Department
for Environment,
Food & Rural Affairs

Air Pollution in the UK 2024

September 2025

We are responsible for improving and protecting the environment. We aim to grow a green economy and sustain thriving rural communities. We also support our world-leading food, farming and fishing industries.

Defra is a ministerial department, supported by 34 agencies and public bodies.

OGL

© Crown copyright 2025

This information is licensed under the Open Government Licence v3.0. To view this licence, visit www.nationalarchives.gov.uk/doc/open-government-licence/

Where we have identified any third party copyright information you will need to obtain permission from the copyright holders concerned.

This publication is available at www.gov.uk/defra

Any enquiries regarding this publication should be sent to us at aqie.correspondence@defra.gov.uk.

Contents

Executive Summary 5

Glossary 8

1 Introduction 14

2 Legislative and Policy Framework 16

2.1 The Air Quality Standards Regulations (2010) 16

2.2 Environment Act (2021): $PM_{2.5}$ Targets 19

2.3 The National Emission Ceilings Regulations (2018) 21

2.4 The Environmental Permitting Regulations (EPR 2016 and 2018) 22

2.5 Policies to Improve UK Air Quality 22

2.6 Local Authority Air Quality Management 28

2.7 Official Statistics and Indicators 31

3 The Evidence Base 35

3.1 Pollutants of Concern 35

3.2 Assessment of Air Quality in the UK 41

3.3 Modelling 53

3.4 Access to Assessment Data 55

4 Assessment of Compliance 56

4.1 Definition of Zones 56

4.2 Air Quality Assessment for 2024 58

4.3 Comparison with Previous Years 72

5 Spatial Variation and Changes Over Time 80

5.1 About the Maps and Charts in this Section 80

5.2 Nitrogen Dioxide 81

5.3 PM_{10} Particulate Matter 84

5.4 $PM_{2.5}$ Particulate Matter 89

5.5 Ozone 92
5.6 Sulphur Dioxide..99
5.7 Carbon Monoxide..104
5.8 Benzene..106
5.9 1,3-Butadiene..109
5.10 Metallic Elements..111
5.11 Benzo[a]pyrene...124
6 Air Pollution Episodes in 2024..128
6.1 Overview of Pollution Episodes and the Daily Air Quality Index...........................128
6.2 SO_2 from Volcanic Activity 132
6.3 Elevated Summer O_3 135
6.4 Transboundary and Local PM 137
7 Where to Find Out More..141
8 References..143

Executive Summary

The UK's Air Quality Standards Regulations (2010) and the Environment Act (2021) require reporting of compliance and progress made on an annual basis. The underlying data are reported on the UK-AIR website. This report continues the series of annual compliance reporting against The Air Quality Standards Regulations (2010) and details progress towards meeting the two targets set in The Environmental Targets (Fine Particulate Matter) (England) Regulations (2023). This report provides background information on the pollutants covered by these regulations, their sources and effects, the UK's monitoring networks, and the UK's modelling methodology. It then summarises the results of the UK's ambient air quality assessment for 2024, presenting measurements from national air pollution monitoring networks and air quality modelling data. The pollutants covered in this report are:

- nitrogen oxides (NO_X) comprising NO and NO_2
- PM_{10} and $PM_{2.5}$ particulate matter
- ozone (O_3)
- sulphur dioxide (SO_2)
- carbon monoxide (CO)
- benzene
- 1,3-butadiene
- metals: lead, cadmium, nickel and mercury, and the metalloid arsenic
- benzo[a]pyrene
- ammonia.

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 Air Quality Standards Regulations (2010), the UK is divided into 43 zones. The 2024 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 all 43 zones
- 38 zones met the limit value for annual mean NO_2, with five zones exceeding
- all zones required to meet the critical level for annual NO_X set for protection of vegetation (non-agglomeration zones) did so. This has been the case since 2008

- all zones met the limit value for daily mean concentration of PM_{10} particulate matter, without the need for subtracting the contribution from natural sources

- all zones met the limit value for annual mean concentration of PM_{10} particulate matter, without the need for subtracting the contribution from natural sources

- all zones met the limit value for annual mean concentration of $PM_{2.5}$ particulate matter. Subtraction of natural source contribution is not allowed in the case of $PM_{2.5}$

- the UK continues to meet its 2020 national exposure reduction target for $PM_{2.5}$, based on the Average Exposure Indicator (AEI) statistic (explained in Sections 4 and 5 of this report). In 2024, the three-year running mean AEI was 7 µg m^{-3}; this statistic has therefore remained within the National Exposure Reduction Target (which was for the AEI to reduce to 11 µg m^{-3} by 2020).

- The Environmental Targets (Fine Particulate Matter) (England) Regulations (2023) set a legally mandatory target of 10 µg m^{-3} for annual mean $PM_{2.5}$ concentrations to be achieved across England by 2040. Legal compliance is assessed using measurements from monitoring stations in England of all site types. One monitoring station in England exceeded this target in 2024 (London Marylebone Road, a roadside site in central London). However, in 2024 no monitoring stations exceeded the interim target of 12 µg m^{-3}, to be met by January 2028.

- The Environmental Targets (Fine Particulate Matter) (England) Regulations (2023) also set a legally mandatory $PM_{2.5}$ Population Exposure Reduction Target (PERT) of 35% compared to 2018 to be achieved across England by 2040. An interim target of 22% is to be met by January 2028. The population exposure value for 2024 was 7.56 µg m^{-3}, which constitutes a reduction of 25% from the 2018 value. Therefore in 2024 England met the interim PERT of 22%

- for ozone, there are two target values (which are being met) and two long term objectives (where there are exceedances)

    - all zones met both the target value based on the daily maximum eight-hour mean, which was set for the protection of human health

    - all zones met the target value based on the AOT40 statistic (explained in Sections 4 and 5 of this report), which was set for the protection of vegetation

    - 12 zones out of 43 were compliant with the more stringent long-term objective for ozone, set for the protection of human health (31 zones exceeded). This is based on the daily maximum eight-hour mean

    - 39 zones out of 43 were compliant with the more stringent long-term objective for ozone, set for the protection of vegetation (four zones exceeded). This is based on the AOT40 statistic, explained in Sections 4 and 5 of this report

- there were no measured exceedances of the ozone population information threshold of 180 µg m^{-3} in 2024
- all zones met the limit values for sulphur dioxide, carbon monoxide, benzene and lead, and the target values for arsenic, cadmium
- 2024 was the first year in which all zones have been compliant with the target value for benzo[a]pyrene.
- three zones out of 43 exceeded the target value for nickel.

A summary of the air quality assessment for 2024, and a comparison with previous years' air quality assessments since 2008 can be found in Section 4 of this report.

Section 5 presents a summary of spatial distribution of pollutant concentrations, and changes over time. Section 6 looks at specific periods of poor air quality in 2024 – referred to as air pollution 'episodes'. This year, section 6 features several periods of high sulphur dioxide concentration caused by volcanic eruptions in Iceland, and some smaller episodes of higher than usual ozone and particulate matter pollution.

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 uk-air.defra.gov.uk, scottishairquality.scot/, airquality.gov.wales and airqualityni.co.uk/.

Glossary

In this glossary, we have used ***bold italics*** to show terms explained elsewhere in the glossary.

Agglomeration Zone. In the context of air quality assessment and reporting, any urban area with a population greater than 250,000.

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

Air Quality Standards Regulations (2010). Prior to 31 January 2020, the UK was a Member State of the European Union. As such, the UK was required to incorporate - or 'transpose' - the provisions of EU Directives into their own national law by a specified date. The Air Quality Standards Regulations (2010) are the legislation by which the UK fulfilled this requirement for the ***Air Quality Directive*** and ***Fourth Daughter Directive***.

Air Quality Strategy. England's Air Quality Strategy is a framework for local authority delivery. It was published in April 2023 in line with requirements in the Environment Act (1995), as amended by the Environment Act (2021).

Ambient Air. Outdoor air.

Annual Mean Concentration Target (AMCT). A legally mandatory target set in ***The Environmental Targets (Fine Particulate Matter) (England) Regulations (2023),*** for ambient concentrations of ***$PM_{2.5}$***. Annual mean $PM_{2.5}$ concentrations measured at all $PM_{2.5}$ monitoring stations in England must be less than or equal to 10 µg m^{-3} by the end of 2040.

Annual Mean Daily Maximum 8-Hour Mean O_3 Concentrations. This is an annual mean of the **'daily maximum 8-hour mean'** for ***ozone***. An 8-hour mean is only valid if there are at least six hours of data within the 8-hour period (75% data capture).

Arsenic (As). A metalloid which occurs naturally in the environment but can also be emitted into the air from human activities, for example the open burning of waste wood that has been treated with products containing arsenic.

Average Exposure Indicator (AEI). The statistic on which the national exposure reduction target of ***The Air Quality Standards Regulations (2010)*** 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 hydrocarbon compound, chemical formula C_6H_6. As an air pollutant, benzene can be emitted from domestic and industrial combustion processes, and road vehicles.

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***, which measures the attenuation of beta rays passing through a filter tape on which particulate matter from sampled air has been collected.

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.

Cadmium (Cd). A metallic element that can be released into the air, for example from combustion in the manufacturing industry and production processes.

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

Clean Air Strategy (CAS): published in 2019, this is the UK Government's framework document setting out policy action to drive down national emissions of five damaging pollutants to achieve statutory emissions reduction commitments, reduce background pollution, and minimise human exposure to harmful concentrations of pollution.

Cleaner Air for Scotland 2 (CAFS2): published in 2021, sets out the framework for air quality policy in Scotland to 2026.

Daily Maximum 8-Hour Mean O_3 Concentrations. For a given day the 'daily maximum 8-hour mean' for ***ozone*** is derived from the 8-hour means beginning with the 8-hour period from 17:00 p.m. on the previous day to 01:00 a.m. and ending with the 8-hour period from 16:00 p.m. to 00:00 a.m. The highest of these consecutive 8-hour averages is taken as the daily maximum 8-hour mean. A daily maximum 8-hour mean is only valid if there are at least 18 valid 8-hour means within the day, each with at least six hours of data (75% data capture).

Digitel™ 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).***

Emissions. Pollutants released into the air from any source: these can result from human activities (such as industrial processes or vehicle exhaust, tyre and brake wear), or natural sources (such as wildfires or wind-blown dust). The UK's estimated emissions of a range of pollutants are quantified in the ***National Atmospheric Emissions Inventory (NAEI)***.

Emission Reduction Commitments. Commitments set by the UK's ***National Emission Ceilings Regulations (NECR)*** of 2018 requiring the UK to reduce its human-made emissions of oxides of nitrogen (NO_X), oxides of sulphur (SO_X), non-methane volatile organic compounds (NMVOC), ammonia (NH_3) and particulate matter as $PM_{2.5}$, by specified amounts, to achieved between 2020 to 2029 and from 2030 onwards.

Environmental Targets (Fine Particulate Matter) (England) Regulations (2023). Regulations which came into force in January 2023 for England. They set a new target for maximum ambient concentrations of ***$PM_{2.5}$ particulate matter*** to be achieved by 2040, and for reduction of the population's exposure to $PM_{2.5}$ over the period between 2018 and 2040.

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).

Eutrophication. Increased levels of plant nutrients such as phosphorus and nitrogen, in soil or bodies of water such as lakes or rivers. This can cause an increase in growth of water plants and algae which, in turn, can affect the water's ability to support other life such as fish.

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

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'.) The provisions of the Fourth Daughter Directive were transposed into UK law by means of The Air Quality Standards Regulations (2010).

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.

Lead (Pb). A metallic element that can be an air pollutant. The main sources include industrial production processes, and vehicle brake wear.

Leckel SEQ™. A type of ***gravimetric sampler*** used for measuring ambient concentrations of ***particulate matter***.

Limit value. 'Limit values' are set for ambient concentrations of pollutants within ***The Air Quality Standards Regulations (2010)***. Limit values are legally-binding and where they are exceeded, Government must implement measures to achieve compliance in the shortest possible time.

Long-Term Objectives. As well as limit values and ***target values***, ***The Air Quality Standards Regulations (2010)*** set 'long-term objectives' (LTOs) for ozone concentration. A Long-Term Objective means "*a level to be attained in the long term, save where not achievable through proportionate measures, with the aim of providing effective protection of human health and the environment*". The legal requirement is for the UK to ensure all necessary measures not involving disproportionate costs are taken to ensure target values and LTOs are met. The ozone LTOs are based on the same statistics as the ozone target values but are more stringent: unlike target values, the legislation does not specify a date by which LTOs should be met.

Major ions in rainwater. Major ions in rainwater are those commonly found dissolved in rainwater as cations (positively charged) or anion (negatively charged). The UKEAP network measures the following in rural precipitation - cations: calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}) and ammonium (NH_4^{+}) and anions: sulphate (SO_4^{2-}), chloride (Cl^{-}) and nitrate (NO_3^{-}).

Mercury (Hg). A metallic element that can be an air pollutant. The main UK sources include coal use in industry, iron and steel production processes, and disposal of products containing mercury.

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

Microgram per cubic metre (µg m^{-3} or µg/m^3). Unit often used to express the concentration of a pollutant in air. 1 µg = 1 millionth of a gram 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.

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

National Atmospheric Emissions Inventory (NAEI): a database of estimated UK annual pollutant ***emissions*** from 1970 to the most current publication year for a wide range of pollutants: https://naei.energysecurity.gov.uk/ .

