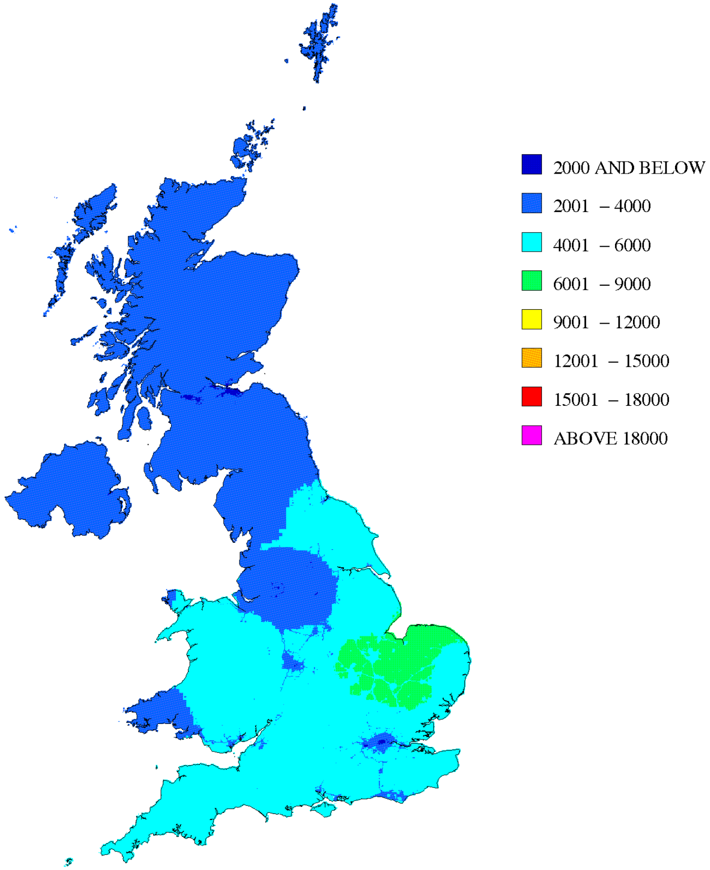
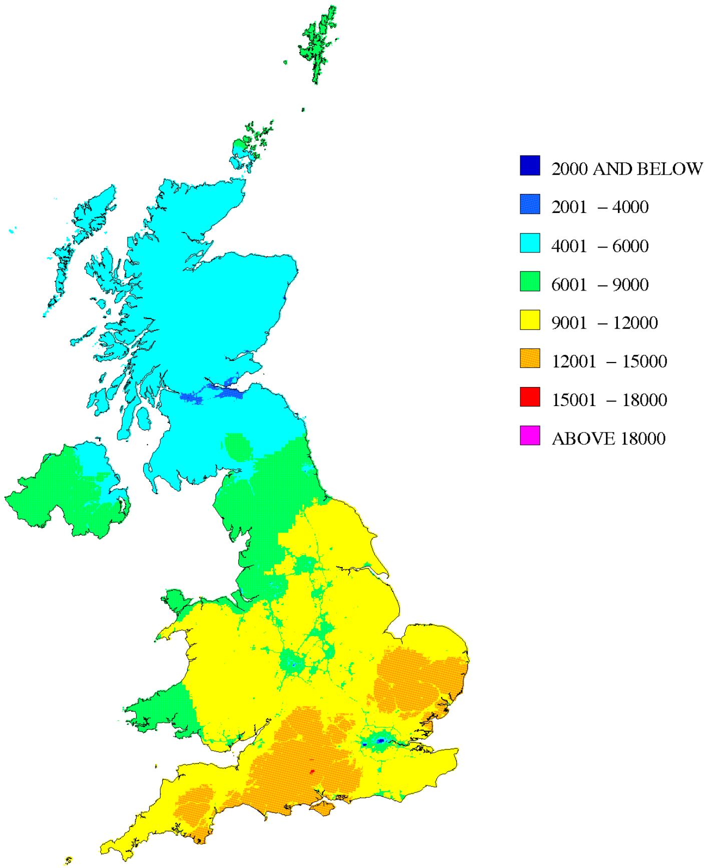


Figure 5-32 Average AOT40, 2018 (µg m^{-3}.hours)

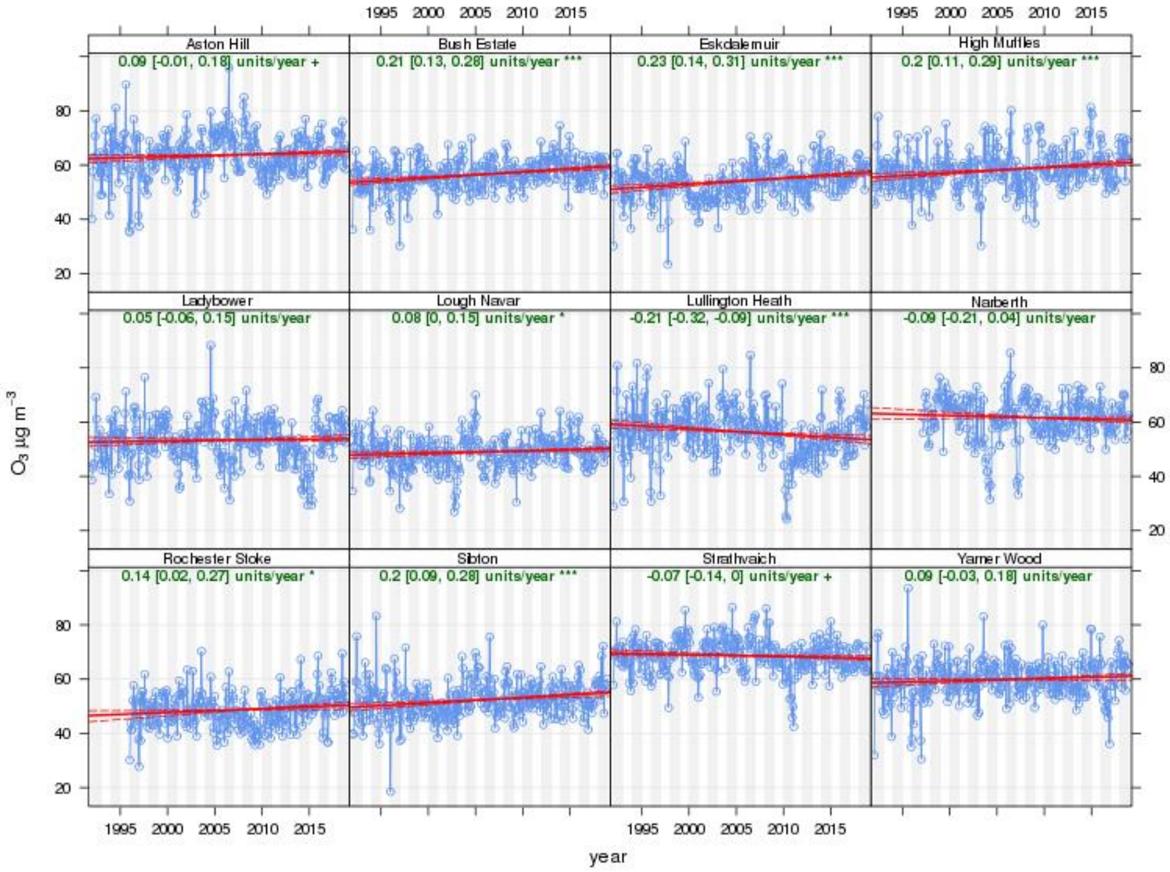


5.8.2 O_3: Changes Over Time

Figure 5-33 shows a trend plot of hourly mean ozone concentrations at 12 long-running rural AURN sites (Aston Hill, Bush Estate, Eskdalemuir, High Muffles, Ladybower, Lough Navar, Lullington Heath, Narberth, Rochester Stoke, Sibton, Strathvaich and Yarner Wood). Rural sites have been chosen because concentrations of ozone are typically highest in rural areas.

Four sites (Bush Estate, Eskdalemuir, High Muffles and Sibton) show highly significant positive trends over this period. Three (Aston Hill, Lough Navar and Rochester Stoke) show positive trends of lower significance. Three (Ladybower, Narberth and Yarner Wood) show no statistically significant trend, while one site (Lullington Heath) shows a highly statistically significant negative trend. While there is no consistent pattern, upward trends are present at half of these sites. There is evidence that the 'hemispheric background' ozone concentration has increased since the 1950s, and the observed trends may reflect this[65].

Figure 5-33 De-seasonalised Trends in Ozone Concentration at 12 Long-Running Rural AURN sites, 1992 - 2018.



Ozone is not emitted in significant quantities directly from any source in the UK (instead, it is formed from reactions involving other pollutants). Ozone is therefore not included in the NAEI, and trends in ozone emissions are not covered by this report.

5.9 Metallic Elements

5.9.1 Metallic Elements: Spatial Distribution

Figure 5-34, **Figure 5-35**, **Figure 5-36** and **Figure 5-37** show modelled annual mean concentrations of lead (Pb), arsenic (As), cadmium (Cd) and nickel (Ni) respectively in 2018. The spatial distribution patterns are discussed below.

Pb: background concentrations were less than 0.01 µg m^{-3} over most of the UK. (The map shows concentrations in microgrammes per cubic metre, as this is the unit used for the Air Quality Directive limit value.) There were some small areas (mostly industrial areas) where higher concentrations in the range 0.02 – 0.05 µg m^{-3} were modelled, but concentrations were well within the limit value of 0.5 µg m^{-3} throughout the UK.

As: this toxic element is a metalloid rather than a metal but is nevertheless measured by the Heavy Metals Network. Background concentrations were less than 6.0 ng m^{-3} over the whole UK, and less than 1.9 ng m^{-3} over most of the country. However, concentrations of 1.9 ng m^{-3} and above occurred in some areas – particularly the north-eastern part of England, Yorkshire and Humberside. This pattern reflects the natural sources of airborne arsenic, particularly wind-blown dust. Modelled concentrations were 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 0.3 ng m^{-3} over most of the UK. Some major road routes are visible: this is due to re-suspended road dust. Very few locations had modelled concentrations greater than 0.6 ng m^{-3}; these were associated with 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.) No locations exceeded the target value of 5 ng m^{-3}.

Ni: background concentrations of Ni were typically less than 3 ng m^{-3} (well away from urban areas, usually less than 1 ng m^{-3}). Like As and Cd, Ni is found in suspended road dust, so some major road routes are visible on the map. There are also some small areas with higher concentrations due to industrial activity, including the areas in Yorkshire and Humberside and South Wales where the modelled concentration exceeded the Ni target value of 20 ng m^{-3} in 2018.

Figure 5-34 Annual Mean Background Lead Concentration, 2018 (µg m^{-3})

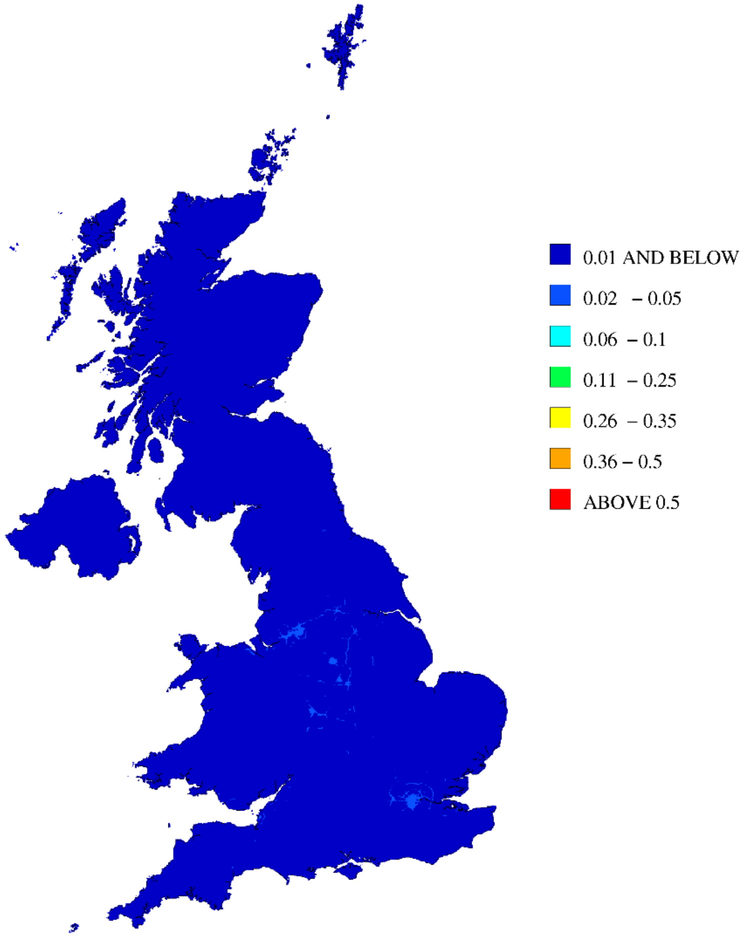


Figure 5-35 Annual Mean Background Arsenic Concentration, 2018 (ng m^{-3})

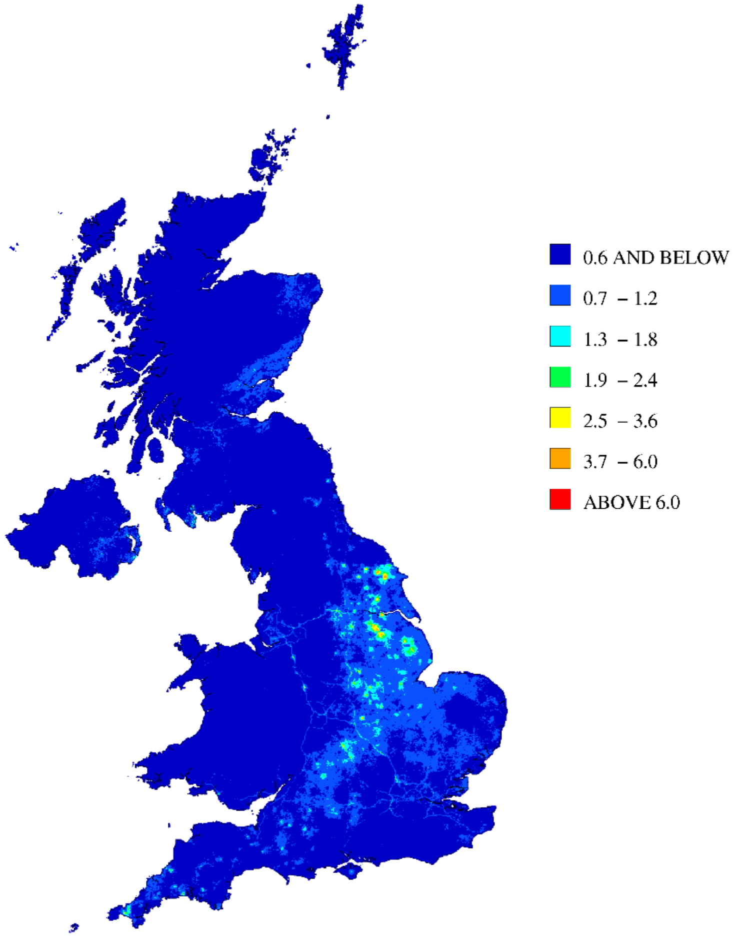


Figure 5-36 Annual Mean Background Cadmium Concentration, 2018 (ng m^{-3})