Nanogram per cubic metre (ng m^{-3} or ng/m^3). Unit often used to express concentrations of pollutants such as metallic elements and ***PAH****,* which are usually found at low concentrations in air. 1 ng = 1 billionth of a gram or 1 x 10^{-9} g.

National Emission Ceilings Regulations. These 2018 regulations set ***emission reduction commitments (ERCs)*** for human-made emissions of oxides of nitrogen (NO_X), oxides of sulphur (SO_X), non-methane volatile organic compounds (NMVOC), ammonia (NH_3) and particulate matter as $PM_{2.5}$ to be met between 2020 to 2029 and from 2030 onwards.

National Exposure Reduction Target (NERT). Under ***The Air Quality Standards Regulations (2010)***, the UK was required to achieve a National Exposure Reduction Target (NERT) for $PM_{2.5}$, over the period 2010 to 2020. This was achieved by the due date and compliance has been maintained.

Net Zero. Net zero ***emissions*** are reached when anthropogenic (i.e. human-caused) emissions of greenhouse gases to the atmosphere are balanced by anthropogenic removals over a specified period.

Nickel (Ni). A 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 combines with oxygen to form nitrogen dioxide.

Nitrogen Dioxide (NO_2). One of the oxides of nitrogen formed in combustion processes.

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.

Non-agglomeration zones. Air quality assessment zones containing no single large urban population.

Objective Estimation. The process of estimating whether a zone or agglomeration is likely to be compliant with a given limit or target value, based on available evidence where measurements using reference or equivalent methods or model results are not available. The methods used depend on the pollutant: these are explained in the Technical Report on UK supplementary modelling assessment under ***The Air Quality Standards Regulations (2010)***. (Pugsley, K. L. et al., 2025).

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.

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 human made.

PM_{10}. Particulate matter comprising 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. PM_{10} is often described as 'particles of less than 10 micrometres in diameter' though this is not strictly correct.

$PM_{2.5}$. Particulate matter comprising 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. $PM_{2.5}$ 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. 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.

Population Exposure Indicator (PEI). A statistic used by ***The Environmental Targets (Fine Particulate Matter) (England) Regulations (2023)*** to quantify exposure of the population to ***$PM_{2.5}$*** (in England). The PEI is used to monitor progress towards achieving the ***Population Exposure Reduction Target (PERT).***

Population Exposure Reduction Target (PERT). A legally mandatory target set in ***The Environmental Targets (Fine Particulate Matter) (England) Regulations (2023),*** for ambient concentrations of ***$PM_{2.5}$***. This requires a reduction of at least 35% in population exposure to $PM_{2.5}$ (based on measurements at urban background and suburban background monitoring stations in England) by the end of 31 December 2040, compared with a three-year baseline period of 2016 to 2018.

Primary pollutant. A pollutant which is emitted directly into the atmosphere from a source.

QA/QC (or QAQC): Quality Assurance and Quality Control. Quality assurance procedures are implemented to ensure that collected data are of a high standard. Quality control relates to the management of quality assurance related actions (e.g. audits of data collection systems and management records).

Secondary pollutant. A pollutant which is formed by chemical reactions from other pollutants in the atmosphere. Ozone, for example, is a secondary pollutant. ***Particulate matter*** ($PM_{2.5}$ and PM_{10}) consists of a mix of primary material (directly emitted from sources) and secondary material (formed by reactions in the atmosphere).

Statistical significance. Statistical significance is a measure of the likelihood of seeing this result if chance alone was operating. ‘Statistically significant at the 0.05 (or 5%) level’ indicates that, if chance alone was operating, a result like this would occur less than 5% of the time.

Sulphur dioxide (SO_2). An acid gas formed when fuels containing sulphur impurities are burned. An alternative spelling of ‘sulphur’ is ‘sulfur’.

Target Value. *The Air Quality Standards Regulations (2010)* set target values for some pollutants. These are similar to ***limit values***, but while the UK must take all necessary measures not entailing disproportionate costs to meet the target values by the specified date, achievement is not legally mandatory. However, the targets set by ***The Environmental Targets (Fine Particulate Matter) (England) Regulations (2023)***, i.e. the ***AMCT*** and ***PERT***, differ in that achievement by the specified date is legally mandatory.

Toxic Organic Micropollutants (TOMPs). These are compounds that are present in the environment at very low concentrations but are highly toxic and persistent. They include dioxins and dibenzofurans.

1 Introduction

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 for our prosperity. Improving air quality remains a key priority for the UK. 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
- to provide a mechanism to test and validate models.

The UK's Air Quality Standards Regulations (2010) (UK Government, 2010)**,** (Scottish Government, 2010)**,** (Welsh Government, 2010)**,** (Department of Environment Northern Ireland, 2010) [1] require the UK to undertake an air quality assessment and report the findings on an annual basis. The UK has statutory monitoring networks in place to meet the requirements of the above Regulations, with air quality modelling used to supplement the monitored data. (See section 2.1.1 for more information on these Regulations).

The Environmental Targets (Fine Particulate Matter) (England) (2023) Regulations also require an annual assessment of progress towards the targets in England. Assessment uses data from the same monitoring network, but without any supplementation by air quality modelling.

The UK is also required to 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 2024*' continues this series, and has two aims:

- to provide a summary of the UK's 2024 air quality assessment and findings. A separate Compliance Assessment Summary document is also published, based upon Section 4 of this report. This provides a concise summary aimed at the public

[1] Northern Ireland's former Department of Environment is now the Department of Agriculture, Environment and Rural Affairs.

- 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 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 in 2024 with the limit values, target values and long-term objectives set out in The Air Quality Standards Regulations (2010) and of progress towards the $PM_{2.5}$ targets set in The Environmental Targets (Fine Particulate Matter) (England) Regulations (2023) (Section 4)
- compares this with previous years (Section 4)
- explains the spatial distribution of the main pollutants of concern within the UK during 2024 and looks at how ambient concentrations have changed in recent years (Section 5)
- explains noteworthy pollution events that occurred during 2024 (Section 6). This year, Section 6 features rare episodes of sulphur dioxide pollution caused by volcanic eruptions in Iceland, also periods of elevated ozone concentrations, and particulate pollution around Bonfire Night
- explains where to find out more (Section 7).

Further information on air quality in the UK can be found on Defra's online UK-AIR website (Defra, 2025).

2 Legislative and Policy Framework

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

1) legislation regulating concentrations of pollutants in ambient air – The Air Quality Standards Regulations (2010) and The Environmental Targets (Fine Particulate Matter) (England) Regulations (2023)

2) legislation regulating total national emissions of air pollutants – The National Emission Ceilings Regulations (2018) and the Gothenburg Protocol to the UNECE Convention on Long-range Transboundary Air Pollution

3) legislation such as The Environmental Permitting (England and Wales) Regulations (2016) and the Clean Air Act (1993), regulating emissions from specific sources. Note: Northern Ireland does not have Environmental Permitting Regulations but instead regulates industrial emissions via the Pollution Prevention and Control (Industrial Emissions) Regulations (Northern Ireland) (2013) (as amended) (Department of Environment Northern Ireland, 2013).

In February 2022, the UK Government published the Air Quality Common Framework (UK Government, 2022). The Policy Paper is available online, which explains how the UK Government and the Devolved Administrations propose to work together to develop air quality policy, following the UK's exit from the European Union.

Reducing air pollution requires action to reduce emissions from UK sources, as well as working closely with international partners to reduce transboundary pollution (pollutants blown over from other countries and international shipping) which, at times, can account for a significant proportion of pollutant concentrations experienced in the UK. For example, a 2013 report prepared by the Air Quality Expert Group on behalf of Defra and the Devolved Administrations 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 (Air Quality Expert Group, 2013). Modelling that informed the $PM_{2.5}$ targets set through the Environment Act (2021) reached similar conclusions (Imperial College London, 2022).

2.1 The Air Quality Standards Regulations (2010)

2.1.1 Background to The Air Quality Standards Regulations (2010)

In the UK, the concentrations of a range of pollutants in ambient air are regulated by The Air Quality Standards Regulations (AQSR) (2010) as follows:

- The Air Quality Standards Regulations (2010) (UK Government, 2010) and in England their December 2016 amendment (UK Government, 2016)

- The Air Quality Standards (Scotland) Regulations (2010) in Scotland (Scottish Government, 2010), and their December 2016 amendment (Scottish Government, 2016)
- The Air Quality Standards (Wales) Regulations (2010) in Wales (Welsh Government, 2010)
- The Air Quality Standards Regulations (Northern Ireland) (2010) (Department of Environment Northern Ireland, 2010) and their January 2017 amendment (DAERA, 2017)
- The Environment (Air Quality Standards) Regulations (Gibraltar) and their December 2016 amendment (HM Government of Gibraltar, 2016)**.**

These Regulations have their origins in the following European Union legislation:

- Directive 2008/50/EC of 21 May 2008, on Ambient Air Quality and Cleaner Air for Europe (European Parliament and Council of the European Union, 2008). This is referred to in this report as 'the Air Quality Directive' and 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 previously existing EU air quality legislation relating to the above pollutants

- Directive 2004/107/EC of 15 December 2004 (European Parliament and Council of the European, 2004), relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air. This is referred to as 'the Fourth Daughter Directive' and covers the four elements cadmium, arsenic, nickel and mercury, together with polycyclic aromatic hydrocarbons (PAH).

Following the UK's exit from the European Union, the following amendments were made to the AQSR (2010):

The Air Quality (Amendment of Domestic Regulations) (EU Exit) Regulations SI (2019/74) (UK Government, 2019). This regulation amends the AQSR (2010): it is largely consistent with the AQSR (2010) but allows the PM_{10} fraction attributed to resuspension of particles to be deducted from measurements when influenced by winter sanding and salting of road surfaces. It also transfers responsibilities previous held by EU Member States to the UK Government.

- The Air Quality (Miscellaneous Amendment and Revocation of Retained Direct EU Legislation) (EU Exit) Regulations (2018) (UK Government, 2018) also contains an amendment which transfers responsibilities previously held by EU Member States to the UK Government.

Rules for reporting air quality compliance are contained within the Implementing Decision (European Parliament and Council of the European Commission, 2011) as amended by UK Statutory Instrument No. 1407 Part 2 Regulation 4 (UK Government, 2018).

In addition, concentrations of fine particulate matter are regulated by more recent legislation, The Environmental Targets (Fine Particulate Matter) (England) Regulations (2023) (UK Government, 2023) which are explained in Section 2.2.2.

2.1.2 Provisions of The Air Quality Standards Regulations (2010)

The AQSR (2010) set 'limit values', 'target values', 'long-term objectives' and 'critical levels' for ambient concentrations of pollutants. These are explained below, as well as provisions regarding monitoring, and reporting of data.

Limit values 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 this 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). The UK is legally required to meet the limit values and where there is an exceedance, there is a duty on the Secretary of State to achieve compliance in the shortest possible time.

Target values are set for some pollutants and are configured in the same way as limit values. The UK is legally required to take all necessary measures not entailing disproportionate costs to meet the target values.

For ozone, there are also long-term objectives (LTOs) as well as target values. These are based on the same statistics as the ozone target values but are more stringent and have no specified date by when they should be met. As with target values, the UK is legally required to take all necessary measures not entailing disproportionate costs to meet the LTOs, but achievement is not legally mandatory.

Critical levels are thresholds set for annual mean and winter mean SO_2 concentration in rural areas. These are intended for the protection of ecosystems and are not applicable to built-up areas.

The AQSR (2010) include detailed provisions on the monitoring and reporting of 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 UK has statutory monitoring networks in place to meet the requirements of the above legislation, with air quality modelling used to supplement the monitored data.

2.2 Environment Act (2021): $PM_{2.5}$ Targets

2.2.1 Background to the Targets

The UK Environment Act (2021) (UK Government, 2021) established a duty for the UK Government to set a legally mandatory target in England to reduce $PM_{2.5}$, alongside at least one further long-term target on air quality. The long-term target is part of the wider framework for setting legally binding environmental targets, which also covers biodiversity, water, waste reduction and resource efficiency.

Within this framework, the Environmental Targets (Fine Particulate Matter) (England) Regulations (2023) (UK Government, 2023) came into force in January 2023. These regulations set two new targets: for ambient concentrations of particulate matter measured as $PM_{2.5}$, and for $PM_{2.5}$ population exposure reduction over the period between 2018 and 2040.

These two targets are designed to work together to drive actions that both reduce concentrations where it is highest and reduce the pollution that everyone in the country experiences.

These targets are in addition to the AQSR (2010) and apply only in England. The $PM_{2.5}$ annual mean limit value and the National Exposure Reduction Target for the UK still stand in addition to these new targets.

The meaning of ‘targets’ in this legislation is different to that of ‘target values’ in the AQSR (2010) (which is explained in **Section 2.1.2**). Unlike the ‘target values’, there is a legal requirement to achieve the targets of The Environmental Targets (Fine Particulate Matter) (England) Regulations (2023) by the specified dates.

2.2.2 Provisions of The Environmental Targets (Fine Particulate Matter) (England) Regulations (2023)

The targets apply to England only, and are as follows:

- the annual mean concentration target (AMCT), requires that by the end of 31 December 2040 the annual mean concentration of $PM_{2.5}$ in ambient air must be equal to or less than 10 µg m^{-3} (“the target level”)

- the population exposure reduction target (PERT) is for at least a 35% reduction in population exposure by the end of 31 December 2040 (“the target date”), as compared with the average population exposure in the three-year period from 1 January 2016 to 31 December 2018 (“the baseline period”).