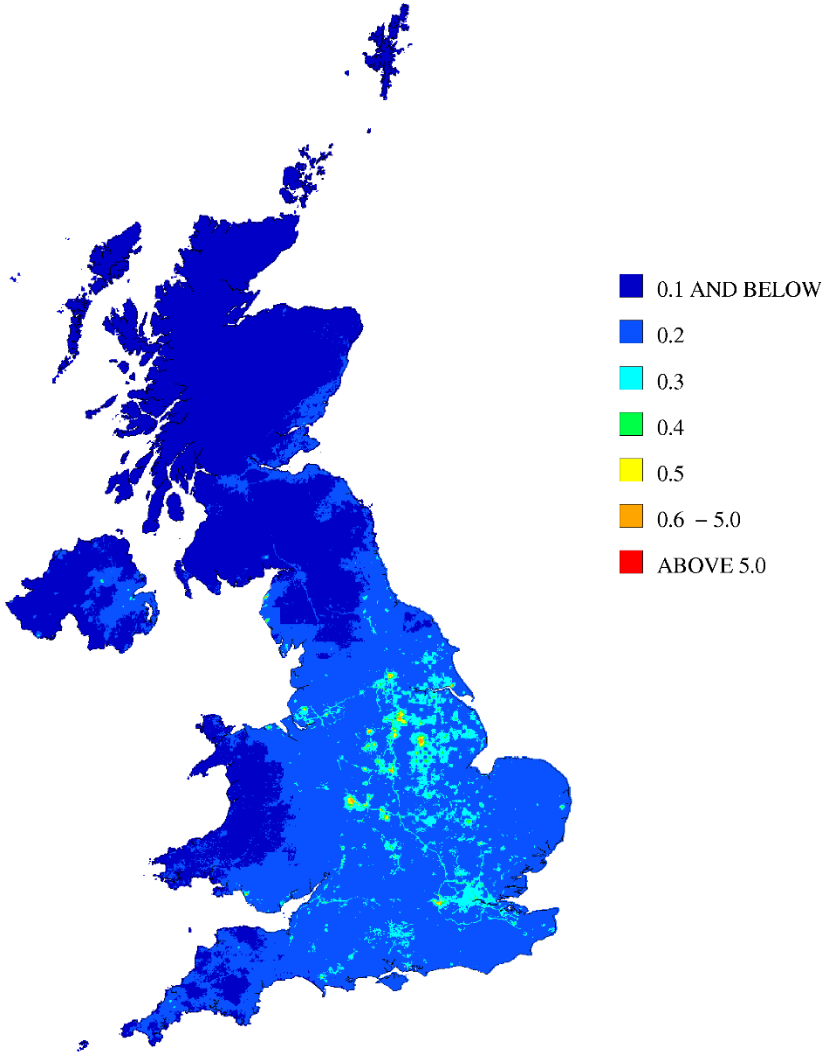
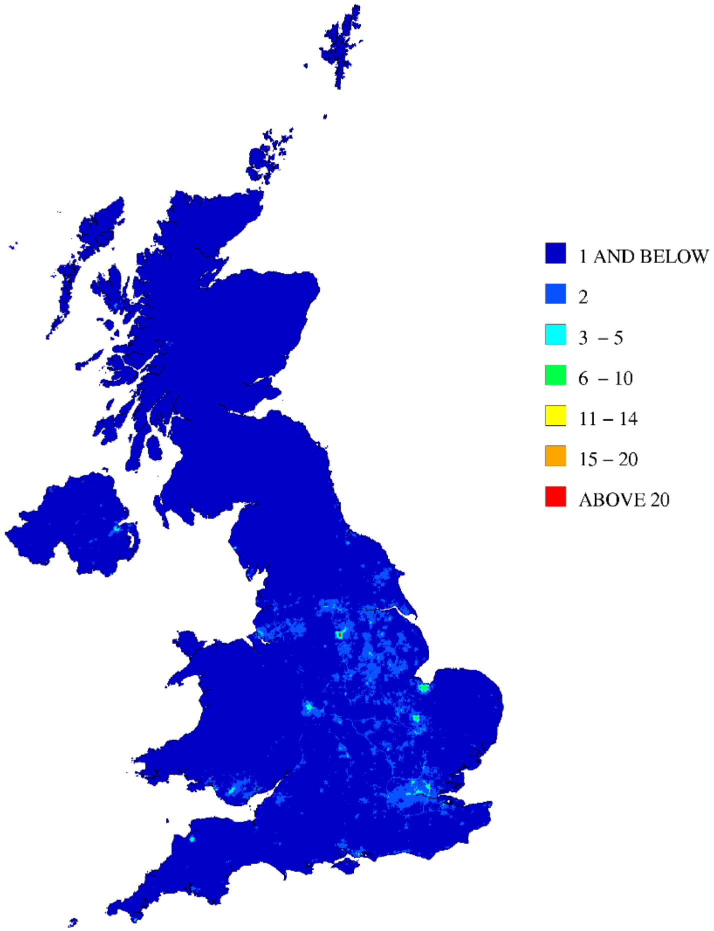


Figure 5-37 Annual Mean Background Nickel Concentration, 2018 (ng m^{-3})



5.9.2 Lead: Changes Over Time

The Heavy Metals Network monitoring stations are very diverse, ranging from remote rural sites to urban industrial locations. The range of measured ambient concentrations reflects this diversity: annual mean concentrations can be an order of magnitude higher at some sites than at others. Consequently, if using a network average concentration to show changes over time, caution is needed. If the arithmetic mean is used, this statistic can be dominated by the sites with highest concentrations. If one of these sites starts or ceases operation, or if its measured concentrations change substantially (e.g. due to changes in local industry), this may cause a discontinuity in the time series.

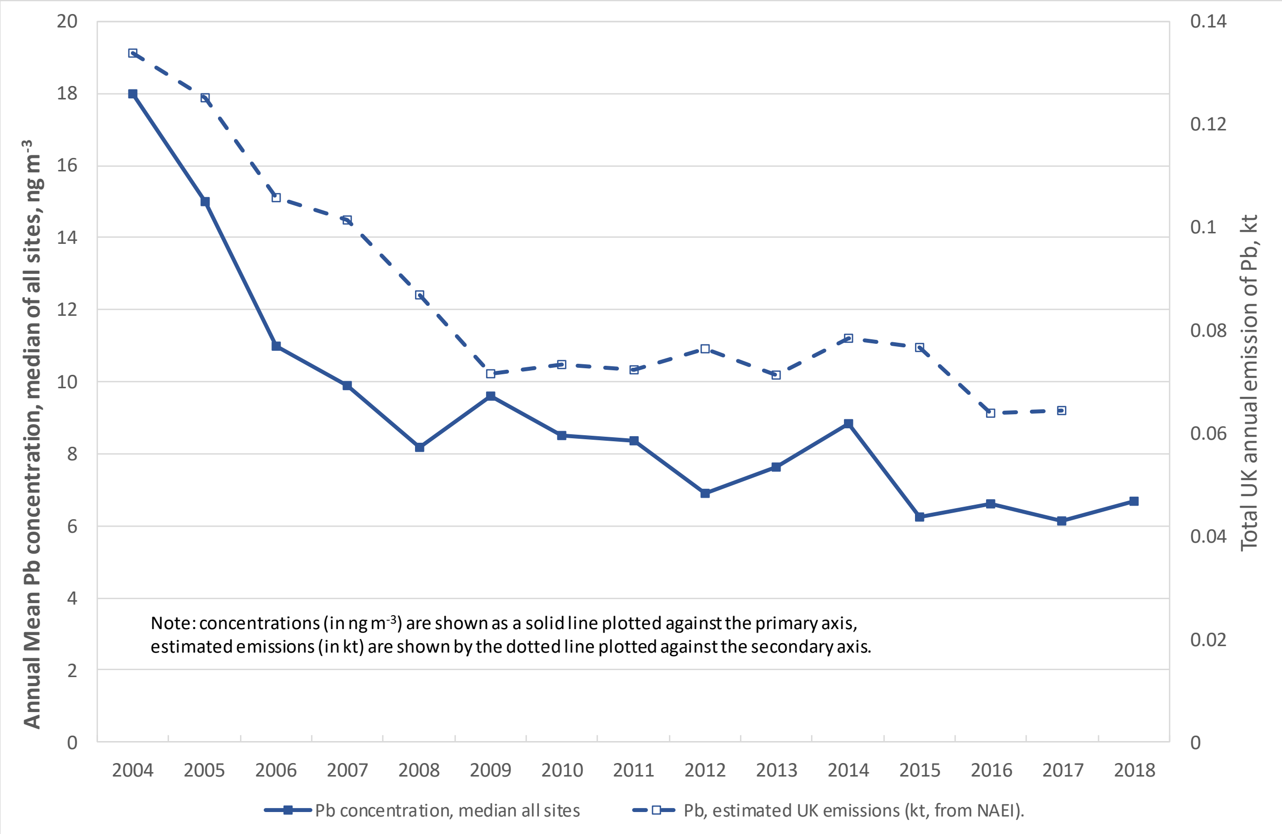
Therefore, the time series graphs for metals Pb, As, Cd and Ni show the *median* (50^{th} percentile), rather than the arithmetic mean, of the annual mean concentrations at all Heavy Metals Network sites. (This approach, used in '*Air Pollution in the UK*' reports for years 2017 onwards, is that used by the network operators, NPL, to investigate trends in ambient concentrations[66]. However, please note that '*Air Pollution in the UK*' reports for years up to and including 2016 used a different approach; the metals graphs showed the arithmetic mean but included urban sites only.)

Figure 5-38 shows a time series of the median annual mean concentration of Pb in the PM_{10} particulate fraction, as measured from 2004 by the UK Heavy Metals Network, as described in Section 3.3.2. (Prior to 2004, Pb in the particulate phase was measured by the six sites comprising the former Multi-Element Network. For further information on this, please see earlier reports in this series. However please note that the sampling method used by the Multi-Element Network is not directly comparable with current sampling methods as it was not size-selective).

The median of the annual mean concentrations from all sites in the Heavy Metals Network is shown, both urban and rural. (As highlighted above, this is a change from the 2016 and earlier reports in this series, which showed the arithmetic mean for urban sites only).

Figure 5-38 also shows NAEI estimated total annual UK emissions of this metal (plotted as a dotted line, against the right-hand y-axis). The largest sources of lead in the UK are production processes and other industrial combustion. In the case of Pb, measured ambient concentrations follow the same general pattern as the estimated total UK emissions.

Figure 5-38 Ambient Concentrations of Pb in PM_{10}, and Total Estimated UK Emissions



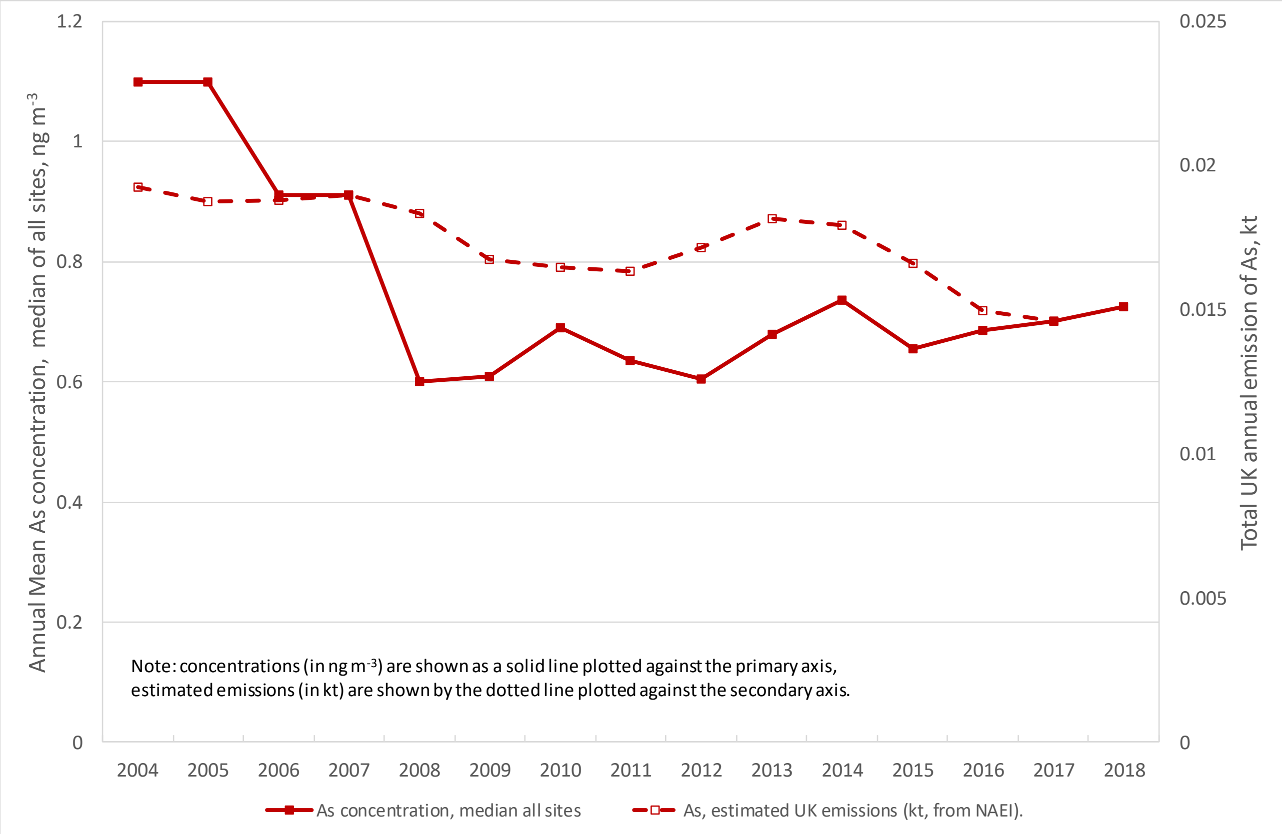
5.9.3 Arsenic: Changes Over Time

Figure 5-39 shows a time series of ambient concentration of arsenic (As) in the PM_{10} fraction, expressed as the median annual mean of all sites in UK Heavy Metals Network, as described in Section 3.3.2. (For pre-2004 non-size selective measurements from the Multi-Element Network, please see earlier reports in this series.)

The average used is the median of all sites' annual means, rather than the arithmetic mean, to avoid confounding effects due to changes at sites where concentrations are particularly high. All sites, both urban and rural have been included. This time series is represented by the solid line.

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 largest human-made sources of As are production processes, waste (particularly the open burning of treated wood), and metal (iron and steel) production processes. Trends in measured ambient As concentrations do not appear to follow estimated total emissions. The reasons for this have not been investigated but it may be that the results from the monitoring sites reflect local rather than national trends. Furthermore – as mentioned in section 5.8.1 above – wind-blown dust is a major natural source of airborne arsenic in some areas.

Figure 5-39 Ambient Concentrations of As in PM_{10}, and Total Estimated UK Emissions



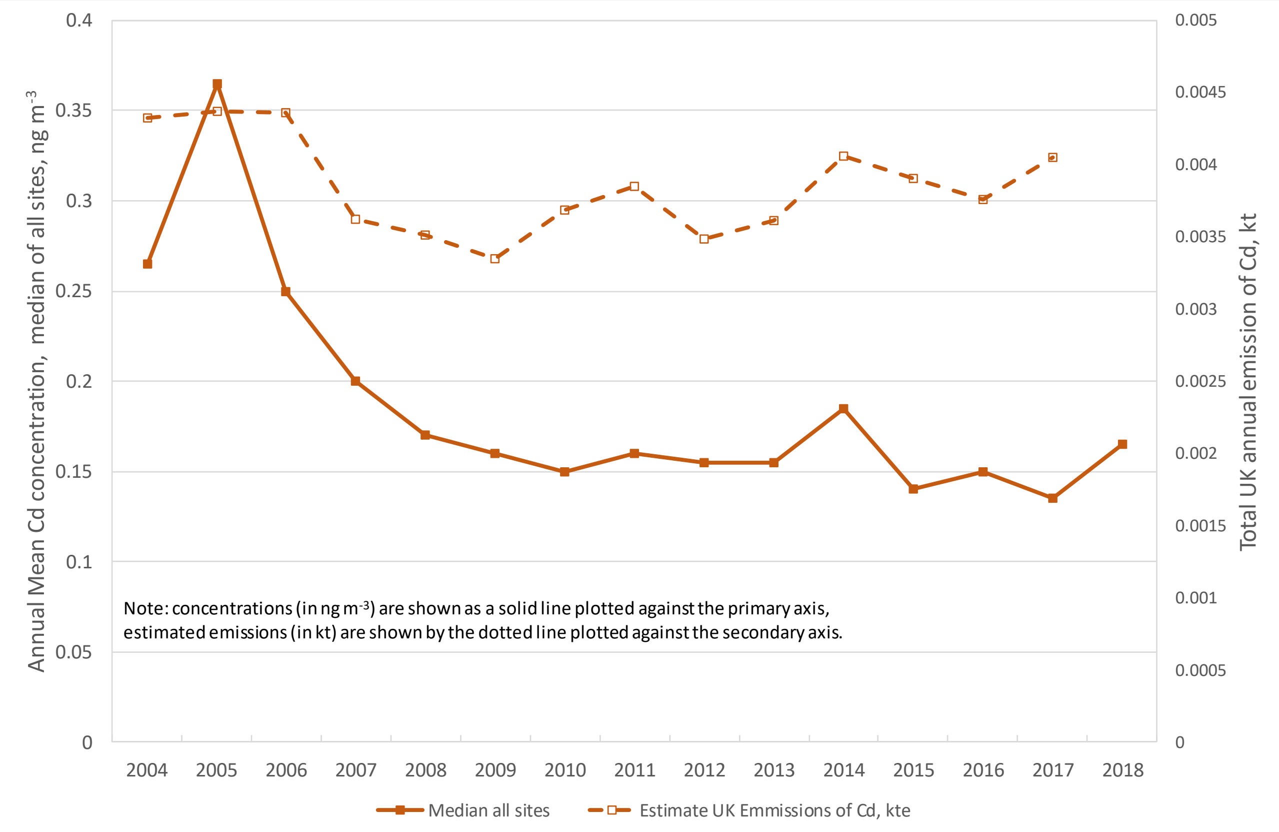
5.9.4 Cadmium: Changes Over Time

Figure 5-40 shows a time series of ambient concentration of cadmium (Cd) in the PM_{10} fraction as measured by the UK Heavy Metals Network, described in Section 3.3.2. (For pre-2004 non-size selective measurements from the Multi-Element Network, please see earlier reports in this series.)

The median has been used, rather than the arithmetic mean, for the reasons outlined in section 5.9.2 above. All sites – both urban and rural – have been included; there were 24 sites in operation during 2018.

Also shown (plotted as a dotted line, against the right-hand y-axis) is the UK's estimated total annual emission of Cd (in kilotonnes), from the NAEI. The main human-made sources of Cd are combustion in manufacturing industry, metal production and transport (road dust). While there are some similarities, in general the trend in average ambient Cd concentration does not follow changes in estimated UK emissions.

Figure 5-40 Ambient Concentrations of Cd in PM_{10}, and Total Estimated UK Emissions

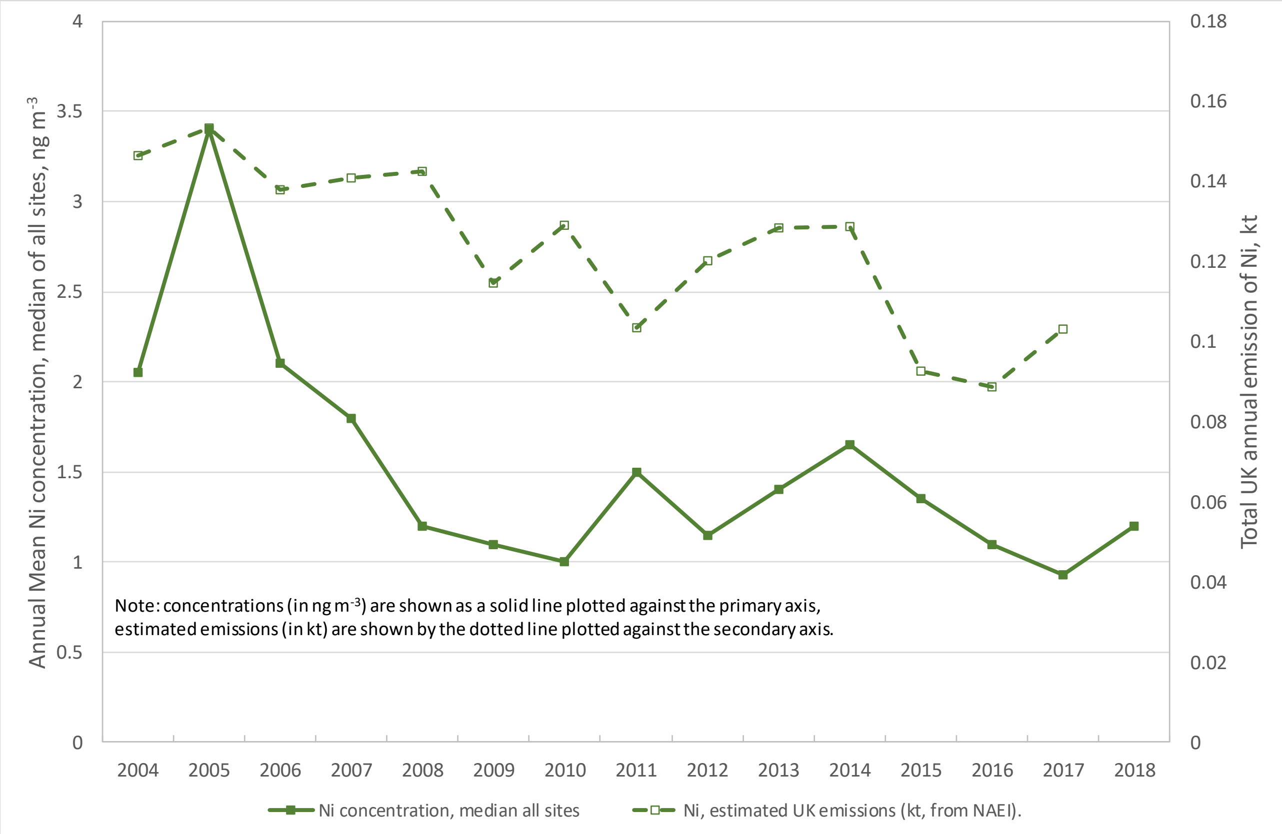


5.9.5 Nickel: Changes Over Time

Figure 5-41 shows a time series of median annual mean concentrations of nickel (Ni) in PM_{10}, as measured by all sites in the UK Heavy Metals Network. As with the other metals, information on non-size selective measurements from the older Multi-Element Network can be found in earlier reports in this series.

The graph shows the median, rather than the arithmetic mean, of annual mean concentrations at all sites. This avoids confounding effects due to a small number of sites which measure ambient Ni concentrations very much higher than the others. **Figure 5-41** also shows total estimated annual UK emissions of Ni, from the NAEI (as a dotted line, plotted against the right-hand axis). Stationary combustion is the major source. The NAEI data appear to show a general decrease in Ni emissions over the period shown; ambient concentrations also show a general (though not consistent) decrease over the same period.

Figure 5-41 Ambient Concentrations of Ni in PM_{10}, and Total Estimated UK Emissions



5.9.6 Mercury: Changes Over Time

At the end of 2013, the Heavy Metals Network ceased measuring mercury (Hg) in PM_{10}. This decision was taken because the majority of ambient Hg is in the vapour phase. Monitoring of Total Gaseous Mercury (TGM) was also scaled down to two sites: Runcorn Weston Point (an urban industrial site which measured ambient Hg concentrations an order of magnitude greater than any other sites in the network), and London Westminster (an urban background site in central London). Measurement of vapour-phase Hg, using the Tekran instrument, (see Section 3.3.12) also continued at two rural sites: Auchencorth Moss in Lothian, and Harwell in Oxfordshire, until the latter site closed at the end of 2015 and was replaced by Chilbolton Observatory. These four sites comprised two urban locations where TGM was likely to be highest, and two rural background sites, for the purpose of understanding transboundary contribution to ambient Hg concentration.

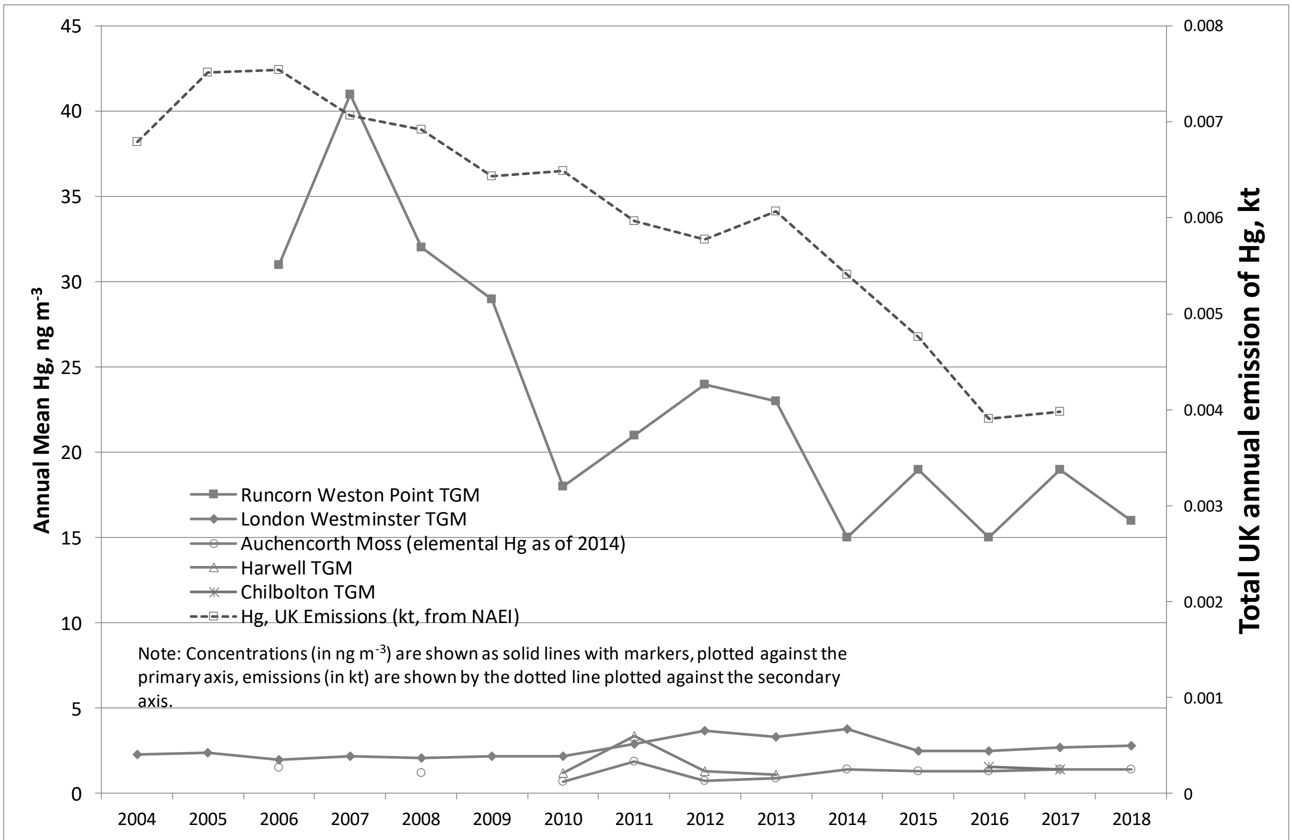
For information on the measurements of total mercury (TGM plus particulate phase) taken at urban sites in the UK Heavy Metals Network and its predecessors from 2004 to 2013, please refer to "*Air Pollution in the UK 2014*" and earlier reports in this series.