An overview of these targets can be found on the UK-AIR website.

The AMCT will be considered met if, at every relevant monitoring station, the annual mean concentration of $PM_{2.5}$ in ambient air, rounded to the nearest whole number of µg m^{-3}, is equal to or less than the target level in the year 2040. This must be reported by 15 July 2041. All monitoring stations will be included in the assessment, if they have met the minimum annual data capture requirement of 85% of the year. Further information can be found on the UK-AIR website's calculation page.

Population exposure is assessed using the 'Population Exposure Indicator' (PEI), which is a measure of average population exposure in the three-year period ending on 31 December in that year. The PEI is based on measurements from urban background and suburban background monitoring stations, which are representative of the exposure of people living in England. Monitoring stations are only included in any given year's PEI if they have met the minimum annual data capture requirement of 85% of the year. A statistical calculation method is used to accommodate changes in the monitoring network when comparing a given year's PEI against the PEI for the 2018 base year. The above regulations set out in detail how the PERT is calculated, and further information can be found on the UK-AIR website's calculation page.

The Environmental Targets (Fine Particulate Matter) (England) Regulations (2023) outline how compliance should be assessed (including calculation methods) and also specifies the siting criteria for monitoring stations. The siting criteria for monitoring stations are the same as those contained within the AQSR (2010), and they determine the overall location of a monitoring station to ensure it captures representative pollution levels for the targeted area, while also ensuring the equipment accurately samples the air in its immediate vicinity.

2.2.3 Monitoring Progress Towards the Targets

The Environmental Improvement Plan 2023 (Defra, 2023) set interim targets (for England only) and outlines policies to meet these. The interim targets are that by January 2028 annual mean concentrations must be 12 µg m^{-3} or lower and the population exposure (based on the PEI for that year) must be reduced by at least 22% compared to 2018. The assessment method for the interim 2028 targets is the same as described above for the long-term 2040 targets.

The Environment Act (2021) established a framework for reporting and reviewing all Environment Act targets. Progress is reported annually, and the Environmental Improvement Plan is updated at least every five years.

Data on progress towards these $PM_{2.5}$ targets (and more information on how this is calculated) is published on the UK-AIR website's progress page.

2.3 The National Emission Ceilings Regulations (2018)

The National Emission Ceilings Regulations (NECR) (2018) (UK Government, 2018a) sets emission reduction commitments (ERCs) for anthropogenic (originates from human activity) emissions of oxides of nitrogen (NO_X), oxides of sulphur (SO_X), non-methane volatile organic compounds (NMVOC), ammonia (NH_3) and particulate matter as $PM_{2.5}$ to be met between 2020 to 2029 and to be met from 2030 onwards. The revised National Emission Ceilings Directive (European Parliament and Council of the European Union, 2016) came into force on 31 December 2016. This revised Directive was transposed into UK legislation in February 2018 via the NECR (2018) and the new UK legislation came into force on 1 July 2018 (UK Government, 2018a). Regulations 9 and 10 of the NECR (2018) and Commission Implementing Decision 2018/1522 concerning the preparation and publication of a National Air Pollution Control Programme (NAPCP) were revoked at the end of 2023 under the provisions of the Retained EU Law Act[2].

The Gothenburg Protocol (United Nations Economic Commission for Europe (UNECE), 1999) was revised in May 2012 to set emission reduction commitments (ERCs) for 2020 and beyond (from the 2005 baseline) for NO_X, NMVOC, NH_3, SO_X and $PM_{2.5}$. Under the NECR and Gothenburg Protocol, the UK is required to prepare and annually update national emissions inventories for these and a number of other air pollutants. The UK is part of negotiations to revise the 2012 amended Gothenburg Protocol to set new commitments to further reduce transboundary air pollution across the region. Negotiations are expected to conclude by 2027. The Gothenburg Protocol is part of the Convention on Long-Range Transboundary Air Pollution (CLRTAP) of the United Nations Economic Commission for Europe.

In 2023 (the most recent year for which data have been reported), the UK met domestic and international 2020 and beyond emission reduction commitments for emissions of fine particulate matter as $PM_{2.5}$, NOx, SO_2, NMVOCs, and for ammonia (NH_3) with the inclusion of an approved adjustment. Under this adjustment, ammonia emissions from the application of non-manure digestates to land (referring to the solid substances produced by anaerobic digestion processes, which can be used as fertiliser) are excluded for compliance purposes. Under existing regulations an adjustment is permitted in certain cases, for example where a source was not in the inventory when the commitments were set but was later added to the inventory as an improvement, as was the case with the application of non-manure digestates to land. As required, the UK submitted an adjustment application to the UNECE, which was reviewed and accepted by UNECE experts. To fulfil the reporting requirements under the Convention for Long Range Transboundary Air Pollution (CLRTAP) and in the NECR, the UK compiles and reports its

[2] Retained EU Law (Revocation and Reform) Act 2023 (legislation.gov.uk)

air pollutant emissions inventory on an annual basis. The latest emissions data available are for the year 2023 and can be found on the NAEI website's data page.

2.4 The Environmental Permitting Regulations (EPR 2016 and 2018)

The Environmental Permitting (England and Wales) Regulations (2016) (as amended) (EPR) set standards and 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. The EPR aims to prevent or minimise pollution from industrial sources and therefore protect the environment and human health. Equivalent legislation, referred to as Pollution Prevention and Control (PPC), exists in Scotland (Scottish Government, 2018) and Northern Ireland (Department of Environment Northern Ireland, 2013).

Under the EPR and PPC legislation, industrial facilities must obtain an environmental permit which sets out conditions including limits on allowable emissions and ongoing monitoring requirements. Permit conditions are based on the application of Best Available Techniques (BAT). BAT means the economically and technically viable techniques or technologies which are the best for preventing or minimising emissions and impacts on the environment as a whole. The UK is committed to maintaining high environmental standards and has put in place a process for determining future BAT for the largest industries. Since 2021, the UK Government, jointly with the devolved governments, has operated the UKBAT regime for tackling industrial emissions from our largest industry in an integrated way. The regime is based on the principles followed since the UK originally devised the concept; a detailed, transparent, collaborative, data-led process that builds on existing high levels of environmental protection. This approach has significantly reduced industrial pollution over the past three decades.

2.5 Policies to Improve UK Air Quality

Domestic, EU and internationally driven environmental legislation introduced over the past seventy years has provided a strong impetus to reduce the levels of harmful air pollutants in the UK. As a result, current concentrations of many recognised pollutants are now at the lowest they have been since measurements began. The UK's 1956 Clean Air Act tackled city smog caused by domestic and industrial coal burning, and significant progress has continued to improve air quality throughout subsequent decades. Between 1970 and 2023 (the most recent year for which estimates are available), UK estimated emissions of nitrogen oxides have fallen by 80%, UK estimated emissions of PM_{10} particulate matter have fallen by 84% and UK estimated emissions of $PM_{2.5}$ particulate matter have fallen by 90% (Defra, 2025a).

The UK Government is addressing the issue of particulate pollution via The Environmental Targets (Fine Particulate Matter) (England) Regulations (2023), summarised in Section 2.2 above.

The Environment (Air Quality and Soundscapes) (Wales) Act (2024) (Welsh Government, 2024) received Royal Assent on 14 February 2024. The Act includes provisions for a national air quality target setting framework, with specific duties for Welsh Ministers to set a short or long-term target for the annual mean level concentration of $PM_{2.5}$ in ambient air and to set an additional long-term target in respect of one of the following listed pollutants: ammonia; PM_{10}; ground level ozone; nitrogen dioxide; carbon monoxide; and sulphur dioxide. The Act requires that regulations setting a $PM_{2.5}$ target are laid before Senedd Cymru within three years of the Act receiving Royal Assent, and that regulations setting a long-term target in respect of one of the listed pollutants are laid before Senedd Cymru within six years of the Act receiving Royal Assent. The Act also includes powers for Welsh Ministers to set long-term targets in respect of any matter relating to air quality in Wales.

The Act builds on our commitments in the Clean Air Plan for Wales; Healthy Air, Healthy Wales, enhancing existing legislation and delivering air quality improvements. This will improve the quality of our air environment and reduce the impacts of air and noise pollution on human health, biodiversity, the natural environment and our economy.

In Northern Ireland, a draft Climate Action Plan 2023 to 2027 is out for public consultation at the time of writing. It contains a proposed air quality target which states that “in 2025 DAERA will engage with other departments and key delivery organisations, with a view to considering the feasibility of implementing new regulations that would bring into operation tighter annual average limits/targets/objectives for $PM_{2.5}$ and PM_{10}, in line with interim target 4 of the World Health Organisation Air Quality Guidelines 2021 of 10 and 20 µg m^{-3} respectively.”

2.5.1 Environmental Improvement Plan 2023

The Environmental Improvement Plan 2023 (EIP) (Defra, 2023) was the first five-yearly statutory review[3] of the 25 Year Environment Plan. The EIP applies to England only and sets out how the Government will improve all aspects of the environment. The Clean Air chapter of the EIP updated the 2019 Clean Air Strategy. Under the Environment Act, two legally binding long-term targets to reduce concentrations and drive down people’s exposure to $PM_{2.5}$ have been set. The EIP sets interim targets against both of these long-term targets. The Government has concluded a rapid review of the existing EIP and published a statement of the review’s key findings. It will publish a revised EIP to protect and restore our natural environment. This will be a clearer, prioritised plan for achieving environmental outcomes such as reducing waste across the economy, planting more trees, improving air quality and halting the decline in species.

Progress towards meeting the goals set out in the EIP is published in an annual report.

[3] Environment Act 2021 (legislation.gov.uk) chapter 1, reg 10

2.5.2 Air Quality Strategy 2023

The Air Quality Strategy 2023 fulfils the statutory requirement of the Environment Act 1995 (as amended by the Environment Act 2021) to publish a national air quality strategy setting out air quality standards, objectives, and measures for improving ambient air quality every five years. The Strategy published in April 2023 replaces the 2007 version; it applies in England only, including London. The 2007 Strategy (Defra, 2007) remains in force in Northern Ireland until the Clean Air Strategy for Northern Ireland is published. The Scottish Government intends to publish a replacement to the 2007 version, and until then that version remains in force. In addition, the Scottish Government's Cleaner Air for Scotland 2 strategy sets out the current air quality policy framework in Scotland (Scottish Government, 2021). The Clean Air Plan for Wales: '*Healthy Air, Healthy Wales*', published in 2020 (Welsh Government, 2020), sets the 10-year strategic direction across multiple policy areas. This now forms the National Air Quality Strategy for Wales, in place of the 2007 UK Strategy but retaining the air quality objectives. In April 2023 Welsh Government published an Update Report on Progress Against Actions in the Clean Air Plan for Wales (Welsh Government, 2023).

The Air Quality Strategy 2023 sets out the actions the Government expects local authorities to take in support of achieving our long-term air quality goals, including the new Environment Act $PM_{2.5}$ targets. It provides a framework to enable local authorities to make the best use of their powers and deliver for their communities.

There is an existing suite of air quality publications to which local authorities can refer; a comprehensive list can be found at Annex B of the Air Quality Strategy 2023. This includes local guidance as well as national strategies and plans. These documents set out actions that the UK Government will take to improve air quality. The Air Quality Strategy complements rather than replicates or replaces these publications and is a locally focused document to enable local authorities to clearly understand their role, responsibilities and powers relating to air quality. The Strategy sets out a strong support and capability-building framework to ensure local authorities have the necessary tools to take local action, supporting progress towards local and national targets.

The Department of Agriculture, Environment and Rural Affairs (DAERA) is finalising Northern Ireland's first Clean Air Strategy, driven by the need to protect public health. In autumn 2020, a Discussion Document was issued to public consultation. It invited views on a range of matters relating to air quality and was an opportunity for stakeholders to put ideas to the Department. The consultation closed in spring 2021 and responses were analysed in detail. A synopsis of the responses, along with the Discussion Document, has been published. DAERA is working with the other departments to finalise this important cross-cutting Strategy.

DAERA held a public consultation on the draft Ammonia Strategy for Northern Ireland from January to March 2023. A High-Level Report and a Summary Report of responses to the consultation on the draft Ammonia Strategy have been published[4]. Additional consultation then took place on the two proposed mandatory measures in the draft Ammonia Strategy as part of the public consultation on DAERA's proposed Nutrients Action Programme for 2026 to 2029 from May to July 2025.

2.5.3 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, 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. More information can be found on the UK-AIR website's DAQI page.

The group of pollutants covered, and the thresholds between the various index bands, were updated by Defra as of 1 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 (COMEAP, 2011). In December 2021, Defra (with support from DHSC and UKHSA) launched a comprehensive review into the way air quality information is communicated to the public. This review is being guided by an independent steering group of multidisciplinary experts. As part of the review process the steering group will make recommendations for any improvements that should be made to the Daily Air Quality Index. Progress on the air quality information system review is being published on the UK-AIR websites air quality systems review page.

Currently, 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, X (formerly Twitter) and RSS feeds. Anyone may subscribe to the free air pollution bulletins by using the UK-AIR website's subscription service. Latest forecasts are issued daily, available from the UK-AIR website's forecasting page. Defra also provides automated updates on current and forecasted air quality via X @DefraUKAIR, and a free telephone information service, with current air pollution levels and forecasts updated every hour. To use this service, call 0800 556677 and follow the instructions.