The present report focuses only on TGM, and on the four sites which have continued monitoring this element into 2018: Auchencorth Moss, Chilbolton Observatory, London Westminster and Runcorn Weston Point. However, measurement of TGM at both urban sites ceased in August 2018, leaving just the two rural sites measuring this pollutant.

Figure 5-42 shows annual mean concentrations of TGM from 2004 (when the UK Heavy Metals Network began operation) to 2018. (Harwell is included for continuity). Please note that because Runcorn Weston Point and London Westminster only operated for part of 2018, they only achieved annual data captures for TGM of 57% and 62% respectively. Therefore, the 2018 annual means should be treated with caution. (There is no valid annual mean for Chilbolton Observatory). The graph clearly shows that the measured annual mean concentrations of Hg at Runcorn Weston Point are an order of magnitude higher than those measured at the rural sites. However, Hg concentrations at this industrial site appear to have decreased over the past 10 years (though not consistently or steadily). Mercury concentrations at London Westminster do not appear to have decreased. Nor do the rural sites show any consistent pattern of increase or decrease. Annual mean Hg concentrations at Chilbolton Observatory in 2016 and 2017 are consistent with those measured at Auchencorth Moss, and at Harwell in previous years.

The graph also shows estimated annual UK emissions of Hg (data from the NAEI), as a dotted line plotted against the right-hand y-axis. The main emission sources of Hg in 2017 are coal use in electricity generation and industrial combustion, iron and steel production processes, cremation, and emissions from the disposal of products containing mercury.

Figure 5-42 Measured Concentrations of Total Gaseous Hg, and Total Estimated UK Emissions



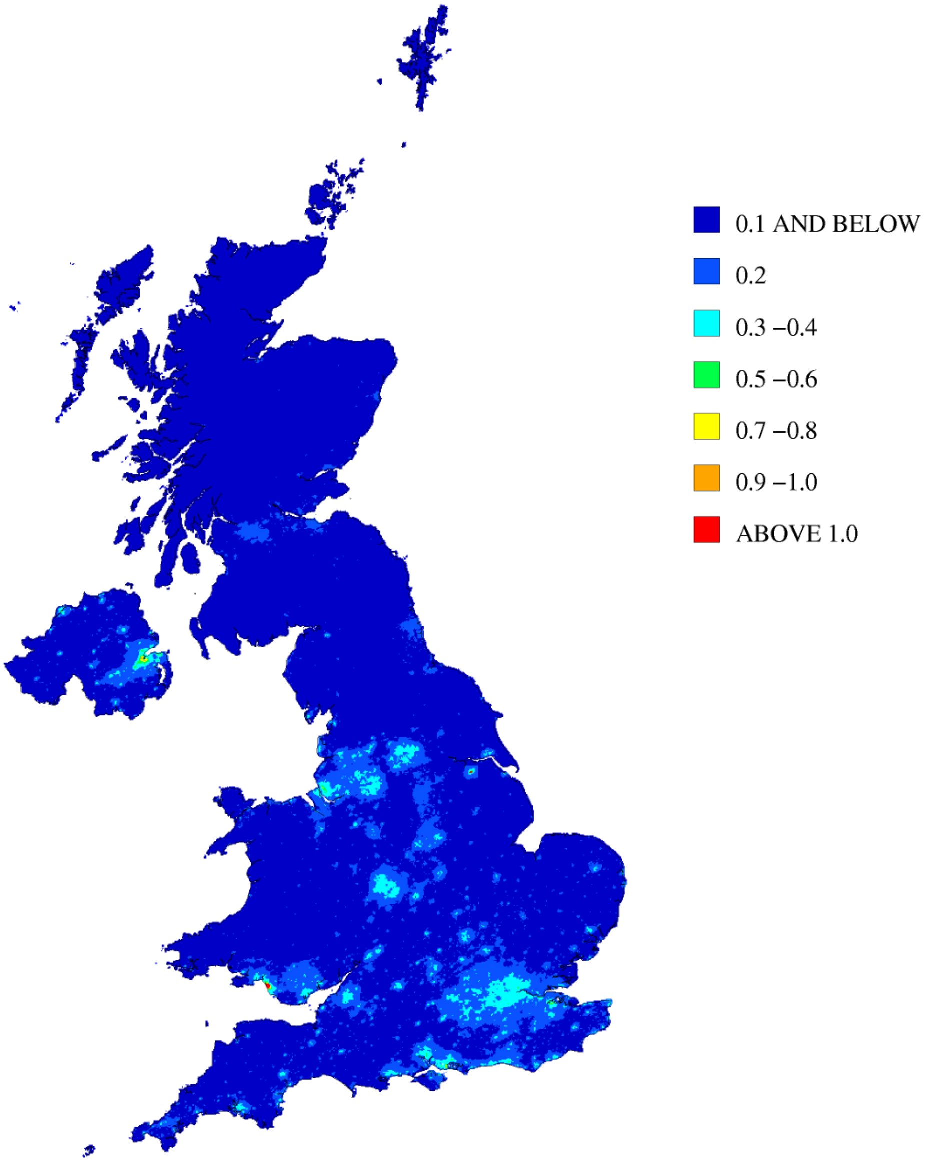
5.10 Benzo[a]pyrene

5.10.1 B[a]P: Spatial Distribution

Figure 5-43 shows the modelled annual mean background concentration of benzo[a]pyrene (B[a]P). The areas of highest concentration reflect the distribution of industrial sources, and areas where there is widespread domestic use of oil and solid fuels for heating. This has historically included the Belfast area and other urban parts of Northern Ireland: also, parts of Yorkshire, Humberside and South Wales.

The only reporting zones with modelled annual mean B[a]P concentrations in excess of 1 ng m^{-3} in 2018 were Yorkshire and Humberside, Swansea and South Wales.

Figure 5-43 Annual mean background B[a]P concentration, 2018 (ng m^{-3})

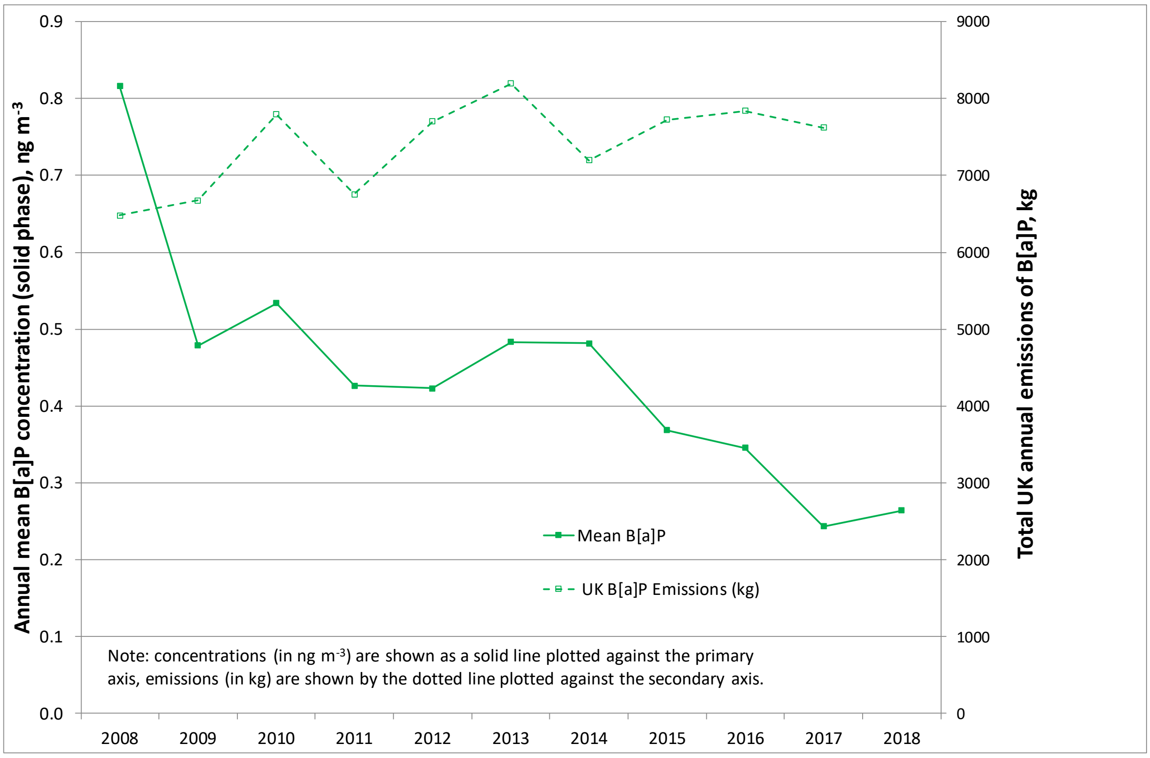


5.10.2 B[a]P: Changes Over Time

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) was 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[67].

Because of these changes in the composition of the network, and in particular the techniques used, temporal variation in PAH concentrations has only been analysed from 2008 in this report. **Figure 5-44** shows how the average annual mean B[a]P concentration has changed in the years since 2008. This graph is based on the average of all sites in the PAH Network: the composition of this network has changed little since 2008 so it is considered appropriate here to use the average of all sites. Following a marked drop in average measured concentrations of B[a]P between 2008 and 2009, average B[a]P concentrations then appear to have remained generally stable until 2014. Further decreases occurred in years 2015 to 2017, though there has been an upturn in 2018. **Figure 5-44** also shows the estimated total annual UK emission of B[a]P (in kg), from the NAEI (shown as a dotted line and plotted against the y-axis on the right). This indicates that emissions have slightly increased since 2008. Emissions of B[a]P at the present time are dominated by domestic combustion of coal, and the NAEI data indicate that it is this source (described as “residential/commercial/institutional”) that is increasing.

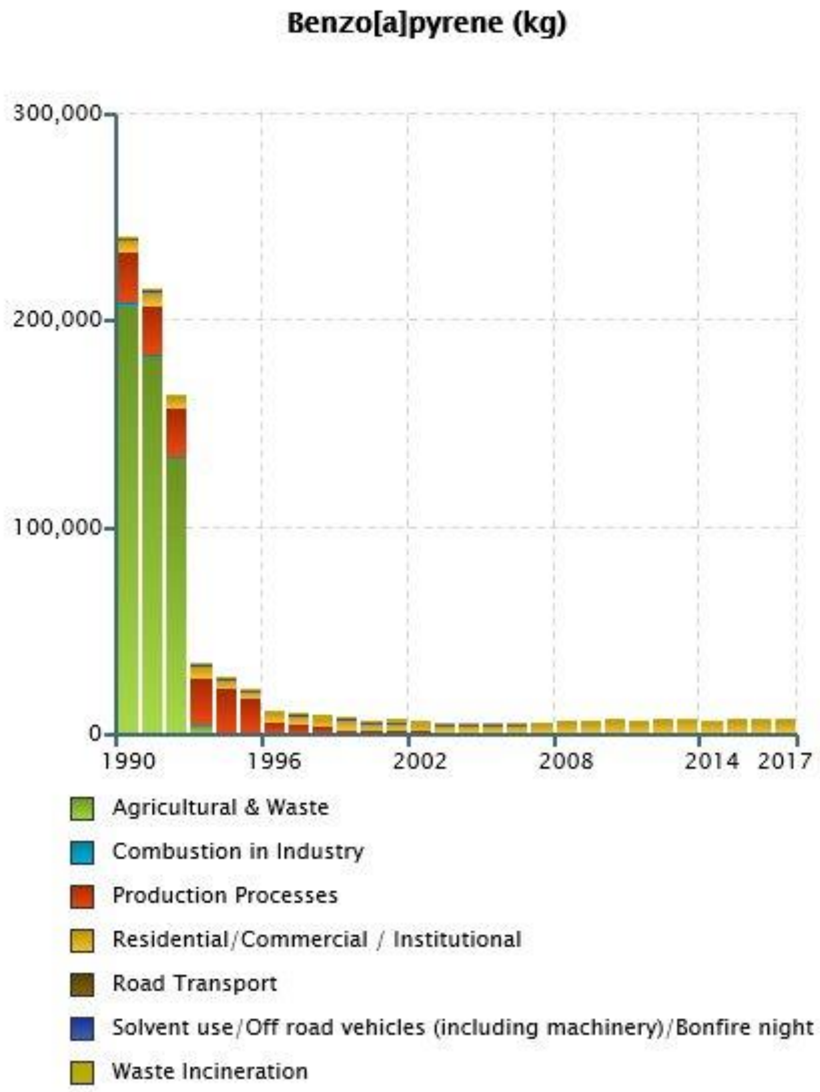
Figure 5-44 Ambient Concentrations of Particulate Phase B[a]P and Total Estimated UK Emissions



However, to put this into context, estimated total UK emissions of B[a]P have decreased substantially in recent decades and are orders of magnitude lower than in the early 1990s (**Figure 5-45**). According to the NAEI, most of this reduction is due to decreasing emissions from industry, and the banning of stubble burning in 1993.

The NAEI's estimated B[a]P emissions for years 1990 (the earliest year for which emissions of this pollutant are estimated) to 1992 underwent a substantial increase in 2017 (as noted in the 2017 report in this series). This is because the emission factors used by the NAEI for the agriculture and waste sector were revised. The new emission factors, particularly for stubble burning, resulted in the estimated total UK emission of B[a]P for years 1990 - 1992 increasing by a factor of four[68].

Figure 5-45 Estimated Annual UK Emissions of Benzo[a]pyrene (kg), 1990 – 2017 Source: NAEI



6 Pollution Events in 2018

6.1 Particulate Pollution Episodes

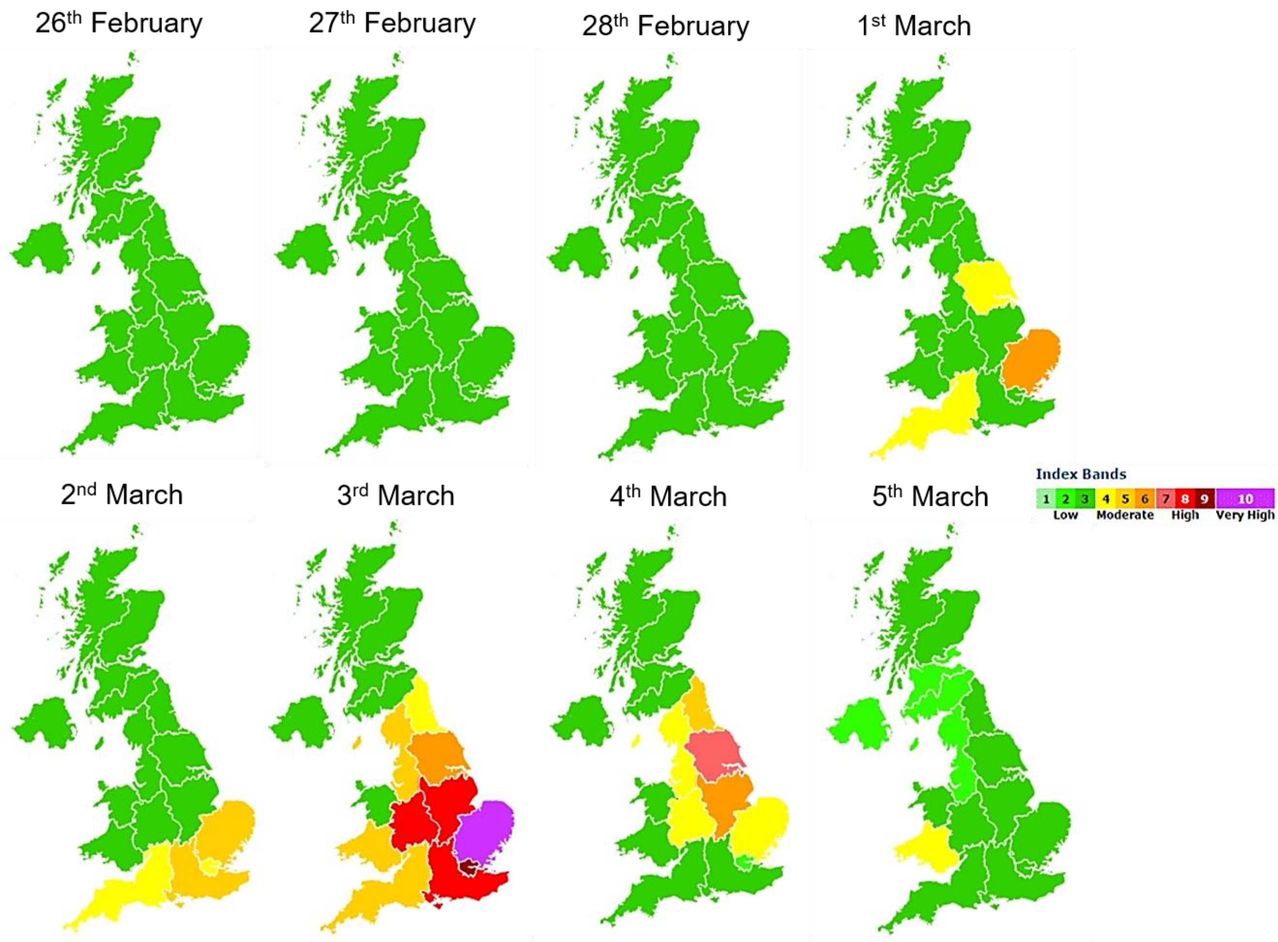
In 2018, there were three particularly significant periods of elevated particulate pollution recorded by the Automatic Urban and Rural Monitoring Network (AURN) at monitoring stations across the UK. These had different causes: the first of these episodes occurred at the end of February, running into March, and was associated with a period of extreme cold weather. The second was localised, resulting from moorland fires in the North West of England. The third, in November, was associated with Bonfire Night.

6.1.1 Particulate Pollution Episode 26th February – 4th March 2018 (associated with the "*Beast from the East*" weather event)

Between 26th February and 4th March, the UK experienced extremely cold weather, ice and snow due to northerly and easterly winds referred to by the media as "*the Beast from the East*".[69] The period 28th February to 1st March was particularly affected. Severe travel disruption was the likely cause of the measured decrease in oxides of nitrogen (NO_X); these trends were particularly obvious at urban traffic monitoring sites. In contrast, particulate matter (PM_{10} and $PM_{2.5}$) concentrations increased during this period of cold weather, especially over the weekend of 3rd – 4th March. The pollution episode most severely affected London, the South East of England, and the Midlands. It also extended through the rest of England and South Wales. A westerly wind brought in cleaner air overnight on 3rd March, culminating in the end of this episode on Monday 4th March.

The maps in **Figure 6-1** are based on the Daily Air Quality Index (DAQI) which has been designed to inform the public about levels of air pollution and provides recommended actions and health advice. The index is numbered 1-10 and divided into four bands, 'Low' (1-3), 'Moderate' (4-6), 'High' (7-9) and 'Very High' (10), to provide detail about air pollution levels in a simple way[70]. On the 3rd March, the Eastern zone reached the 'Very High' Daily Air Quality Index band. The South East, West Midlands and East Midlands all reached the 'High' banding on the same day.

Figure 6-1 Maps Showing DAQI, 26th February to 5th March 2018 (Source: UK-AIR)



Using the HYSPLIT transport and dispersion model on the NOAA Air Resources Laboratory (ARL) website[71], it is possible to model the paths taken by air masses arriving over the UK; these are known as 'back trajectories'.

Figure 6-2 shows 24-hour back trajectories for (A) 26th February, (B) 1st March and (C) 4th March. The back trajectories show a slow-moving north-easterly air flow transporting already-polluted air from Belgium, Germany and the Netherlands, which mixed with UK emissions to contribute to the start of this pollution episode. On the 1st March, the strong easterly winds of the "*Beast from the East*" can be seen tracking all the way across from the eastern parts of continental Europe. By 4th March, the clean westerly wind arrived and ended the pollution episode.

London Air reported increased levels of sulphate particles from coal burning, as well as contributions from traffic and wood burning during this particle pollution episode.[72] There were additional contributions from local wood burning and associated secondary particles.

Figure 6-2 Back Trajectories (24-hr) Showing Air Masses Arriving in London on (A) 26th February, (B) 1st March and (C) 4th March 2018 (Source: HYSPLIT trajectory model[73,74] NOAA website[71]) *The authors gratefully acknowledge the NOAA Air Resources Laboratory (ARL) for the provision of the HYSPLIT transport and dispersion model and READY website (http://www.ready.noaa.gov) used to prepare this figure.*

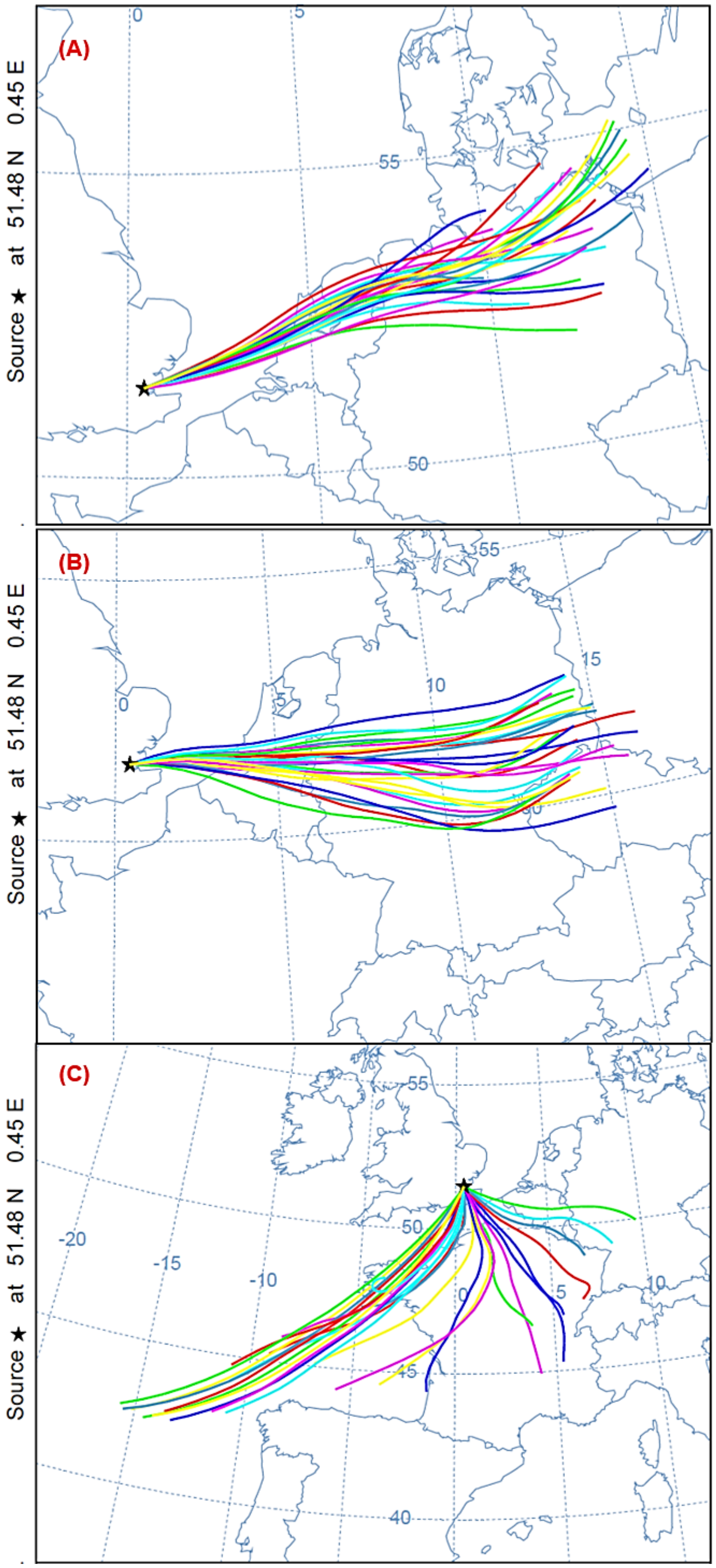


Figure 6-3 and **Figure 6-4** show daily mean PM_{10} and $PM_{2.5}$ concentrations, respectively, for the period affected by the pollution episode. The DAQI thresholds for the 'Moderate', 'High' and 'Very High' bands are also shown. Both particulate concentrations peaked on 3rd March, however, only the $PM_{2.5}$ concentrations reached the 'Very High' band.

Figure 6-3 Average Daily Mean PM_{10} Concentrations, Monitoring Sites in South East, East and Greater London, 26th February – 5th March 2018

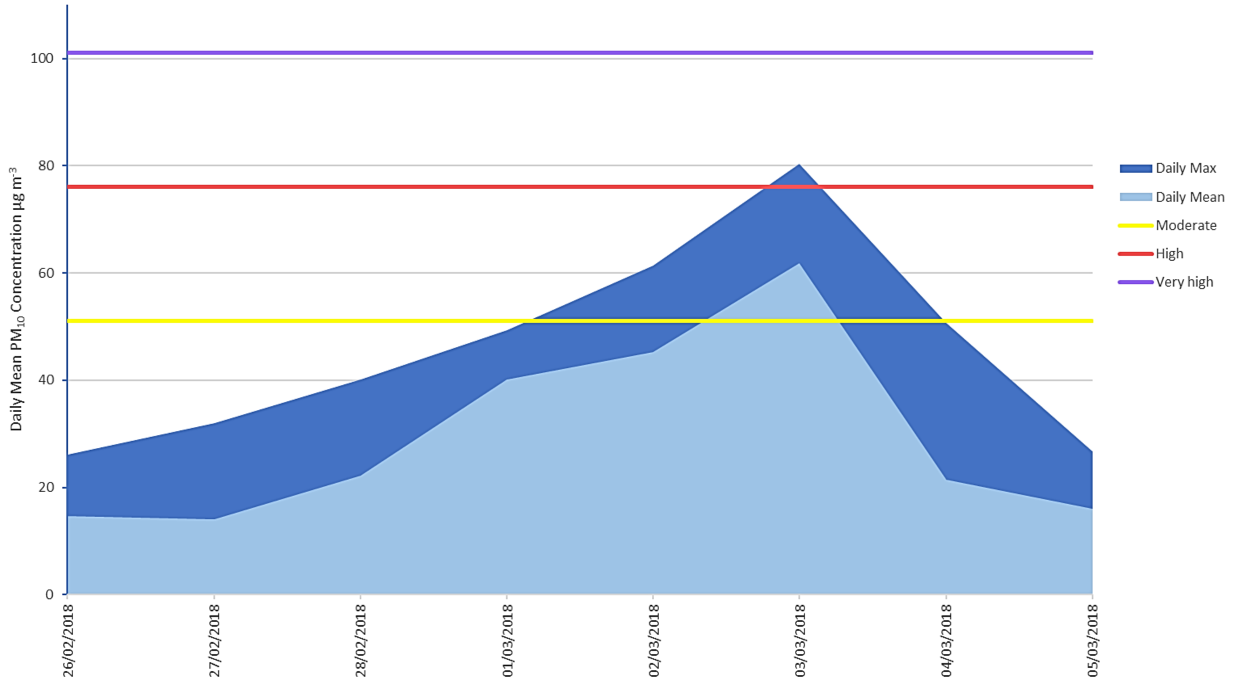
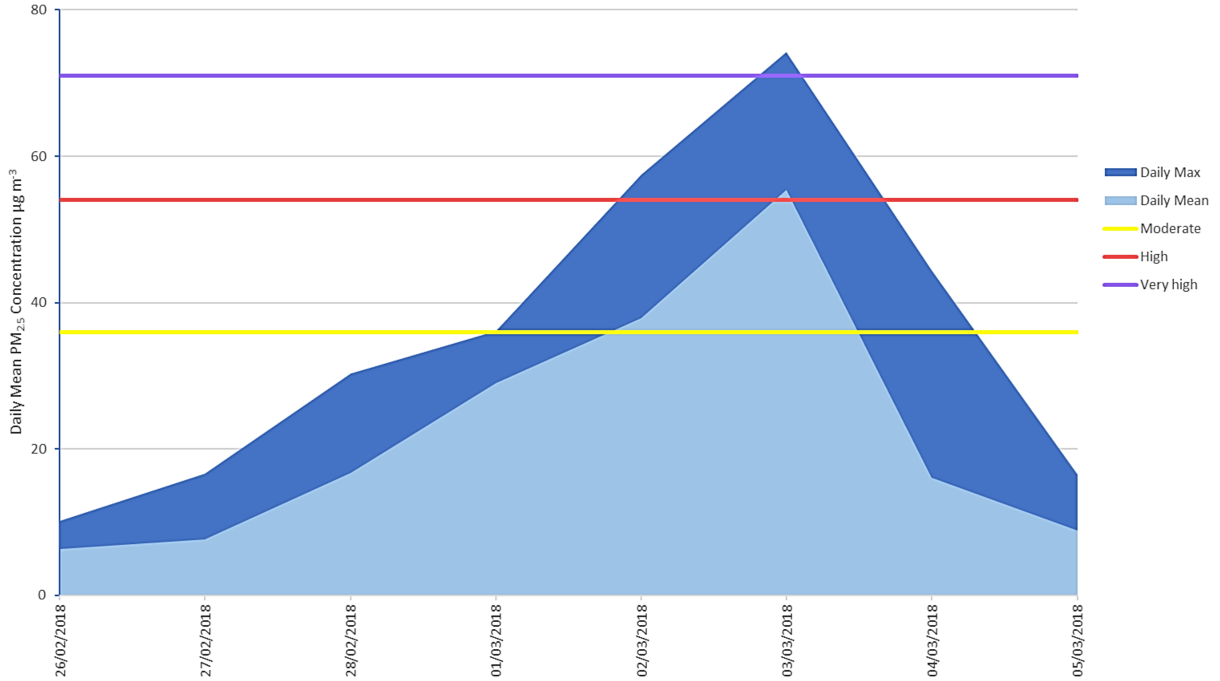