2.5.4 NO_2 Air Quality Plans

The UK Government has provided £576 million to help local authorities tackle exceedances of the NO_2 annual mean limit value and achieve compliance with legal limits for NO_2 in the shortest possible time. This funding supports local authorities to deliver their air quality measures to improve the health of their residents and meet legal limits for NO_2.

[4] https://www.daera-ni.gov.uk/consultations/draft-ammonia-strategy-northern-ireland-consultation

These air quality measures have been varied and highly targeted, including traffic management schemes, engineering solutions, grants and loans for vehicle upgrades and encouraging behavioural change. Clean Air Zones were implemented in Bath, Birmingham, Bradford, Bristol, Portsmouth, Sheffield and the Tyneside conurbation covering Newcastle and Gateshead between 2021 and 2023, encouraging the use of cleaner vehicles in these areas. The support provided to local authorities includes funding to help them mitigate the impact of their plans on individuals and businesses. Local authorities have used this funding to provide grants to individuals and businesses to upgrade their fleets, Electric Vehicle (EV) charging infrastructure and discounted access to public transport. In July 2025, the Government announced a £28m grant to fund zero-emission buses and charging infrastructure to target NO_2 hotspots in Bradford and Sheffield.

Government assesses whether a local authority has successfully delivered sustained compliance with NO_2 legal limit values, and whether this is likely to be maintained if the local authority wishes to remove measures. At this point the legal obligation to continue with measures will expire and the local authority can exit the NO_2 Programme. The assessment that informs this process is separate to the national assessment of compliance with limit values, although it shares some of the same evidence (data from the Automatic Urban and Rural Network and the UK Urban NO_2 Network).

Welsh Government funding of over £25m has been supporting two Welsh local authorities to introduce measures to tackle exceedances. In both cases, feasibility studies ruled out charging Clean Air Zones as alternative measures were identified which would be at least as effective at reducing NO_2 and could be delivered more quickly. Measures delivered include building demolition to allow for greater dispersion of air pollutants and city centre infrastructure schemes to reduce general vehicle access and enhance active travel and public transport connections. Reduced 50mph speed limits, with average speed enforcement, have been applied on the motorway and trunk road network to help lower emissions where NO_2 exceedances were identified. The Welsh supplemental plan was published in November 2018.

Scotland has introduced Low Emission Zones for the improvement of air quality in four cities: Glasgow, Aberdeen, Dundee and Edinburgh. These were introduced on 31 May 2022, with local grace periods of between 12 and 24 months in place prior to enforcement starting. In Glasgow, a LEZ restriction for buses began in 2018: enforcement for other vehicle types started on 1 June 2023 (a year later for residents within the zone). LEZ enforcement began on 30 May 2024 in Dundee, and on 1 June 2024 in Edinburgh and Aberdeen.

To help lower income households and small businesses adapt to LEZs, the Scottish Government has provided financial support towards the disposal of non-compliant vehicles. A total of £15m has been paid out through a LEZ support scheme since 2019 that has seen over 4,000 non-compliant high polluting vehicles disposed of. A further £2m is allocated for 2025 to 2026.

A separate LEZ Retrofit Fund has provided over £4m grant funding for taxi retrofits in Scotland since 2019. This has seen over 560 taxis retrofitted to Euro 6 standard. A further £1m was made available in 2024 to 2025.

A total of £24m in grants has been awarded by the Scottish Government through the Bus Emission Abatement Retrofit (BEAR) programme, allowing over 1100 midlife buses/coaches to be retrofitted with equipment designed to reduce tailpipe air pollutant emissions since 2018.

Since 2018/19 significant funding has been made available to local authorities, transport operators and the general public to support LEZ introduction. Other Scottish local authorities with Air Quality Management Areas have completed assessments to determine whether an LEZ would be an appropriate intervention in their areas.

The Scottish Government also provides a total of £1.6 million per year to support local authority air quality work, spends over £2 billion per year on public transport and has committed to investing at least £188 million on active travel in 2025 to 2026.

In Northern Ireland, DAERA operates a funding mechanism for Local Air Quality Management (LAQM) which councils can apply for to enable them to help meet their obligations under the provisions of Part III of the Environment (Northern Ireland) Order (2002). Furthermore, as air quality is a cross-cutting issue, a number of other Northern Ireland Departments play a role. For example, the Climate Change Act (Northern Ireland) (2022) requires the Department for Infrastructure to develop sectoral plans for transport which set a minimum spend on active travel from the overall transport budgets of 10%.

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

The Air Quality Standards Regulations (2010) set target values for a number of metallic elements including nickel and for benzo[a]pyrene (B[a]P). The UK exceeded target values for B[a]P and nickel during all years from 2013 to 2023 inclusive, except for nickel in 2017. The year 2024 was the first year in which the UK was fully compliant with the target value for B[a]P. However, some zones still exceeded the target value for nickel.

These exceedances are reported as part of the UK's annual compliance assessment. For details of previous exceedances please see earlier 'Air Pollution in the UK' reports in this series.

The UK published reports providing details of the assessment of the exceedances in years 2013 to 2022. 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 explain that the UK Government is taking steps to address all the exceedances through existing long-term measures and through improvements in their understanding to help target measures appropriately. The nickel overview report details existing and new measures put in place and the continued work with environmental regulators to improve understanding and management of these exceedances.

B[a]P and nickel Reports on Measures are available on the UK-AIR website. At the time of writing, the 2022 reports are the most recent in the series. The 2023 reports will be published in December 2025.

2.6 Local Authority Air Quality Management

Requirements for local air quality management (LAQM) are set out in Part IV of the Environment Act (1995) (UK Government, 1995) as amended by the Environment Act (2021) (UK Government, 2021), and the Environment (Northern Ireland) Order (2002) (Northern Ireland Government, 2002). 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 not to have been achieved, or areas where it is thought there is a risk that they will not be achieved.

Local authorities in England, Scotland, Wales and Northern Ireland undertake Review and Assessment against the objectives prescribed in The Air Quality (England) Regulations (2000) (UK Government, 2000), The Air Quality (Scotland) Regulations (2000) (Scottish Government, 2000), Environment (Air Quality and Soundscapes) (Wales) Act (2024) (Welsh Government, 2025), The Air Quality (Wales) Regulations (2000) (Welsh Government, 2000) and The Air Quality (Northern Ireland) Regulations (2003) (Northern Ireland Government, 2003), together with subsequent amendments (UK Government, 2002), (Welsh Government, 2002), (Scottish Government, 2002)**,** (Scottish Government, 2016).

With regards to LAQM statutory reporting requirements, in 2018, authorities in Wales adopted reporting in the form of an Annual Progress Report in line with the streamlined LAQM regime (Welsh Government, 2017). The Welsh Government has since published updated guidance for Local Authorities to help them deliver their obligations in relation to Local Air Quality Management and the four Smoke Control Areas in Wales (Welsh Government, 2025). In England and Scotland, reporting in the form of the adopted Annual Status / Progress Reports has continued (Defra, 2022) (Scottish Government, 2023), whilst London authorities continued working against the revised London-specific London Local Air Quality Management policy guidance (Mayor of London, 2019) through the preparation of Annual Status Reports. District Councils in Northern Ireland are required to carry out their appraisal of local air quality on a three-yearly cycle, producing an Updating and Screening Assessment every three years, with shorter Progress Reports in the years in between. Northern Ireland’s District Councils produced their most recent Updating and Screening Assessments in 2024, the start of the ninth round of the review and assessment cycle in Northern Ireland. These are available from the Northern Ireland Air website.

When the Review and Assessment process identifies an exceedance of an air quality objective, the local authority must declare an ‘Air Quality Management Area’ (AQMA) and develop an Action Plan to reduce pollutant concentrations in the affected areas. Action

Plans formally set out the measures the local authority proposes to take. As of 2022, local authorities in England (including London) must now state a date by which each measure will be carried out to secure achievement of air quality objectives. Actions may include a variety of measures such as traffic management, behaviour change campaigns or sustainable freight. In England, excluding London, all local authorities are expected to take proactive action to improve air quality, whether or not they have an AQMA. Local authorities without an AQMA, should specify proactive measures they will take in their Air Quality Strategy.

Information on AQMAs in the UK is summarised in **Table 2-1** below. At the time of writing (September 2025), 223 Local Authorities (61.8 per cent 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.

Table 2-1 Current UK-wide status of AQMAs (as of September 2025).

Region	Total LAs	LAs with AQMAs	AQMAs for NO_2	AQMAs for PM_{10}	AQMAs for SO_2
England (outside London)	263	159	352	20	4
London	33	33	35	28	0
Scotland	32	11	15	11	0
Wales	22	11	32	1	0
Northern Ireland	11	9	16	2	0
TOTAL	**361**	**223**	**450**	**62**	**4**

Most AQMAs in the UK are in urban areas and have been established to address the contribution to air pollution from roadside 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.

Where an AQMA is declared, the local authority specifies the main sources of pollutants involved – for example road transport, industrial emissions or domestic sources, or a mixture of several. The methodology for counting AQMAs by source has changed since the 2022 report in this series: the number of AQMAs by source is now split by geographic area rather than pollutant type. This is summarised in **Table 2-2**.

Table 2-2 Current UK Air Quality Management Areas by Source (as of September 2025)

Source	England	Wales	Scotland	Northern Ireland	London
County or Unitary Authority Road	123	14	4	0	1
Domestic Heating	1	0	0	1	0
Strategic Road Network	23	0	0	0	0
Industrial Source	7	1	0	0	0
Mixture of Road Types	58	5	1	1	2
Not Defined	1	0	0	2	0
Road Transport (unspecified)	138	14	14	14	27
Transport and Industrial Source	11	0	1	0	4
Transport, Industrial and Domestic Sources	3	0	0	0	2

Data from the UK-AIR website's AQMA summary page

For up-to-date information on AQMAs throughout the UK, please refer to the interactive AQMA map on UK-AIR. This interactive map provides information on the location of the AQMA, the date it was declared, the pollutants for which it was declared, and information on the type of pollutant sources.

2.7 Official Statistics and Indicators

2.7.1 Air Quality in the UK - Accredited Official Statistics

For many years, the UK has reported the following two indicators as Accredited Official Statistics for ambient air quality:

- **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 2.5.3 which deals with forecasting). From the 1 January 2012, $PM_{2.5}$ particles replaced carbon monoxide in the pollutants featured in this publication. 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 sites.

The latest Accredited Official Statistics for Air Quality, were released on 27 Jun 2025.

2.7.2 Emissions of Air Pollutants - Accredited Official Statistics

The UK reports annual emissions estimates for the following pollutants as annual Accredited Official Statistics, Emissions of Air Pollutants. This is a large publication comprising multiple sections: there is a summary section and a background section, as well as individual sections for each pollutant which are summarised below.

- 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 Accredited Official Statistics Release covers 1990 to 2023 (the most recent year for which emission statistics are available). The main conclusions are as follows:

- 'Emissions of sulphur dioxide have decreased by 97 per cent since 1990, to 95 thousand tonnes in 2023. This was driven by a decline in coal use in energy industries. Emissions from the combustion of coal in energy industries decreased by 83 per cent of 1990 levels by 2005, following which they decreased by almost 100 per cent from 2005 levels through to 2023. Stricter limits being placed on the sulphur content of liquid fuels has also reduced emissions in the long-term. Emissions of sulphur dioxide decreased by 5 per cent from 2022 to 2023 reaching the lowest level since emissions estimates have been calculated.' From Section 2 of 'Sulphur Dioxide'.

- 'Emissions of NOx have decreased by 79 per cent since 1990, to 602 thousand tonnes in 2023. This trend was driven by a decline in coal use in power stations and industrial sites and by the modernisation of the road transport fleet. Emissions of NOx decreased by 6 per cent between 2022 and 2023. This continues the long-term decline since 1990 as total emissions have decreased on average by 5 per cent per year between 1990 and 2023'. From Section 2 of 'Nitrogen Oxides'.

- 'Emissions of NMVOCs decreased by 73 per cent since 1990, to 756 thousand tonnes in 2023. Emissions decreased by 1 per cent between 2022 and 2023. NMVOC emissions decreased on average by 5 per cent per year between 1990 and 2009. This was largely due to improvements to emissions standards for road transport and stricter limits applied to industrial processes. However, more recently annual changes have been much smaller, emissions decreased on average by 2 per cent per year since 2009.' From Section 2 of 'Non-methane volatile organic compounds (NMVOCs)'

- ‘Emissions of ammonia have decreased by 14 per cent since 1990, to 265 thousand tonnes in 2023. The majority of this reduction occurred between 1990 and 2008. Emissions of ammonia then remained relatively stable from 2008 to 2013. Annual ammonia emissions reached the lowest in the time series in 2013 at 257 thousand tonnes. Since then, emissions have been higher but have remained below the levels seen prior to the mid-2000s. Changes in the trend of emissions of ammonia are largely driven by changes to farming practices and herd sizes.’ From Section 2 of ‘Ammonia’.