Figure 6-4 Average Daily Mean $PM_{2.5}$ Concentrations, Monitoring Sites in South East, East and Greater London, 26th February – 5th March 2018

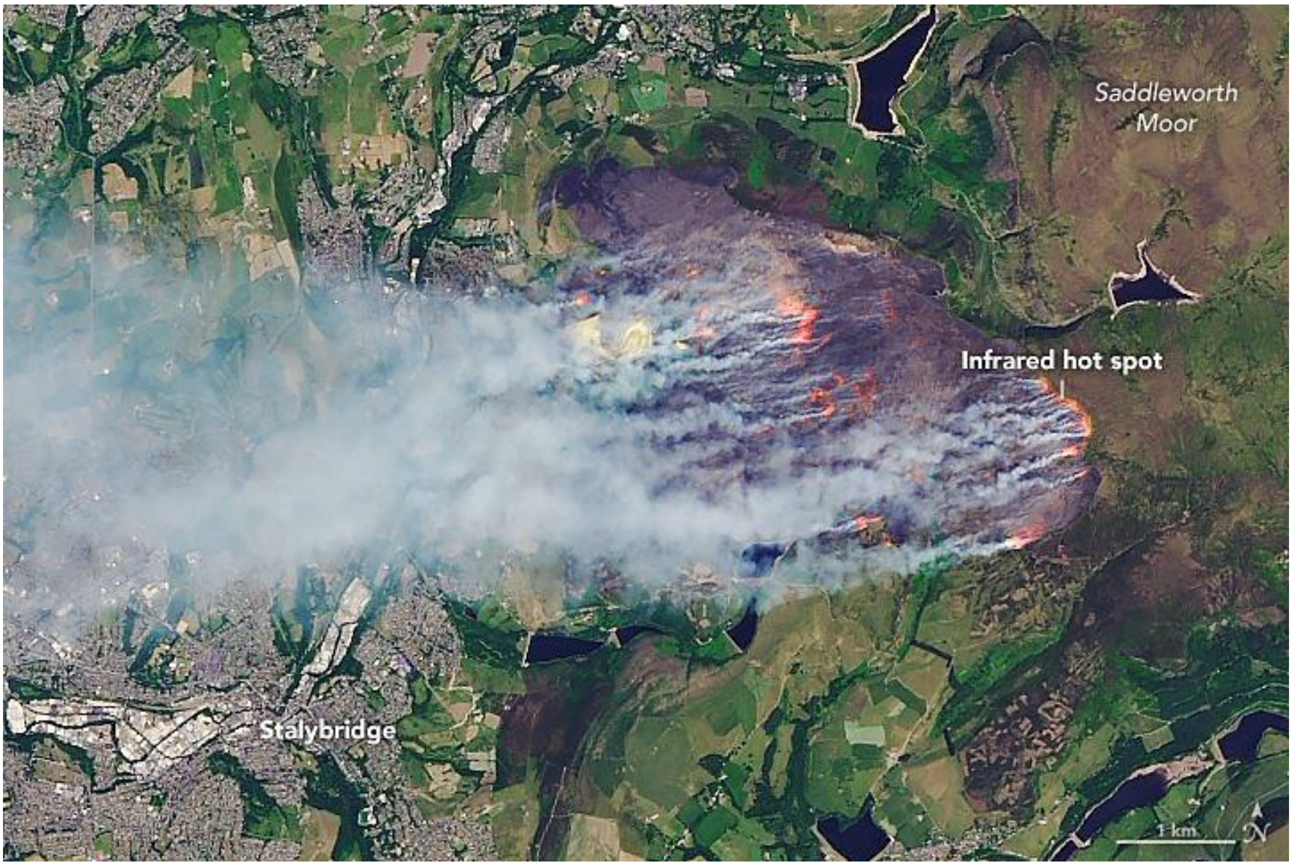


6.1.2 North West England Moorland Wildfires Particle Pollution Episode 24th June – 18th July 2018

Summer 2018 brought two serious wildfires to the moors in the North West of England. The first began on 24th June, burning until 18th July, and encompassed approximately seven square miles of Saddleworth Moor (**Figure 6-5**). The second wildfire started on 28th June at Winter Hill in the Pennines, with the final flames not extinguished until as late as 23rd July (although the fire was deemed 'under control' by 16th July). Consequently, a particulate pollution episode was measured by nearby monitoring stations in the AURN.

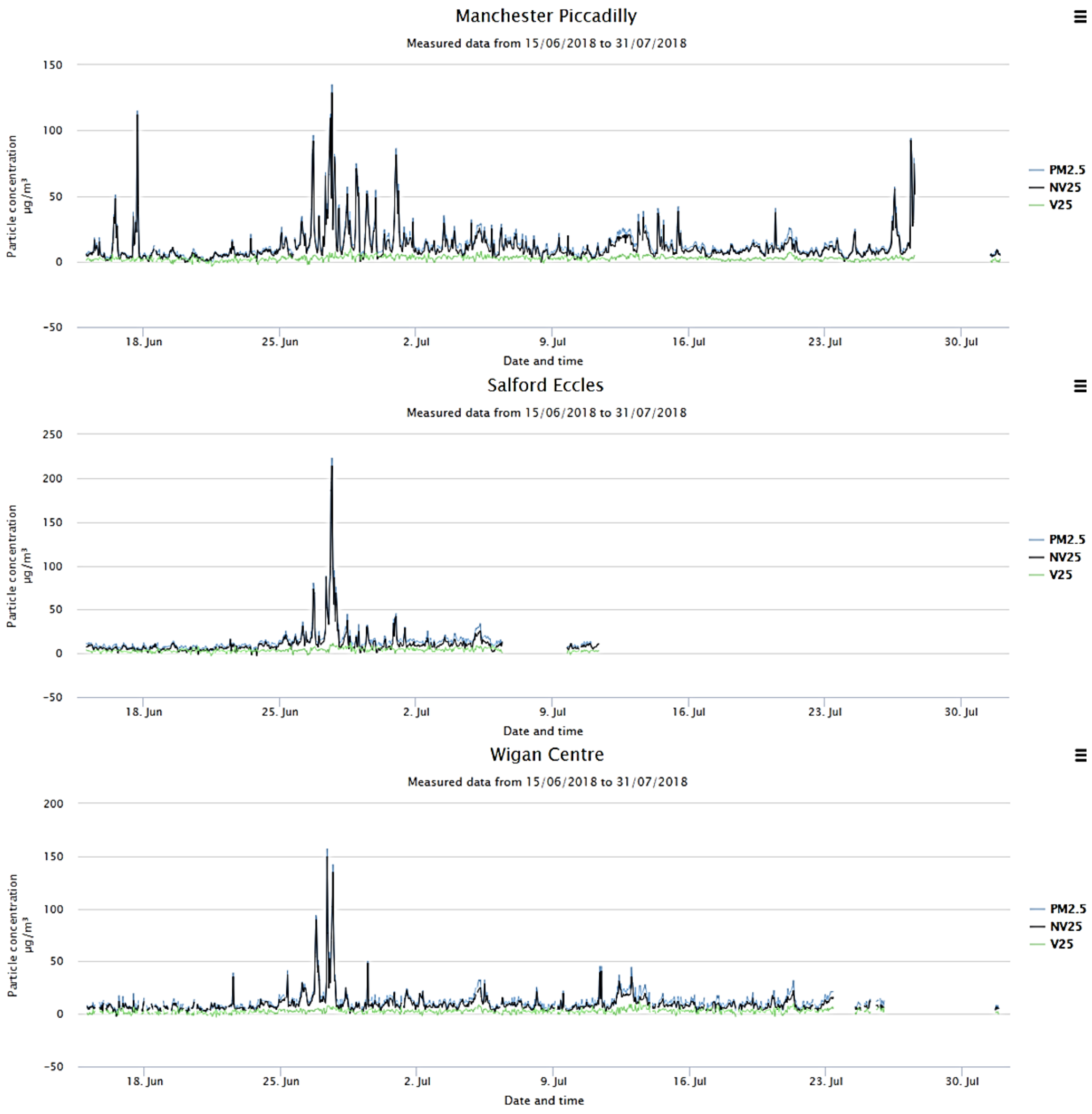
This particulate pollution episode coincided with a national heatwave and an ozone pollution episode, discussed in Section 6.2. Therefore, the DAQI maps for this period are discussed in Section 6.2 and concentrations of particulate matter only are discussed in this section.

Figure 6-5 NASA Satellite Photo Showing Extent of the Saddleworth Moor Wildfire, Taken Midday 27th June 2018[75]



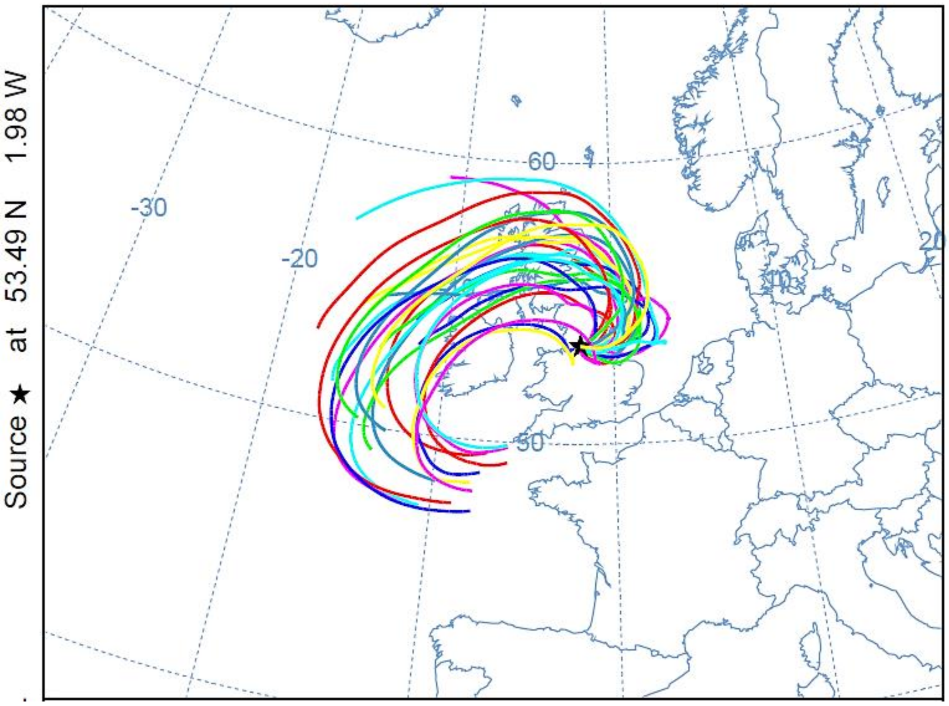
Monitoring stations in the Manchester area were examined; none of the AURN stations showed substantially increased concentrations of NO_X during the pollution episode. However, substantial peaks in particulate concentrations were recorded, in particular on the 26th and 27th June. $PM_{2.5}$ plots for three monitoring locations; Manchester Piccadilly, Salford Eccles and Wigan Centre, are shown in **Figure 6-6**.

Figure 6-6 Hourly Mean $PM_{2.5}$, $NV_{2.5}$ and $V_{2.5}$ Concentrations at Manchester Piccadilly, Salford Eccles and Wigan Centre, 15th June – 31st July 2018 (Source: UK-AIR)



At the three monitoring sites, concentrations greater than 100 µg m^{-3} $PM_{2.5}$ were measured at 16:00 on 27th June. The volatile fraction of the $PM_{2.5}$ ($V_{2.5}$, green) concentration remained low throughout and the non-volatile $PM_{2.5}$ ($NV_{2.5}$, dark blue) was the dominant fraction. This indicates the particulate matter was primary material, directly emitted from the wildfire, rather than secondary material formed from reactions as polluted air is transported over from Europe. The majority of other sites in the North West and Merseyside area also did not show any peaks similar to the ones in **Figure 6-6**. **Figure 6-7** shows 96-hour air mass back trajectories for 27th June; these indicate air circulating over the UK rather than coming from Europe, again suggesting the particulate matter was primary material of local origin.

Figure 6-7 Back Trajectories Showing Air Masses Arriving in Manchester on 27th June 2018 (Source: NOAA website) *The authors gratefully acknowledge the NOAA Air Resources Laboratory (ARL) for the provision of the HYSPLIT transport and dispersion model and READY website (http://www.ready.noaa.gov) used to prepare this figure.*



6.1.3 Bonfire Night Particulate Pollution Episode 5th – 6th November 2018

Bonfire Night particulate pollution episodes, arising from fireworks and bonfires, are generally short-lived but noticeable. In 2018, Bonfire Night (5th November) fell on a Monday with cloudy skies and mild temperatures across most of the UK.[76] Unsettled conditions are more likely to encourage low concentrations, but this calm period resulted in poor dispersion conditions and consequently a particulate pollution episode.

The DAQI maps in **Figure 6-8** show 'Very High' pollution levels in the North East and Yorkshire & Humberside, as well as 'High' levels in the North West & Merseyside and the East Midlands on 5th November. 'Moderate' pollution was recorded for the majority of the South of England. On the 6th November, 'Moderate' pollution continued in the North East, Yorkshire & Humberside and the East Midlands, as a result of lingering smoke from the night before. Despite the 5th November falling on a Monday, the weekend of 3rd – 4th November showed low pollution across the UK, possibly due to wetter weather and more unsettled conditions.[76] **Figure 6-9** shows the peak of this early November episode on the 5th and the lingering elevated PM_{10} concentration on the 6th of the month.

Figure 6-8 Maps Showing DAQI, 3rd – 7th November 2018 (Source: UK-AIR)

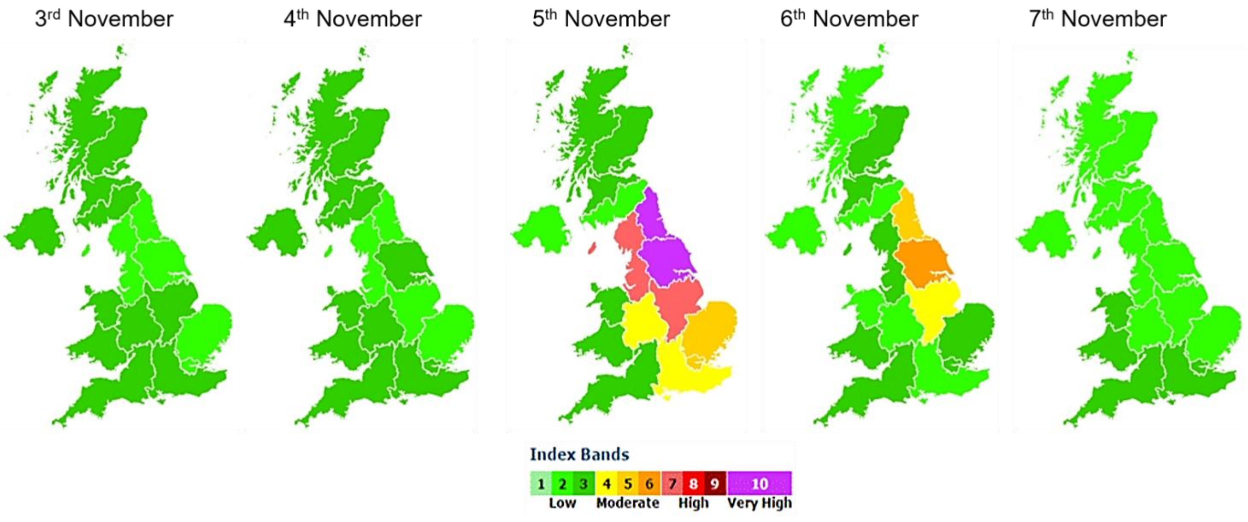
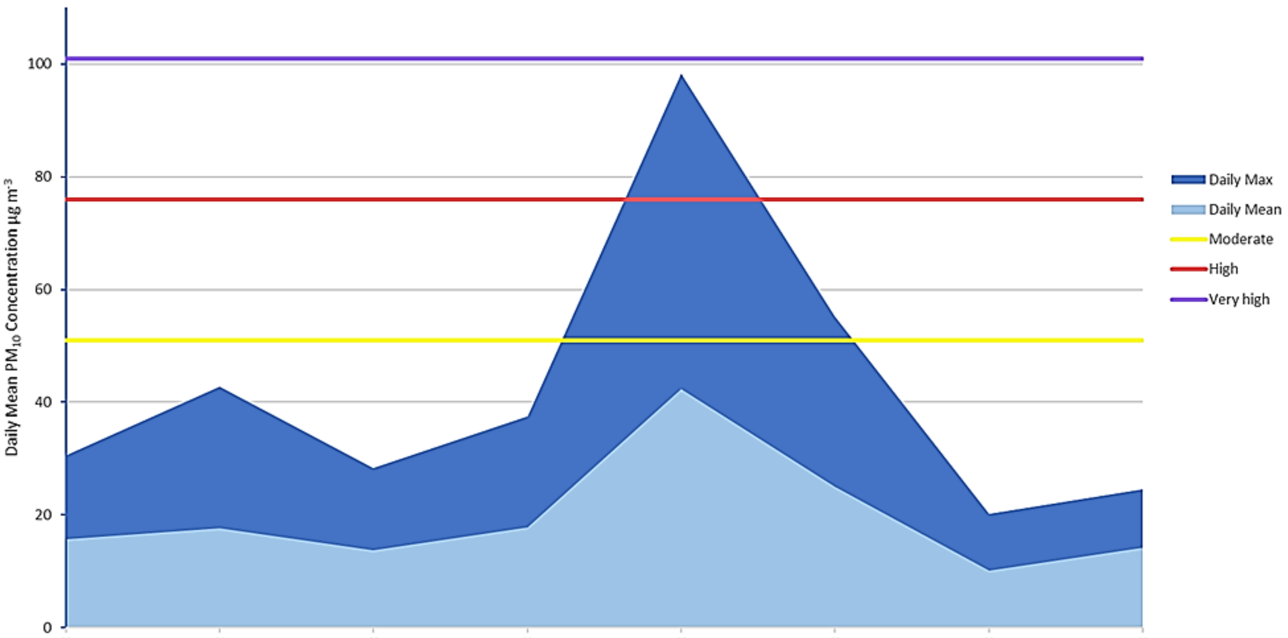
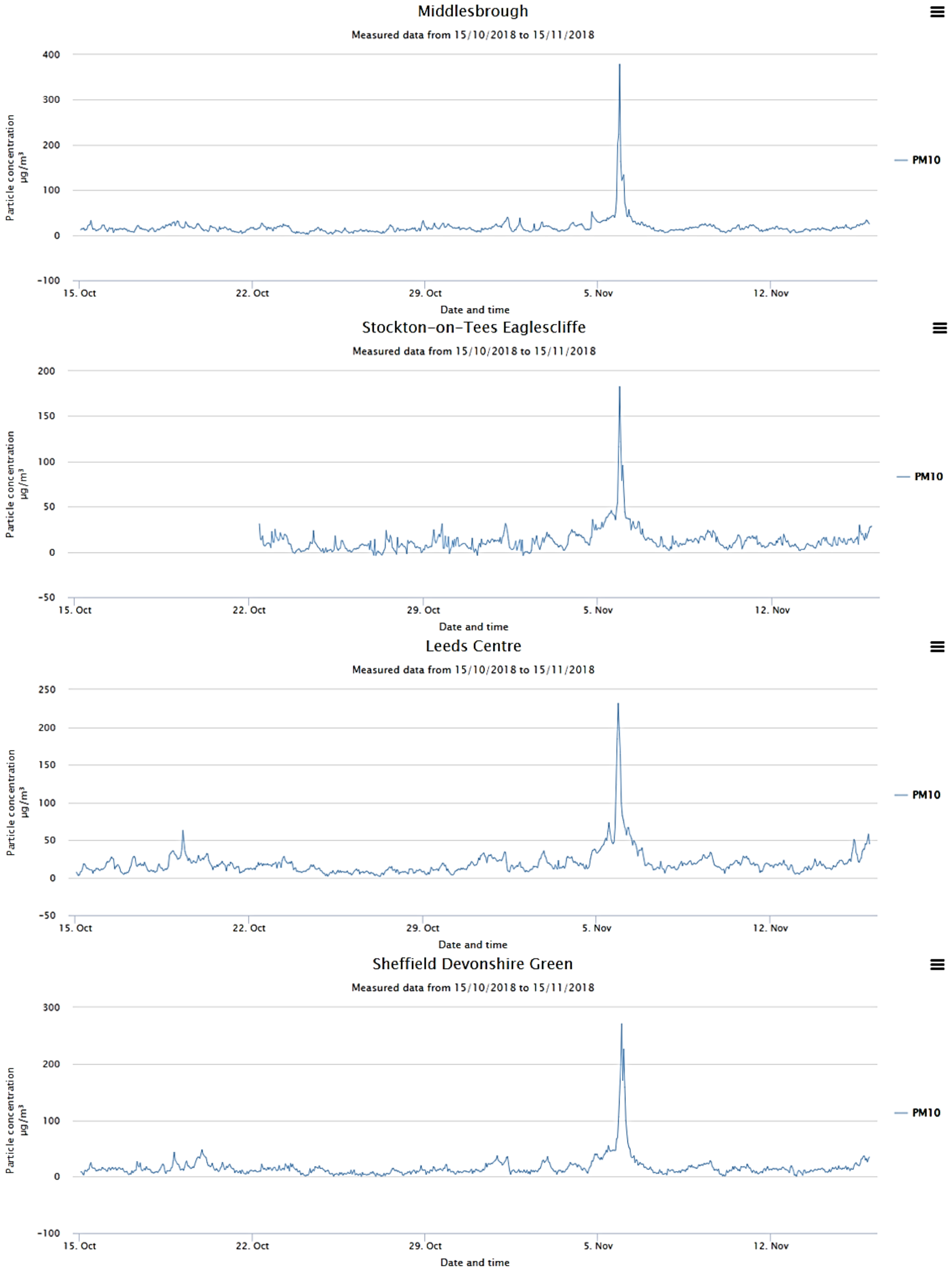


Figure 6-9 Average Daily Mean PM_{10} Concentrations in the UK, average of all sites, 1st – 8th November 2018



Bonfire Night pollution episodes may be very localised, depending on local variations in the weather, the timing of local fireworks and bonfires, and their proximity to monitoring sites. A sharp short-term peak in PM concentration was evident on the night of 5th – 6th November, particularly in data from the North East of England, and Yorkshire & Humberside where pollution reached the 'Very High' level. **Figure 6-10** illustrates this for four monitoring stations in these regions. Over the 5th – 6th November, Middlesbrough monitoring station measured a maximum concentration of 378.6 µg m^{-3}, Sheffield Devonshire Green measured a maximum of 271.5 µg m^{-3} and Leeds Centre measured a maximum of 231.7 µg m^{-3}.

Figure 6-10 Hourly Mean PM_{10} Concentrations in the UK, 15th October – 15th November 2018, for four AURN Sites in the North East, and Yorkshire & Humberside



6.2 Summer Ozone and Particulate Matter Events

Air pollution episodes due to ozone commonly occur in the UK during spring and summer. In 2018, a heatwave in June and July contributed to ozone pollution episodes. These episodes occurred at the end of June, and again at the end of July, although the DAQI maps showed ‘Moderate’ pollution in one or more regions every day from 24th June – 29th July (except 9th – 12th July and 18th July). These ozone events coincided with particulate episodes, described in Section 6.1.2.

6.2.1 Ozone Episode 25th June – 5th July 2018

From the 21st June the UK experienced a heatwave, with multiple locations recording temperatures greater than 30 ºC from the 25th onwards.[77] This weather was attributed to high pressure, also causing high UV and pollen count across the UK. ‘Moderate’ ozone concentrations (101 µg m^{-3} or more, as an 8-hr running mean) were measured by the AURN at one or more monitoring sites from 23rd June – 9th July. The 26th – 28th June had the highest concentrations of ozone, with Lough Navar and Wigan Centre monitoring sites both reaching the ‘High’ banding (161 µg m^{-3} or more).

This ozone pollution episode coincided with the moorland wildfires described in Section 6.1.2. The DAQI maps for 25th June – 5th July are shown in **Figure 6-11**. The worst pollution was measured on the 27th June, with North West & Merseyside reaching 8 in the ‘High’ banding and almost all other regions in the ‘Moderate’ banding.

Figure 6-11 Maps Showing DAQI, 25th June – 5th July 2018 (Source: UK-AIR)