- ‘Annual emissions of PM_{10} have decreased by 70 per cent since 1990, to 113 thousand tonnes in 2023. They have decreased by 8 per cent between 2022 and 2023. Annual emissions of $PM_{2.5}$ have decreased by 76 per cent since 1990, to 56 thousand tonnes in 2023. They have decreased by 6 per cent between 2022 and 2023. In the UK $PM_{2.5}$ emissions decreased by 47 per cent between 2005 and 2023. Therefore, in 2023, the UK met the 30 per cent emission reduction commitment required between 2020 to 2029 as set out in the National Emission Ceilings Regulations (NECR). Emissions of particulate matter generally decreased between 1990 and the early 2000’s. There are many reasons for this long-term decrease, which covers most emissions sources, but the reduction in the burning of coal and improved emission standards for transport and industrial processes are major drivers. Since the late 2000s annual emissions of PM have generally continued to fall, but the rate of change has reduced. Compared to earlier decades, emission levels have been relatively steady with small annual fluctuations. In these more recent years, considerable decreases in emissions from some sources (e.g. from road transport and energy industries) have been partly offset by increases in emissions from other activities, such as wood burning in domestic settings and the burning of biomass-based fuels in industry. In 2020 PM emissions fell at a greater rate than in recent years due to reduced activity across a number of emissions sources. Whilst there was a small increase in 2021, the overall downward trend has continued. In 2023 $PM_{2.5}$ and PM_{10} emissions were at the lowest level since emission estimates have been calculated. Emissions of particulate matter fell from 2022 to 2023, in part due to a fall in emissions from construction and quarrying activity, as well as reduced emissions from product use.’ From Section 2 of ‘Particulate Matter (PM_{10} and $PM_{2.5}$).

Updated statistics for UK Emissions of Air Pollutants, containing data up to 2024, will be published in February 2026.

2.7.3 Indicators

The UK Government's Public Health Outcomes Framework for England 2016 to 2019 (Department of Health and Social Care, 2016) recognises the burden of ill-health resulting from poor air quality as well as other public health concerns. This framework includes a metric for assessing the impact of ambient air pollution within its 60 health outcome indicators, ensuring that public health officials monitor and consider the adverse effects of air pollution. The indicator is described as:

- 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, $PM_{2.5}$).

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 ($PM_{2.5}$). Annual estimates of the percentage of mortality attributable to long term exposure to particulate air pollution in England are available from the Public Health Outcomes Framework data tool. The most recent estimate for England at the time of writing, which is based on year 2023, is 5.2 per cent.

As part of Northern Ireland's Programme for Government (PfG) 2024-2027 'Our Plan: Doing What Matters Most' a Wellbeing Framework has been designed to identify areas of concern and help the Northern Ireland Executive to understand if projects and programmes are working for everyone. It can be found on the Wellbeing Framework page and contains a specific air pollution indicator measuring annual mean roadside levels of nitrogen dioxide.

Wales has a national indicator under the Well-being of Future Generations (Wales) Act 2015 and the Welsh Public Health Outcomes Framework, which has been published online on StatsWales. Guidance has also been published for public health professionals in supporting the collective management of air quality across Wales, in an online report: Working together to reduce outdoor air pollution, risks and inequalities.

The Scottish Government's National Performance Framework includes 81 National Indicators, many of which relate to environmental and human health.

Defra's Air theme within the Outcome Indicator Framework, which was developed to show progress towards achieving the desired outcomes in the 25 Year Environment Plan, includes metrics which track air pollution sources, atmospheric concentrations, and environmental impacts across England. This contains two indicators relating to the impacts of air pollution on ecosystems (Indicators A6 & A7), and more detail on these impacts can be found in an annual Air Pollution Trends Report available on the UK-AIR website.

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 and the Devolved Administrations. These needs include assessment of compliance with legislation, 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 Air Quality Standards Regulations (2010). It describes the air pollutants which are of concern and how these are monitored and modelled in the UK.

3.1 Pollutants of Concern

This section summarises the sources and effects (both on human health and the environment) of the pollutants being assessed in relation to The Air Quality Standards Regulations (2010).

The information on sources has largely been summarised from the National Atmospheric Emission Inventory (NAEI) website's pollutant information pages (National Atmospheric Emissions Inventory, 2025), together with Table 1 of the Air Quality Strategy (Defra, 2007). Information on health effects has been summarised from reports produced by the World Health Organization (WHO), the Expert Panel on Air Quality Standards (EPAQS) and the Committee on the Medical Effects of Air Pollutants (COMEAP). It is estimated that long-term exposure to the air pollution mixture in the UK has an annual effect equivalent to 29,000 to 43,000 deaths for adults aged 30 and over (UK Health Security Agency, 2022a).

3.1.1 Oxides of Nitrogen

There are several oxides of nitrogen. The ones of most interest in relation to air quality are nitric oxide (NO) and nitrogen dioxide (NO_2). Together, they are often referred to as NO_X. Nitrogen oxides are emitted from combustion processes, with combustion from industry, passenger cars and other transport being the most important UK sources (National Atmospheric Emissions Inventory, 2025).

NO_2 is a respiratory irritant: short-term exposure to concentrations of NO_2 higher than 200 µg m^{-3} can cause inflammation of the airways and may increase susceptibility to respiratory infections (WHO, 2013). There is a high level of confidence that short-term exposure to NO_2 in outdoor air is associated with all-cause mortality (Orellano, et al., 2020). It has been difficult to identify the direct health effects of NO_2 at ambient concentrations because it is often emitted from the same sources as other pollutants such as particulate matter (PM). However, the WHO's REVIHAAP study (WHO, 2013), COMEAP's 2015 statement, (COMEAP, 2015) and COMEAP's 2018 report on associations of mortality with NO_2 have reported increasing evidence that NO_2 itself is responsible for health effects (COMEAP, 2018) . NO is not considered harmful to human health at the concentrations usually found in ambient air but is quickly oxidised to form NO_2.

NO_X can contribute to the formation of other pollutants. In the presence of sunlight, NO_X can react with volatile organic compounds (VOCs) to produce photochemical pollutants, including ozone. NO_X also contributes to particulate pollution, via the formation of secondary nitrate particles in the atmosphere.

NO_X can be damaging to the environment. High levels of NO_X deposition can harm plants. It contributes to acidification and eutrophication of terrestrial and aquatic ecosystems, damaging habitats and leading to biodiversity loss.

Peak hourly mean NO_2 concentrations in the UK very rarely exceed applicable limit values, except at some congested urban roadside sites – the last occurrence was in 2019. Prior to 2020, annual mean limit values were frequently exceeded at roadside sites in the UK, and in many other countries. The extent of these exceedances was substantially reduced in 2020, and in subsequent years have remained low in comparison with pre-2020 years (see Sections 4 and 6 for details).

3.1.2 Ozone

Ozone (O_3) is a secondary pollutant produced by the effect of sunlight on NO_X and VOCs from sources such as vehicles and industry. O_3 concentrations are therefore typically highest in the summer on hot, sunny, windless days, or days when moderate breezes blow ozone (and other pollutants which contribute to its formation) across from continental Europe.

In the upper atmosphere the O_3 layer has a beneficial effect, absorbing harmful ultraviolet radiation from the sun. However, ground level ozone is a pollutant, which irritates the respiratory system and eyes. High levels may exacerbate asthma or trigger asthma attacks in susceptible people and some non-asthmatic individuals may also experience chest discomfort. Evidence is also emerging of links with cardiovascular and metabolic effects, and effects due to long-term exposure**.**

O_3 can cause damage to many plant species, leading to loss of yield and quality of crops, damage to forests and impacts on biodiversity. O_3 is also a greenhouse gas implicated in climate change. It can travel long distances, accumulate, and reach high concentrations far away from the sources of the pollutants that contributed to its formation. NO_X emitted in cities reduces local O_3 concentrations as NO reacts with O_3 to form NO_2: therefore, levels of O_3 are often higher in rural areas than urban areas.

The UK has been compliant with applicable target values since 2009, but most years see the more stringent long-term objectives exceeded in some areas. Weather conditions during the year determine how widespread such exceedances are.

3.1.3 Particulate Matter: PM_{10} and $PM_{2.5}$

PM_{10} 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 sources of primary PM_{10} particulate emissions in the UK are: combustion in production processes; industrial, residential and commercial fuel use; agriculture; waste treatment, and road transport. In recent years, emissions from residential combustion have increased as a percentage of the UK total, because of increased use of wood as a domestic fuel. This has offset reductions that have occurred due to the decreasing use of coal and other solid fuels. Emissions of particulate matter from road transport include both tailpipe emissions, tyre and brake wear, and road abrasion. Natural sources include wind-blown dust, sea salt, pollens, and soil particles. Like PM_{10}, the finer size fraction $PM_{2.5}$ can be primary or secondary: primary $PM_{2.5}$ has the same main emission sources.

Research shows a range of health effects, including respiratory and cardiovascular illness, cancer, neurodegenerative conditions and mortality, associated with PM_{10} and $PM_{2.5}$ (COMEAP, 2006), (COMEAP, 2009), (COMEAP, 2010), (COMEAP, 2018a), (COMEAP, 2022). No threshold has been identified below which no adverse health effects occur.

$PM_{2.5}$ 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.

The UK has been compliant with applicable limit values for PM_{10} and $PM_{2.5}$ for over a decade. Nonetheless, public health benefits would be expected from further reductions, given that the available evidence has not suggested a threshold for effects. The new $PM_{2.5}$ targets in England were introduced to deliver further reduction.

The environmental effects of particulate pollution are associated with two components of PM: black carbon, which is implicated in climate change, and secondary PM which includes sulphate, nitrate and ammonium. The latter is formed from SO_2, NO_X and NH_3 which are the main drivers for acidification and eutrophication.

3.1.4 Sulphur Dioxide (SO_2)

This acid gas is formed when fuels containing sulphur impurities are burned. The largest UK source of SO_2 is from fuel burning in residential, industrial and commercial settings. It is a respiratory irritant that can cause constriction of the airways, and people with asthma are considered to be particularly sensitive. Health effects can occur rapidly, making short-term exposure to peak concentrations important (COMEAP, 2011) (WHO, 2021).

SO_2 deposition is harmful to plants at high concentrations. It 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.

Ambient concentrations of SO_2 in the UK have not exceeded applicable limit values or objectives since 2004.

3.1.5 Carbon Monoxide (CO)

CO is produced when fuels containing carbon are burned with insufficient oxygen to convert all carbon inputs to carbon dioxide (CO_2). Residential fuel use and other stationary combustion are now the largest UK emission sources of CO; road and other transport now account for smaller, but still significant, proportions of emissions (National Atmospheric Emissions Inventory, 2025).

The effects of high levels of CO on human health are well-known, and long-term low-level exposure may also lead to adverse health effects (UK Health Security Agency, 2022). CO is toxic: it affects the ability of the blood to take up oxygen from the lungs and can lead to a range of symptoms, causing death at high concentrations. However, 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. In the environment, CO can contribute to the formation of ground-level ozone.

The UK has been compliant with all applicable limit values for CO since 1999.

3.1.6 Benzene (C_6H_6)

Benzene (C_6H_6) is an organic chemical compound. It is a hydrocarbon (i.e. composed of carbon and hydrogen) and is a natural component of fossil fuels like crude oil and coal. Ambient benzene arises from domestic and industrial combustion processes, in addition to road transport (Defra, 2007).

Benzene is known to cause leukaemia and potentially other cancers in humans (UK Health Security Agency, 2019a). No safe level can be specified for benzene in ambient air; however, the risk increases with increased exposure. In the environment, benzene can pollute soil and water, leading to exposure via these routes.

Annual mean concentrations of benzene are now low (within limit values and objectives applicable in the UK) due to the introduction of catalytic converters on car exhausts in the 1990s and reductions in the maximum benzene content of petrol from 5% to 1 % in 2000. The UK has been compliant with all applicable limit values for benzene since measurements began in 2003.

3.1.7 Lead (Pb)

Lead (Pb) is a metallic element. Historically, Pb was used as an additive in petrol, and road vehicles were the main source of airborne Pb. Leaded petrol was phased out in 1999, resulting in a 98% reduction to date compared with pre-1999 UK emissions. Today, the main sources are production processes and transport. However, the contribution from transport comes not from tailpipe emissions but tyre and brake wear (National Atmospheric Emissions Inventory, 2025). Recent research has found that airborne particulate matter in cities is still ‘enriched’ with Pb, likely due to emissions from historic combustion of leaded petrol (Resongles, et al., 2021).

Inhalation of Pb can affect red blood cell formation and harm the kidneys, circulatory system, gastrointestinal tract, the joints, reproductive systems, and can cause acute or chronic damage to the central nervous system. The unborn child and young children are the most sensitive to lead toxicity (UK Health Security Agency, 2016). Long-term low-level exposure has been shown to affect intellectual development in young children and the unborn child (EPAQS, 2009).

In the environment, Pb can pollute soil and surface waters. Exposure to contaminated soil and water may then become a health risk. Pb may accumulate in other organisms such as fish and be passed up the food chain. The UK has been compliant with applicable limit values for ambient Pb in air for over 20 years.

3.1.8 Nickel (Ni)

Nickel (Ni) is a metallic element found in ambient air as a result of releases from oil and coal combustion, metal processes, manufacturing and other sources. Currently the main UK emission source is the combustion of petroleum coke, solid fuels containing petroleum coke, and heavy fuel oil, in residential and industrial settings (National Atmospheric Emissions Inventory, 2025). A small number of UK zones continue to regularly exceed applicable target values for annual mean Ni, due to local industrial emissions. There are annual plans published which report the actions and measures already taken or planned, to help the UK meet the target values in the future (Defra, 2023a).