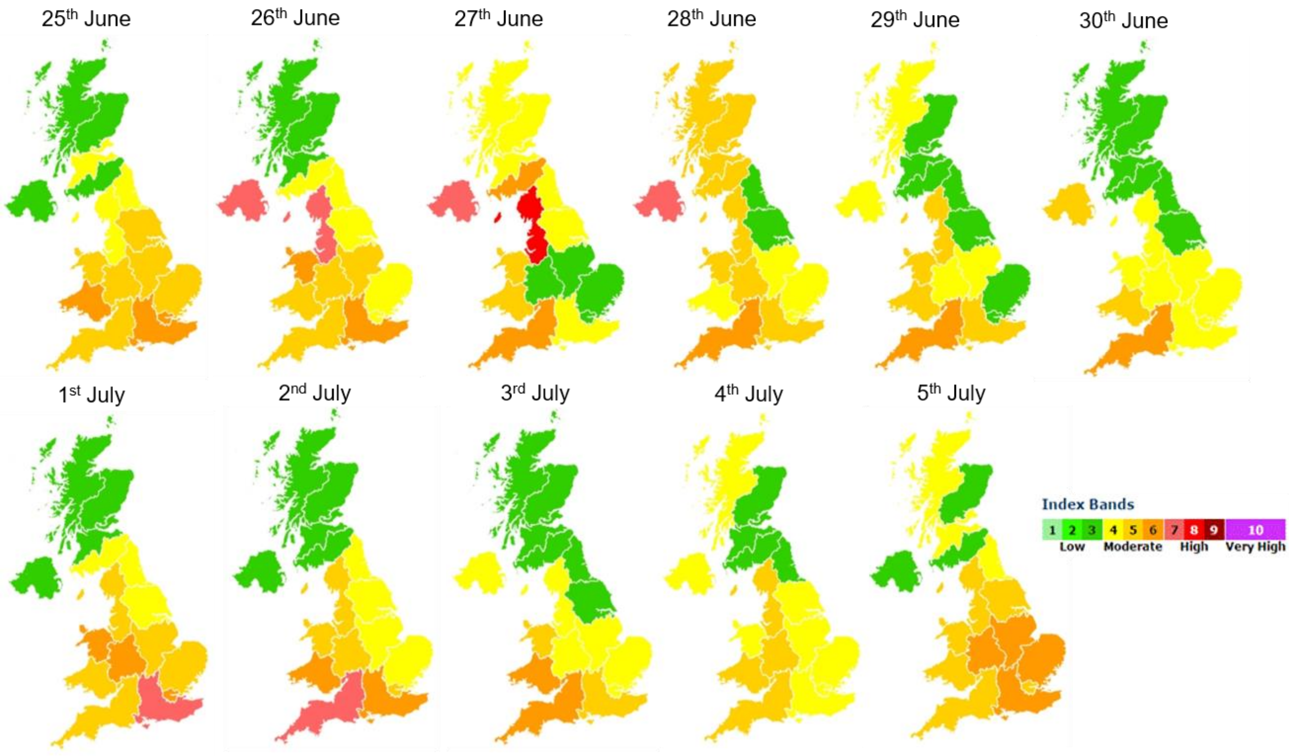
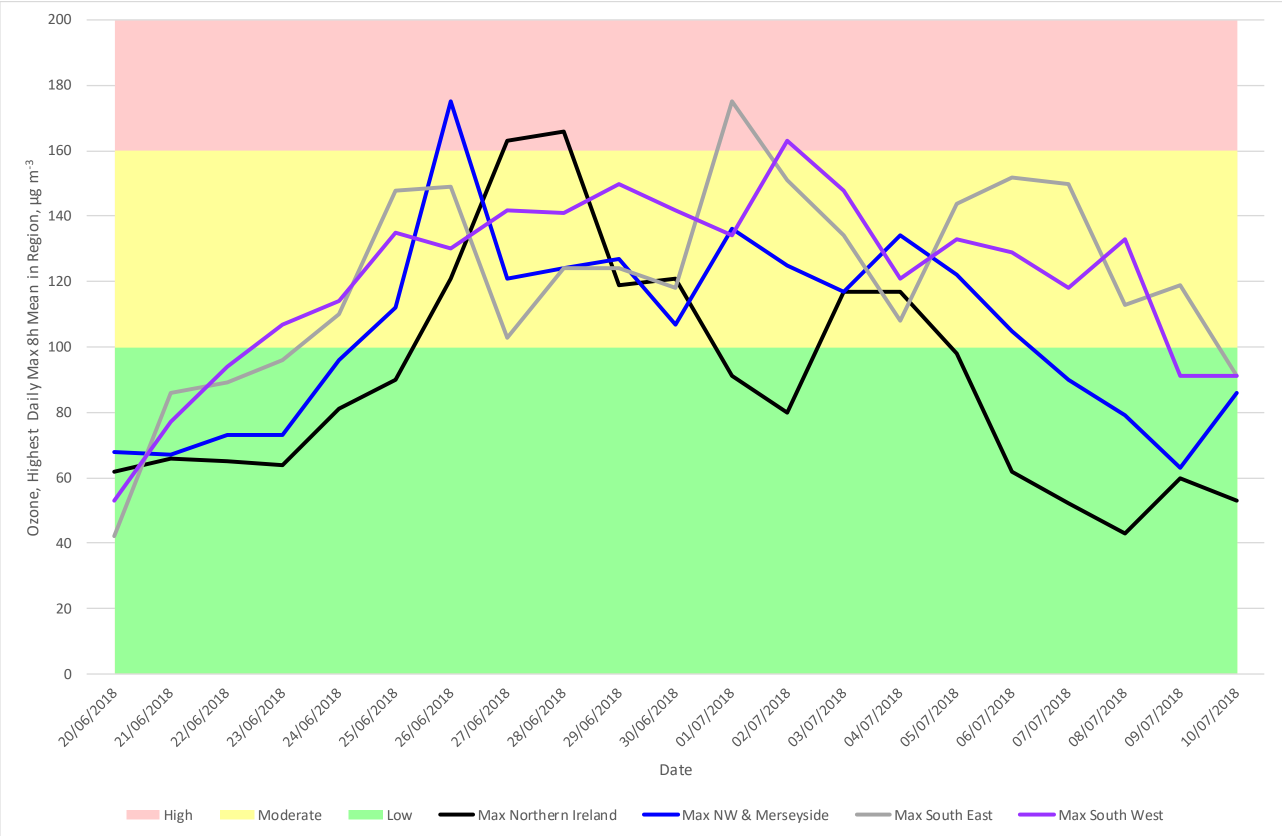


Figure 6-12 shows the *highest* daily maximum 8-hour mean ozone concentration in each of four regions where ozone concentrations reached the 'high' band over this period, i.e. Northern Ireland, North West and Merseyside, the South East and South West.

Figure 6-12 Ozone: Highest Daily Maximum 8-Hour Running Mean in Region, Four Regions where O_3 Reached the 'High' Band, 20th June – 10th July 2018



6.2.2 Ozone Episode 26th – 27th July 2018

Another episode of high ozone occurred at the end of July. The first half of July had continued high pressure running over from June, however, the middle of the month had more unsettled weather and consequently experienced lower pollution. The 23rd – 26th July were the hottest days, and some of the most polluted in terms of ozone, before a thundery breakdown at the very end of the month.[78] Again, this pollution episode coincided with the moorland fires, described in Section 6.1.2. The DAQI maps in **Figure 6-13** show the worst pollution was experienced in the Eastern region on 27th July. Elevated ozone levels were measured by the AURN, shown in **Figure 6-14** where the greatest concentrations can be seen on 26th and 27th July. 'Moderate' ozone was measured at one or more monitoring sites every day from 22nd – 29th July (8-hr running mean). 'High' levels of ozone (161 µg m^{-3} or more) were measured at Wicken Fen, Lullington Heath and Canterbury monitoring sites on 26th July, and at Sibton and Norwich Lakenfields monitoring sites on 27th July (daily max 8-hr running mean). These five monitoring sites are located in the South East or Eastern regions; the highest concentration reported was 190 µg m^{-3} at Sibton monitoring site on the 27th July.

Figure 6-13 Maps Showing DAQI, 25th – 29th July 2018 (Source: UK-AIR)

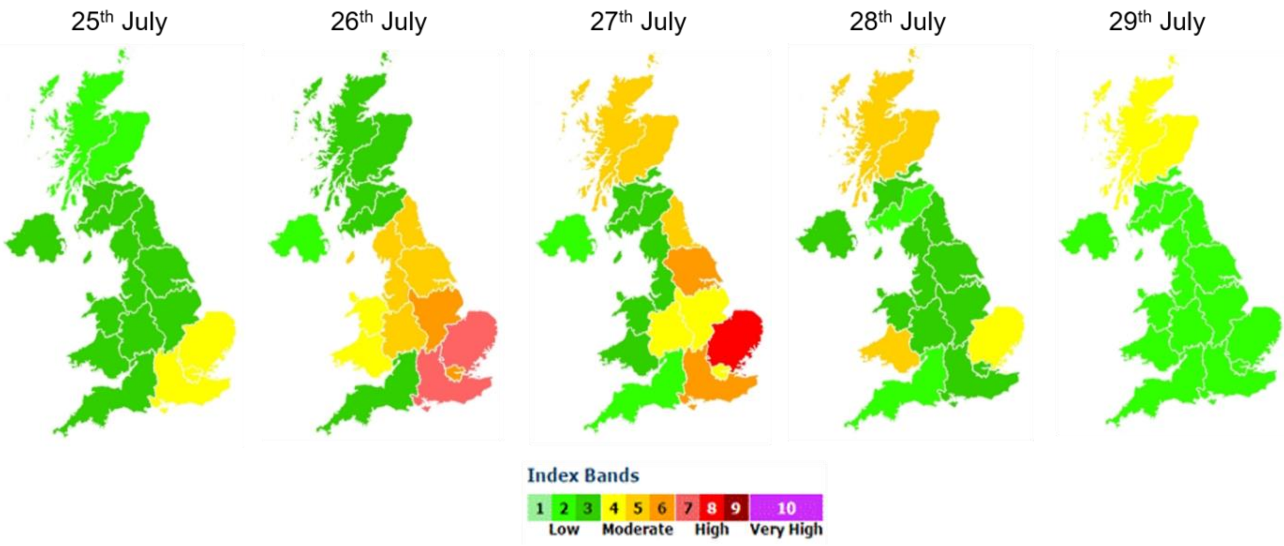
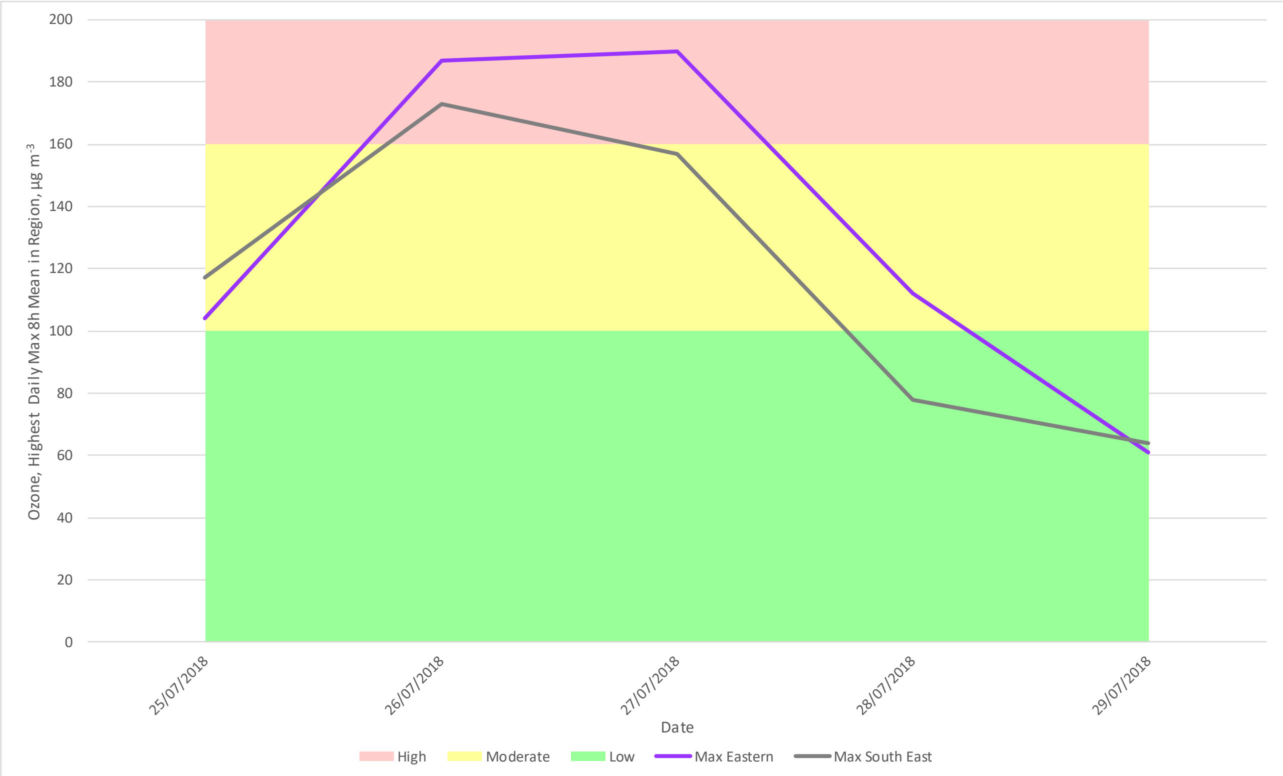


Figure 6-14 Highest Daily Maximum 8-Hour Running Mean in Region, Two Regions where O_3 Reached the 'High' Band, 25th – 29th July 2018



6.3 Forecasting Air Pollution Events

As outlined in Section 2.2.5, air quality forecasts are produced by the Met Office using the Air Quality Unified Model (AQUM). AQUM combines predicted meteorological conditions with gridded emissions data to provide forecasts of air pollution concentrations across the UK. Forecasts are produced with a lead time of up to five days and are reported using the Daily Air Quality Index (DAQI) to align with associated health advice.

Forecast performance in any particular episode can vary based on a number of factors, including the pollutant type responsible for the episode, the accuracy and complexity of the meteorological conditions modelled by AQUM, and the validity of the assumptions made with regard to pollutant emissions.

AQUM uses emissions based on the National Atmospheric Emissions Inventory (NAEI) which presents annual mean emissions at 1 km^2 resolution. Appropriate temporal and vertical profiles (e.g. based on well-established traffic patterns) are applied within AQUM to each emission sector. In the majority of cases this approach provides an appropriate representation of emissions at different times of day and at different times during the year.

7 Where to Find Out More

Defra's web pages relating to air quality can be found at https://www.gov.uk/government/policies/protecting-and-enhancing-our-urban-and-natural-environment-to-improve-public-health-and-wellbeing/supporting-pages/international-european-and-national-standards-for-air-quality. These provide details of what the UK is doing to tackle air pollution, and the science and research programmes in place.

Also, Defra has published a Guide to Air Pollution Information Resources, detailing the types of information that are made available and this can be found at https://uk-air.defra.gov.uk/assets/documents/reports/cat14/1307241318_Guide_to_UK_Air_Pollution_Information_Resources.pdf .

Information on the UK's air quality, now and in the past, is available on UK-AIR, the Defra online air quality resource at http://uk-air.defra.gov.uk/. UK-AIR is the national repository for historic ambient air quality data. It contains measurements from automatic measurement programmes, some 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. Tools available on UK-AIR include the UK Ambient Air Quality Interactive Map at http://uk-air.defra.gov.uk/data/gis-mapping that allows you to look at outputs for the national modelling conducted for compliance assessment, based on pollutant, background or roadside and geographical location.

Similar national online air quality resources have also been developed for Scotland, Wales and Northern Ireland:

- The Welsh Air Quality Archive at https://airquality.gov.wales/
- The Scottish Air Quality Archive at http://www.scottishairquality.scot/
- The Northern Ireland Archive at https://www.airqualityni.co.uk/

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

The 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.

UK-AIR also provides a daily air quality forecast, which is further disseminated via e-mail, RSS feeds and Twitter (see http://uk-air.defra.gov.uk/twitter). Latest forecasts are issued 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 http://naei.beis.gov.uk/.

The Clean Air Hub, at https://www.cleanairday.org.uk/pages/category/clean-air-hub, brings together information on air pollution, how it affects our health, and the actions we can take both to protect ourselves from it, and to help tackle it. There is also information on the annual Clean Air Day. The Clean Air Hub is coordinated by Global Action Plan: more information about Global Action Plan can be found at https://www.globalactionplan.org.uk/.

Additional information from the Devolved Administrations of Scotland, Wales and Northern Ireland can be found at:

- The Scottish Government Air Quality web page at http://www.scotland.gov.uk/Topics/Environment/waste-and-pollution/Pollution-1/16215
- The Welsh Government Environment and Climate Change web pages at https://gov.wales/environment-climate-change .
- The Northern Ireland Department of Agriculture, Environment and Rural Affairs (DAERA) web page at https://www.daera-ni.gov.uk/ .

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Section 2

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