Ni and its compounds are toxic by inhalation, ingestion and skin contact. Ni compounds can cause cancer in humans. Ni can cause irritation to the nose and sinuses (UK Health Security Agency, 2014)

As well as ambient air, Ni can pollute soil and water, leading to exposure via these routes.

3.1.9 Arsenic (As)

Arsenic (As) is a metalloid which occurs naturally in the environment. As is emitted into the atmosphere in the form of particulate matter. Historically the largest source was coal combustion, but this has declined: the largest UK source of As emissions is now the open burning of treated wood as waste (National Atmospheric Emissions Inventory, 2025). The UK has been compliant with applicable target values for As for many years.

As occurs in organic and inorganic forms. Inorganic arsenic compounds are highly toxic, while organic forms are less harmful. Inhalation of air containing high levels of inorganic As can cause lung damage, shortness of breath, chest pain and cough (UK Health Security Agency, 2019b). Inhalation exposure is associated with genotoxic and carcinogenic effects. For the general population, inhalation typically represents a minor route of exposure to inorganic As, although cigarette smoke contains a large amount of As.

3.1.10 Cadmium (Cd)

Cadmium (Cd) is a metallic element. The main emission sources are combustion in the manufacturing industry and production processes. The incineration of municipal solid waste was once a significant source, but improved controls on waste to energy plant in the 1990s have reduced their contribution to 2% of the UK 2022 total (National Atmospheric Emissions Inventory, 2025). The UK has been compliant with applicable target values for Cd for many years.

Acute inhalation exposure to Cd causes effects on the lung such as pulmonary irritation. Chronic exposure via inhalation can lead to lung cancer or cause a build-up of Cd in the kidneys that can lead to kidney disease. (WHO, 2019) In the environment, Cd can pollute soil and water, leading to exposure via these routes.

3.1.11 Mercury (Hg)

Mercury (Hg) is released to the air by human activities. The main current UK sources are coal use in public electricity and heat production and industrial combustion, iron and steel production processes, cremation, and emissions from the disposal of products containing mercury (National Atmospheric Emissions Inventory, 2025).

Acute exposure to high levels of Hg can cause a wide range of symptoms including chest pain, nausea, vomiting, muscle pains, and shortness of breath and affect the central nervous system and kidneys (UK Health Security Agency, 2022b). Chronic inhalation of Hg vapour may cause tremor, fatigue, headaches, depression, irritability and hallucinations (UK Health Security Agency, 2022b).

In the environment, Hg can also pollute soil, freshwater and sea water. Exposure to contaminated soil and water may then become a health risk. Hg may accumulate in other organisms such as fish and be passed up the food chain.

3.1.12 Polycyclic Aromatic Hydrocarbons (PAH)

Polycyclic aromatic hydrocarbons (PAHs) are a large group of chemical compounds which usually occur as complex mixtures rather than as individual compounds.

PAHs are persistent, organic compounds with toxic and carcinogenic effects. Exposure to PAHs can lead to a range of respiratory effects, heart disease, dermatitis and effects on the immune system.

One particular PAH, benzo[a]pyrene (B[a]P) is used as a ‘marker’ for this group of compounds. The International Agency for Research on Cancer (IARC) has classified B[a]P, as causing cancer in humans. Other PAHs have been classified by IARC as probable or possible human carcinogens (UK Health Security Agency, 2018). B[a]P is considered to be one of the most potent carcinogenic PAHs. The main sources of B[a]P and PAHs in the UK are residential, commercial and industrial fuel combustion (National

Atmospheric Emissions Inventory, 2025). The year 2024 was the first year in which the UK was fully compliant with the target value for B[a]P.

3.1.13 Ammonia

Ammonia (NH_3) is a gas that only stays in the atmosphere for a few hours once emitted. However, when ammonia reacts with other gases in the atmosphere, such as nitrogen oxides and sulphur dioxide, it can form particulate matter (e.g. ammonium sulphate and ammonium nitrate particles). This particulate matter (PM) can persist in the air for several days and be transported long distances, affecting air quality in areas a long way from where it was formed. PM formed through this process is classed as a “secondary” pollutant (that is, formed by reactions involving other pollutants). It is therefore not included in the PM emissions estimations reported in this release. However, this secondary PM makes a significant contribution to particulate air pollution, which overall has impacts on the health of people who are exposed to it. Therefore, estimating ammonia emissions is important to help us understand how much secondary PM derived from ammonia contributes to the total PM concentrations.

Chemical compounds containing ammonia can also be deposited to the environment, which can cause significant long-term harm to sensitive habitats by increasing nitrogen concentrations in soil or water. When soil nitrogen levels increase, common plant species that thrive in these conditions can dominate habitats at the expense of other rarer species. This can result in major changes to plant community structure (e.g. affecting the composition and diversity of plant species) which affects associated animal species. Ammonia is also directly toxic to plants and some species of moss and lichen are impacted even at very low concentrations.

The vast majority of UK ammonia emissions come from agricultural sources, in particular livestock manure, urine and the spreading of inorganic fertilisers. A small proportion of ammonia emissions come from waste plus a wide range of other sources, including composting and non-agricultural animals.

3.2 Assessment of Air Quality in the UK

The evidence base for the annual assessment of compliance against The Air Quality Standards Regulations (2010) is underpinned by a combination of measurements and the results of modelling assessments. The use of models enables air quality to be assessed at locations without monitoring sites and reduces the number of monitoring stations required. It has the added benefit of providing additional information on source apportionment and projections to support the development and implementation of air quality policies.

Modelling is undertaken using the national Pollution Climate Mapping (PCM) models. The PCM models have been designed to assess compliance with limit values, target values and long-term objectives at locations defined within The Air Quality Standards Regulations (2010). 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) becomes available and the publication date 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 (LAQM). National air quality modelling for the UK's national compliance assessment 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[5]. LAQM modelling can differ in scope, purpose and methodology from the national compliance assessment. For example, in LAQM modelling they can use a greater level of detail and resolution in order to assess local exposure and pollution hotspots. The more granular modelling enabled under LAQM does not necessarily align with the requirements for national air quality assessment under the Air Quality Standards Regulations (2010). In addition, air quality monitoring under LAQM differs from that of the national assessment. In particular, the placement of air quality monitors under LAQM can be more flexible, allowing for assessment of local hotspots, and therefore does not always align to the siting criteria under the Air Quality Standards Regulations (2010). See **Section 3.3** for more details on the modelling carried out for compliance assessment for more details on the modelling carried out for compliance assessment.

The $PM_{2.5}$ targets set under The Environmental Targets (Fine Particulate Matter) (England) Regulations (2023) (UK Government, 2023) are assessed using fixed measurements from the national Automatic Urban Rural Network (AURN) only: modelling is not used in this case. $PM_{2.5}$ monitoring within the AURN is currently being expanded to support the assessment.

3.2.1 Current UK Air Quality Monitoring

During 2024 there were 600 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 these networks. A summary of the UK national networks is provided in **Table 3-1**: the number of sites shown in this table amounts to considerably more than 600 because some sites belong to more than one network. This table shows the number of sites in operation during part or all of 2024.

[5] A road link is a section of road that is greater than 100m in length.

Table 3-1 The UK's Air Quality Monitoring Networks in 2024

Network	Pollutants	Number of Sites operating in 2024
Automatic Urban and Rural Network (AURN) Automatic London Network (part of AURN)	CO, NO_x, NO_2, SO_2, O_3, PM_{10}, $PM_{2.5}$. (Not all sites measure all these pollutants.)	**172** **15**
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	**24**
Non-Automatic Hydrocarbon Network	Benzene	**35**
Automatic Hydrocarbon Network	Range of volatile organic compounds (VOCs)	**5**
Polycyclic Aromatic Hydrocarbons (PAH) Network.	27 PAH species including benzo[a]pyrene	**37**
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 Concentrations and Numbers (PCN) Network	Total particle number, concentration, size distribution, anions, elemental carbon, organic carbon, speciation of PM_{10} and $PM_{2.5}$.	**4**
Toxic Organic Micropollutants (TOMPs) Network	Range of toxic organics, including dioxins and dibenzofurans.	**9**

Network	Pollutants	Number of Sites operating in 2024
UK Eutrophying and Acidifying Pollutants: NO_2Net (rural diffusion tubes)	NO_2 (rural)	**27**
UK Eutrophying and Acidifying Pollutants: AGANet	HNO_3, HONO, SO_2, Ca, Cl, Mg, Na, NO_2, NO_3 and SO_4	**28**
UK Eutrophying and Acidifying Pollutants: NAMN	NH_3 and/or NH_4^+	**117**
UK Eutrophying and Acidifying Pollutants: PrecipNet	Major ions i.e. those commonly found in rainwater - Ca^{2+}, Mg^{2+}, Na^+, K^+, NH_4^+, SO_4^{2-}, Cl^- and NO_3^-.	**50**
Black Carbon Network	Black Carbon	**26**
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**
UK Urban NO_2 Network	Diffusion tubes with wind-protection membranes measuring NO_2 monthly at urban traffic-related sites.	**300**

3.2.1.1 The Automatic Urban and Rural Network (AURN)

The AURN is currently the largest automatic monitoring network in the UK and forms a large part of the UK's statutory compliance monitoring evidence base. Data from the AURN are available on Defra's UK-AIR website. The Automatic London Network (ALN) is a subset of sites in the AURN which also form part of the wider London Air Quality Network (LAQN). In this report, 'AURN' includes the whole network, i.e. including the ALN subset of sites.

The techniques used for monitoring gaseous pollutants within the AURN are the reference measurement methods defined in the Air Quality Standards Regulations (2010). For particulate matter the AURN uses methods which have demonstrated equivalence to the reference method, but which (unlike the reference method) allow continuous monitoring for dissemination of up-to-date data. Details are provided in **Table 3-2**.

The AURN is currently undergoing an expansion of $PM_{2.5}$ and ozone monitoring. Sixteen new monitoring sites have been added to the network in 2023 and 2024, and many of the existing sites have had $PM_{2.5}$ and/or O_3 monitoring instruments added.

Table 3-2 AURN Measurement Techniques

Pollutant	Method used, including details of CEN Standard Methods
O_3	EN 14625:2024 'Ambient air quality – standard method for the measurement of the concentration of ozone by ultraviolet photometry' (CEN, 2024a)
NO_2/NO_x	EN 14211:2024 'Ambient air quality - Standard method for the measurement of the concentration of nitrogen dioxide and nitrogen monoxide by chemiluminescence' (CEN, 2024b)
SO_2	EN 14212:2024 'Ambient air quality – Standard method for the measurement of the concentration of sulphur dioxide by UV fluorescence' (CEN, 2024c)
CO	EN 14626:2024 'Ambient air quality - Standard method for the measurement of the concentration of carbon monoxide by non-dispersive infrared spectroscopy' (CEN, 2024d)
PM_{10} and $PM_{2.5}$	EN 12341:2023 'Ambient air quality - Standard gravimetric measurement method for the determination of the PM_{10} or $PM_{2.5}$ mass fraction of suspended particulate matter' (BS EN, 2023) In 2024 the AURN used three methods which are equivalent to the reference method for one or both metrics: the Fidas™ 200, an optical technique, the Beta-Attenuation Monitor (BAM), and gravimetric samplers that collect daily samples onto a filter for subsequent weighing (the reference method) at two sites only. Descriptions of these methods are given in the Glossary of this report.

3.2.1.2 The UK Heavy Metals Network

The UK Heavy Metals Network forms the basis of the UK's compliance monitoring for the Air Quality Standards Regulations (2010), which cover lead, arsenic, cadmium, nickel and mercury.

At the end of 2013 Defra merged the existing Urban and Industrial Network with the Rural Heavy Metals 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 (CEN, 2005). Metals (As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Se, V and Zn) in PM_{10} are measured at 24 sites. The network stopped measuring mercury in PM_{10} in 2014.

Metal deposition (Al, As, Ba, Be, Cd, Co, Cr, Cs, Cu, Fe, Hg, Li, Mn, Mo, Ni, Pb, Rb, Sb, Se, Sn, Sr, Ti, U, V, W, Zn) was measured at the following rural sites: Auchencorth Moss, Chilbolton Observatory, Heigham Holmes and Yarner Wood. The same metals were measured at Lough Navar, with the exception of mercury.

The Heavy Metals network stopped measuring total gaseous mercury in August 2018, although the (separate) Rural Mercury Network still measures this at one site in England (Chilbolton Observatory) – see section 3.2.1.11.

3.2.1.3 Non-Automatic Hydrocarbon Network

In this network, ambient concentrations of benzene are measured by the CEN standard method (CEN, 2023). 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 Standards Regulations (2010) limit value for benzene. All sites in the Non-Automatic Hydrocarbon Network are co-located with AURN sites. Nottingham Centre was replaced by Nottingham Kenmore Gardens in January 2024.

3.2.1.4 Automatic Hydrocarbon Network

The Air Quality Standards Regulations (2010) also require measurement and reporting of ozone precursor substances (29 species), which include volatile organic compounds (VOCs). The Air Quality Standards Regulations (2010) refer to Annex X (ten) of the Air Quality Directive, which 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 Air Quality Directive (European Parliament and Council of the European Union, 2008) except formaldehyde and total non-methane hydrocarbons), are made using automated pumped sampling with in-situ gas chromatography. Three Automatic Hydrocarbon sites were operating in 2024: a fourth long running site at London Eltham stopped operating in July 2023, and is to be relocated.

The VOCs monitored include benzene, which is covered by the Air Quality Standards Regulations (2010) as a pollutant in its own right.

3.2.1.5 Polycyclic Aromatic Hydrocarbons (PAH) Network

The PAH Network monitors compliance with the Air Quality Standards Regulations (2010), which include a target value of 1 ng m^{-3} for the annual mean concentration of benzo[a]pyrene as a representative PAH. Samples are collected on filters using the PM_{10} ‘Digitel’ sampler. Samples are subsequently analysed in a laboratory for 23 PAH compounds. Nottingham Centre was replaced by Nottingham Kenmore Gardens in January 2024.

3.2.1.6 European Monitoring and Evaluation Programme (EMEP) Sites in the UK

EMEP is a Europe-wide 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’ in the UK; at Auchencorth Moss in Midlothian (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.

3.2.1.7 Particle Concentrations and Numbers Network

The Air Quality Standards Regulations (2010) require that the chemical composition of $PM_{2.5}$ is characterised at background locations in the United Kingdom. The Particle Concentrations and Numbers Network sites contribute to this statutory requirement. During 2024, 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; the 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 (ammonium, nitrate and sulphate) in $PM_{2.5}$ and PM_1
- total carbon, organic carbon (OC) and elemental carbon (EC) concentrations in $PM_{2.5}$.

PM_{10} speciation was replaced by $PM_{2.5}$ speciation in 2018. PM_1 speciation began at the London Marylebone Road in 2020.

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 were 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.

A multi-metal monitoring system measuring 40 metals in $PM_{2.5}$ and PM_{10} was installed in 2022 at London Marylebone Road and London Honor Oak Park.

3.2.1.8 Toxic Organic Micropollutants (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, polychlorinated biphenyls and brominated flame retardants. The TOMPs Network consists of eight sites across the UK: Auchencorth Moss, Cardiff Lakeside, Hazelrigg, High Muffles, Kilmakee Leisure Centre, Seacole Building (which replaced London Nobel House in February 2024), 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 page on the UK-AIR website. However, this network is not used for compliance monitoring and will not be discussed further in subsequent sections of the report.

3.2.1.9 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 at 275 locations as required for input to the rural NO_x concentration field in the Pollution Climate Model. The sampling sites at Bannisdale Beck and Balquhidder were relocated to Ennerdale and Balquhidder 3, respectively, at the end of 2024. Sampling started at Auchencorth Moss at the start of 2024 as part of an intercomparison with NO_2 specific analysers.

- In 2024 the Acid Gas and Aerosol Network (AGANet) comprised a total of 28 sites. 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 UKEAP National Ammonia Monitoring Network (NAMN) is used to quantify temporal and spatial changes in air concentrations and deposition in ammonia (NH_3) and ammonium (NH_4^+) on a long-term basis using both passive samplers (Alpha Samplers) and low volume denuders (Delta Samplers). The monitoring provides a baseline in the reduced nitrogen species (NH_3 + NH_4^+), which is necessary for examining responses to changes in the agricultural sector and to verify compliance with targets set by international agreements. The network was expanded in 2023 to include an additional 16 Alpha samplers which also form part of Natural England's Long Term Monitoring Network.

- The Precipitation Network (PrecipNet), measuring major ions in precipitation at 48 rural sites. 'Major ions' are those commonly found dissolved in rainwater as cations (positively charged) or anion (negatively charged). PrecipNet measures the following cations; calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), potassium (K^+) and ammonium (NH_4^+), and the following anions; sulphate (SO_4^{2-}), chloride (Cl^-) and nitrate (NO_3^-). Fifteen of the 48 sites form part of the LongTerm Monitoring Network managed by Natural England. PrecipNet network allows estimates of sulphur and nitrogen deposition. Samples are collected fortnightly at all sites and daily at two sites. The sampling sites at Bannisdale Beck and Balquhidder were relocated to Ennerdale and Balquhidder 3, respectively, at the end of 2024.

3.2.1.10 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 2024, monitoring started at 12 additional sites bringing the total to 26 sites. The Aethalometer™ instrument 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.

3.2.1.11 Rural Mercury Monitoring

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 measures just total gaseous mercury.

3.2.1.12 UK Urban NO_2 Network

The UK Urban NO_2 Network (UUNN) was established in December 2019 with monitoring beginning in January 2020. The objective of the network is to provide additional local roadside NO_2 measurements to enhance the UK's national compliance assessment. Monitoring of NO_2 is undertaken using Palmes-type diffusion tubes with wind protection caps, with the tubes exposed monthly in triplicate (sets of three). During 2024 monitoring was undertaken at 300 sites.

3.2.2 Monitoring of Impacts

3.2.2.1 Air Pollution Impacts on Ecosystem Networks (APIENs)

The following information about UK APIENs is summarised from the Air Pollution Information System (APIS) website. The purpose of UK APIENs is to monitor and report the negative impacts of air pollution (e.g. acidification, eutrophication, ozone damage or changes in biodiversity) on ecosystems that are representative of freshwater, natural and semi-natural habitats and forests in the UK. It was formed in 2018 by integrating UK national air quality and ecosystem monitoring networks and surveys, to meet UK monitoring and reporting obligations under the EU National Emissions Ceilings Directive. The Directive was transposed into the UK National Emissions Ceilings Regulations (NECR) (2018). The duty to monitor the negative impacts of air pollution across the UK is set out in Part 5 of the Regulations. Integrated data from APIENs will provide evidence to determine the state of UK ecosystems and provide a baseline against which any changes and potential recovery can be compared.

3.2.2.2 UK Upland Waters Monitoring Network (UK UWMN)

The UK Upland Waters Monitoring Network (UWMN) was first set up in 1988 and at the time it was called the Acid Waters Monitoring Network. Its objective was to assess the chemical and biological response of acidified lakes and streams in the UK to the planned reduction in emissions. It was initially designed to provide chemical and biological data on the extent and degree of surface water acidification in the UK uplands and underpin the science linking acid deposition to water quality and aquatic ecosystem health.

In recent years it has been adapted to address a wider range of questions, particularly with respect to understanding impacts of nitrogen enrichment, the influence of climate change and land use on upland waters, and interactions between these drivers and recovery from acidification.

The eleven lakes and eleven streams were originally selected to cover a wide deposition gradient and included forest-moorland pairs of sites. Sites were required to be subject to minimal point source pollution and catchment disturbance beyond that caused by traditional upland land use practices such as sheep grazing or forestry. Additional stream sites have recently been added to broaden the acid-sensitivity gradient, while thermistor loggers are now deployed to continuously monitor water temperature. Water chemistry has been monitored monthly in streams and quarterly in lakes ever since the inception of the network to the present. Biological monitoring involves annual assessment of algae (diatoms), higher aquatic plants and macroinvertebrates. Fish monitoring was discontinued in 2015 due to budget cuts. In April 2019, the Centre for Ecology and Hydrology (now UKCEH) took over management of the UWMN from ENSIS Ltd. After a significant funding hiatus from 2016, Defra resumed support for collection and analysis of biological samples in 2021. Currently, UKCEH conduct all water chemical analysis while Queen Mary University of London (QMUL) provide all biological sampling and taxonomic analysis.

The UK UWMN also receives funding from the National Environment Research Council (NERC) via the UK Centre for Ecology and Hydrology (UKCEH), NatureScot, the Welsh Government, Natural Resources Wales, Forest Research and Moors for the Future, and has also benefited, or continues to benefit, from considerable in-kind support for sampling and survey activity from UCL, QMUL, the Scottish Environment Protection Agency (SEPA), the Department of Agriculture, Environment and Rural Affairs (DAERA) in Northern Ireland, and several private volunteers. More information can be found from the [UWMN website](#).

3.2.3 Quality Assurance and Quality Control

Air quality monitoring in the UK is subject to rigorous procedures of validation and ratification. The well-established monitoring networks each have a robust and documented Quality Assurance and 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 limit values where applicable. An allowance of 5% is made in some cases for down-time due to planned maintenance. This is the same data capture requirement as specified in The Environmental Targets (Fine Particulate Matter) (England) Regulations (2023) for at least 85% of the hours in a year

- consistent with Data Quality Objectives. The uncertainty requirements of the Air Quality Standards Regulations (2010) are specified as data quality objectives. In the UK, all air quality data meet the data quality requirements of the Air Quality Standards Regulations (2010) in relation to uncertainty

- consistent with methodology guidance defined in the Air Quality Standards Regulations (2010) 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 UK-AIR website 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 included in the UK's assessment of compliance with The Air Quality Standards Regulations (2010) and The Environmental Targets (Fine Particulate Matter) (England) Regulations (2023).

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)*' available from Defra's UK-AIR website (Defra, 2016).

3.3 Modelling

3.3.1 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:

- modelling allows an assessment of levels of pollutants where monitoring does not take place. Whilst our monitoring network is extensive, 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
- modelling provides information about the sources of pollutants to inform policy development
- modelling enables an assessment of levels of pollutants both now and in future years in order to develop policies across government to continue to improve air quality in the UK.

3.3.2 How the Models Work

The national modelling methodology varies between pollutants. The detailed methodology is explained in a technical report (Pugsley, K. L. et al., 2025), and the latest versions of these can be found in the Library section of Defra's UK-AIR website.

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 for some pollutants – concentrations at the roadside of urban major road links throughout the UK (i.e. motorways and major A-roads). There are approximately 9,000 of these urban major road links.

Roadside concentrations are not modelled for CO, SO_2, O_3, 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 Air Quality Standards Regulations (2010) (UK Government, 2010) as relevant for air quality assessment.

3.3.3 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 of the UK. These individual components (supplemented by some additional components for certain pollutants) are:

- large point sources (for example, power stations, steel works and oil refineries)
- small point sources (for example, boilers in town halls, schools or hospitals, crematoria)
- distant sources (characterised by the rural background concentration)
- local area sources (for example, 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 concentrations.

3.3.4 Roadside Air Quality

Roadside concentrations are determined by using a roadside increment model which estimates the contribution from road traffic sources and adds this to the modelled background concentrations discussed above.

For each of the road links that are modelled, there are emission estimates for each pollutant from the National Atmospheric Emissions Inventory (NAEI) (National Atmospheric Emissions Inventory, 2025) and road traffic counts from the Department for Transport. A measured roadside increment concentration is calculated for road links with a roadside monitoring station 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 link 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 for these road links. The application of the RKM ensures that a process-based modelling approach is used to determine the local component of roadside concentrations, including factors influencing dispersion at the roadside, for example road orientation, width, and additional vehicle induced turbulence.

3.4 Access to Assessment Data

Data from the UK's air quality monitoring networks and annual compliance modelling is available under the Open Government Licence (UK Government, 2025) from the UK-AIR website.

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 the UK-AIR website's data catalogue.

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

UK-AIR also houses a Compliance Dashboard which displays all the underlying data used in the compliance assessment against the Air Quality Standards Regulations (2010). The Compliance Dashboard can be found at UK-AIR website's compliance data page and is made up of three parts:

- interactive GIS compliance map – a streamlined viewer facilitating summaries of compliance status across different geographies for different pollutant metrics based on modelled background data, modelled roadside data and measurements

- compliance data hub – a comprehensive data catalogue and extraction tool for underlying data that serves the compliance app. This allows users to acquire the data behind the compliance status either for a specific zone/agglomeration or Local Authority or for the whole of the UK in one process

- XML file library – a catalogue of download links for the machine-readable XML formats of the compliance data.

Data used to assess compliance with The Environmental Targets (Fine Particulate Matter) (England) Regulations (2023) are also published on the UK-AIR website's PM2.5 target calculation page.

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 2024

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 and Merseyside	UK0033	Non-agglomeration
Yorkshire and 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 2024

© Crown copyright. All rights reserved Defra, Licence number 100022861 [2025]

You can see the zone boundaries on the online interactive compliance map available on the UK-AIR website.

4.2 Air Quality Assessment for 2024

The air quality assessment for compliance against the Air Quality Standard Regulations (AQSR) (2010) is derived from a combination of measured pollutant concentrations from the Automatic Urban and Rural Network (AURN) and other networks, together with supplementary assessment. Supplementary assessment can be modelling using the Pollution Climate Mapping (PCM) model, NO_2 diffusion tube measurements from the UK Urban Nitrogen Dioxide Network (the UUNN) or objective estimation. This is explained in Defra's technical report on UK air quality assessment (Pugsley, K. L. et al., 2025). Where both measurements and supplementary assessment results are available for a zone, the assessment of compliance for each zone is based on the higher concentration of the two.

In the case of NO_2, an additional rule was introduced in 2021. This is used where there is roadside monitoring (an AURN monitoring site, a UUNN diffusion tube monitoring site, or both) on a major urban road, which is also modelled by the PCM model. This rule determines the order of precedence of these data sources when used in compliance assessment and is described in Section 4.2.1 below.

Compliance with the $PM_{2.5}$ targets set in The Environmental Targets (Fine Particulate Matter) (England) Regulations (2023) is based only on measured pollutant concentrations from the Automatic Urban and Rural Network (AURN) and modelling is not included in the assessment.

4.2.1 Approach for Nitrogen Dioxide at the Roadside

In compliance assessments for years up to and including 2020, the approach taken when assessing NO_2 concentrations at roadside locations where both modelled and measured concentrations were available was to report all concentrations, but to always use the highest concentration to determine the compliance status, whether measured or modelled. This was a conservative approach in which an exceedance was always reported if any of the data indicated one, but it did not consider the quality of the evidence available. The availability of a new source of evidence - measurements from the UUNN, which was established in 2020 - prompted a review of the approach for NO_2.

A study led by Defra working closely with members of their independent Air Quality Expert Group (AQEG) compared the quality of modelled NO_2 concentrations from the PCM model to measured concentrations from the UUNN and AURN. This concluded that the AURN provides the most accurate assessment of NO_2 concentrations, followed by the UUNN, and then the PCM model.

The method for determining compliance with the annual mean limit value for NO_2 was therefore adjusted to reflect this. As of 2021, all modelled and measured NO_2 concentrations are still reported as part of the assessment, but the order of precedence, for any given major urban road, is as follows:

1. If AURN measurements are available, these have been used to assess compliance in preference to values from the UUNN and/or the PCM model for the same major urban road.

2. If UUNN measurements (but not AURN measurements) are available, the UUNN measurements have been used to assess compliance in preference to values from the PCM model for the same major urban road.

3. If no AURN or UUNN measurements are available, concentrations from the PCM model have been used to assess compliance.

This order of precedence only applies to results for the same major urban road. Therefore, the NO_2 compliance status of a given zone could in theory still be determined on the basis of modelling, if the highest concentration for that zone was a modelled value for a location without co-located monitoring.

No change has been made to the method for determining compliance for other pollutants. This means that the most appropriate evidence-based approach is taken for each pollutant.

4.2.2 Compliance Summary

The results of the air quality assessment for 2024 are summarised in the tables below. The tables have been completed as follows:

- where all measurements were within the relevant limit values in 2024, the table shows this as ‘Compliant’

- where locations were identified as exceeding a limit value, target value or long-term objective, this is shown as ‘Exceedance’

- if the compliance or exceedance was determined by supplementary assessment only, this is indicated by ‘[sup]’, i.e. ‘Compliant [sup]’ or ‘Exceedance [sup]’.

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

Sulphur dioxide (SO_2): in 2024, 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 2024. The 2024 compliance assessment for CO has been based on objective estimation, as explained in Defra’s technical report on UK air quality assessment (Pugsley, K. L. et al., 2025). This is underpinned by NAEI emission trends, AURN measurement trends and historical modelling assessments.

Nitrogen dioxide (NO_2): in 2024, not every zone was compliant with all the limit values. The results of the air quality assessment for nitrogen dioxide for each zone are summarised in **Table 4-2**.

All zones and agglomerations were compliant with the 1-hour limit value (200 µg m^{-3}) in 2024, with none exceeding this limit value on more than the permitted 18 occasions. Prior to 2020 only a few zones (typically one or two) have exceeded this limit value; 2024 is the fifth consecutive year in which all zones have been compliant.

38 zones met the annual mean limit value for NO_2 (40 µg m^{-3}) in 2024. The five zones that exceeded this limit value were:

- West Midlands Urban Area
- Greater Manchester Urban Area
- Liverpool Urban Area
- Bristol Urban Area
- Coventry/Bedworth

The year 2020 saw a large reduction in the number of zones exceeding the annual mean limit value: just five zones exceeded in 2020 compared to 33 zones in 2019. This was attributed to the reduced road traffic flows brought about by the COVID-19 pandemic lockdown restrictions.

In the following year, 2021, 10 zones exceeded this limit value. In 2022, nine zones exceeded this limit value, and in 2023 also, nine zones exceeded this limit value. In 2024 the number of zones exceeding this limit value reduced further, to five.

All non-agglomeration zones within the UK complied with the critical level for annual mean NO_X concentration, set for protection of vegetation, as has been the case for many years.

As part of the 2017 UK plan for tackling roadside nitrogen dioxide concentrations (Defra, 2017), local authorities in England 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 the local data present different results to the national air quality assessment. This is partly due to local monitoring being sited differently to national monitoring in order to target local pollution hotspots. Where possible, Defra is working to develop and improve the national NO_2 compliance assessment to better reflect local level NO_2 concentrations. This included establishing the UUNN in 2020, to provide more local NO_2 measurement data.

Table 4-2 Results of Air Quality Assessment for Nitrogen Dioxide in 2024

Zone	NO_2 Limit Value for heath (1hr mean)	NO_2 Limit Value for health (annual mean)	NO_X critical level for vegetation (annual mean)
Greater London Urban Area	Compliant	Compliant	Not applicable
West Midlands Urban Area	Compliant	**Exceedance [sup]**	Not applicable
Greater Manchester Urban Area	Compliant	**Exceedance [sup]**	Not applicable
West Yorkshire Urban Area	Compliant	Compliant	Not applicable
Tyneside	Compliant	Compliant	Not applicable
Liverpool Urban Area	Compliant	**Exceedance [sup]**	Not applicable
Sheffield Urban Area	Compliant	Compliant	Not applicable
Nottingham Urban Area	Compliant	Compliant	Not applicable
Bristol Urban Area	Compliant	**Exceedance [sup]**	Not applicable
Brighton/Worthing/Littlehampton	Compliant	Compliant	Not applicable
Leicester Urban Area	Compliant	Compliant	Not applicable
Portsmouth Urban Area	Compliant	Compliant	Not applicable
Teesside Urban Area	Compliant	Compliant	Not applicable
The Potteries	Compliant	Compliant	Not applicable
Bournemouth Urban Area	Compliant	Compliant	Not applicable
Reading/Wokingham Urban Area	Compliant	Compliant	Not applicable
Coventry/Bedworth	Compliant	**Exceedance [sup]**	Not applicable
Kingston upon Hull	Compliant	Compliant	Not applicable
Southampton Urban Area	Compliant	Compliant	Not applicable
Birkenhead Urban Area	Compliant	Compliant	Not applicable
Southend Urban Area	Compliant	Compliant	Not applicable
Blackpool Urban Area	Compliant	Compliant	Not applicable
Preston Urban Area	Compliant	Compliant	Not applicable
Glasgow Urban Area	Compliant	Compliant	Not applicable
Edinburgh Urban Area	Compliant	Compliant	Not applicable
Cardiff Urban Area	Compliant	Compliant	Not applicable
Swansea Urban Area	Compliant	Compliant	Not applicable
Belfast Urban Area	Compliant	Compliant	Not applicable
Eastern	Compliant	Compliant	Compliant
South West	Compliant	Compliant	Compliant
South East	Compliant	Compliant	Compliant
East Midlands	Compliant	Compliant	Compliant
North West & Merseyside	Compliant	Compliant	Compliant [sup]
Yorkshire and Humberside	Compliant	Compliant	Compliant
West Midlands	Compliant	Compliant	Compliant [sup]
North East	Compliant	Compliant	Compliant [sup]
Central Scotland	Compliant	Compliant	Compliant [sup]
North East Scotland	Compliant	Compliant	Compliant [sup]
Highland	Compliant	Compliant	Compliant [sup]
Scottish Borders	Compliant	Compliant	Compliant
South Wales	Compliant	Compliant	Compliant
North Wales	Compliant	Compliant	Compliant
Northern Ireland	Compliant	Compliant	Compliant [sup]

The abbreviation [sup] indicates the compliance or exceedance was determined by supplementary assessment only.

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 also compliant with the daily mean limit value of 50 µg m^{-3}, which must not be exceeded more than 35 times a year. 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 the AQSR (2010), the UK is required to identify any exceedances of PM_{10} limit values which are due to natural sources (for example sea salt). 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 2024 there were no modelled exceedances of either the 24-hr or annual mean limit values prior to any natural source correction (Pugsley, K. L. et al., 2025).

Table 4-3 Results of Air Quality Assessment for PM_{10} in 2024

Zone	PM_{10} Limit Value (daily mean)	PM_{10} Limit Value (annual mean)
Greater London Urban Area	Compliant	Compliant
West Midlands Urban Area	Compliant	Compliant
Greater Manchester Urban Area	Compliant	Compliant
West Yorkshire Urban Area	Compliant	Compliant
Tyneside	Compliant	Compliant
Liverpool Urban Area	Compliant	Compliant
Sheffield Urban Area	Compliant	Compliant
Nottingham Urban Area	Compliant	Compliant
Bristol Urban Area	Compliant	Compliant
Brighton/Worthing/Littlehampton	Compliant [sup]	Compliant [sup]
Leicester Urban Area	Compliant	Compliant
Portsmouth Urban Area	Compliant	Compliant
Teesside Urban Area	Compliant	Compliant
The Potteries	Compliant	Compliant
Bournemouth Urban Area	Compliant [sup]	Compliant [sup]
Reading/Wokingham Urban Area	Compliant	Compliant
Coventry/Bedworth	Compliant	Compliant
Kingston upon Hull	Compliant	Compliant
Southampton Urban Area	Compliant	Compliant
Birkenhead Urban Area	Compliant	Compliant
Southend Urban Area	Compliant	Compliant
Blackpool Urban Area	Compliant	Compliant
Preston Urban Area	Compliant	Compliant
Glasgow Urban Area	Compliant	Compliant
Edinburgh Urban Area	Compliant	Compliant
Cardiff Urban Area	Compliant	Compliant
Swansea Urban Area	Compliant	Compliant
Belfast Metropolitan Urban Area	Compliant	Compliant
Eastern	Compliant	Compliant
South West	Compliant	Compliant
South East	Compliant	Compliant
East Midlands	Compliant	Compliant
North West and Merseyside	Compliant	Compliant
Yorkshire and Humberside	Compliant	Compliant
West Midlands	Compliant	Compliant
North East	Compliant	Compliant
Central Scotland	Compliant	Compliant
North East Scotland	Compliant	Compliant
Highland	Compliant	Compliant
Scottish Borders	Compliant [sup]	Compliant [sup]
South Wales	Compliant	Compliant
North Wales	Compliant	Compliant
Northern Ireland	Compliant	Compliant

The abbreviation [sup] indicates the compliance or exceedance was determined by supplementary assessment only.

Particulate Matter as $PM_{2.5}$: all zones met the annual mean limit value (20 µg m^{-3} to have been achieved by 1 Jan 2020).

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

Under the AQSR (2010), the UK was required to achieve a National Exposure Reduction Target (NERT) for $PM_{2.5}$, over the period 2010 to 2020. The UK achieved the NERT in 2016, well before the 2020 target year, but has continued to report compliance annually, even after 2020, to demonstrate that it remains compliant.

Compliance is assessed on the basis of the Average Exposure Indicator (AEI) statistic. The AEI for the UK is calculated as follows:

1. each year, the annual arithmetic mean $PM_{2.5}$ concentration is calculated for the designated AEI subset of urban background sites[6]
2. the mean of the most recent three calendar years' values is taken as the AEI.

The detailed methodology and results of this calculation are presented in Defra's technical report on UK air quality assessment (Pugsley, K. L. et al., 2025).

The AEI for the reference year (2010) was 13 µg m^{-3}; based on this, the AQSR set an exposure reduction target of 15%, which equated to reducing the AEI to 11 µg m^{-3} by 2020.

Most recent annual mean urban background $PM_{2.5}$ concentrations (to one decimal place) were as follows:

- 2022: 8.3 µg m^{-3}
- 2023: 7.3 µg m^{-3}
- 2024: 7.2 µg m^{-3}

The three-year running mean AEI for 2024 (calculated as the mean of the above annual values, rounded to the nearest integer), is 8 µg m^{-3}. Therefore, the UK remained compliant with the NERT in 2024.

[6] The sites used for calculation of the AEI are all the urban background $PM_{2.5}$ monitoring sites that were in operation in the baseline year. Urban background sites that started monitoring $PM_{2.5}$ later, or were not classified as urban background in the baseline year, are not included. (The exception is where the new site is the relocation of an existing AEI site that has been moved by a short distance, and to a similar environment). This means that the AEI is calculated on a largely consistent group of sites from year to year.

Table 4-4 Results of Air Quality Assessment for $PM_{2.5}$ in 2024

Zone	$PM_{2.5}$ annual mean limit value
Greater London Urban Area	Compliant
West Midlands Urban Area	Compliant
Greater Manchester Urban Area	Compliant
West Yorkshire Urban Area	Compliant
Tyneside	Compliant
Liverpool Urban Area	Compliant
Sheffield Urban Area	Compliant
Nottingham Urban Area	Compliant
Bristol Urban Area	Compliant
Brighton/Worthing/Littlehampton	Compliant
Leicester Urban Area	Compliant
Portsmouth Urban Area	Compliant
Teesside Urban Area	Compliant
The Potteries	Compliant
Bournemouth Urban Area	Compliant
Reading/Wokingham Urban Area	Compliant
Coventry/Bedworth	Compliant
Kingston upon Hull	Compliant
Southampton Urban Area	Compliant
Birkenhead Urban Area	Compliant
Southend Urban Area	Compliant
Blackpool Urban Area	Compliant
Preston Urban Area	Compliant
Glasgow Urban Area	Compliant
Edinburgh Urban Area	Compliant
Cardiff Urban Area	Compliant
Swansea Urban Area	Compliant
Belfast Metropolitan Urban Area	Compliant
Eastern	Compliant
South West	Compliant
South East	Compliant
East Midlands	Compliant
North West and Merseyside	Compliant
Yorkshire and Humberside	Compliant
West Midlands	Compliant
North East	Compliant
Central Scotland	Compliant
North East Scotland	Compliant
Highland	Compliant
Scottish Borders	Compliant [sup]
South Wales	Compliant
North Wales	Compliant
Northern Ireland	Compliant

The abbreviation [sup] indicates the compliance or exceedance was determined by supplementary assessment only.

Also, as explained in Section 2.2, The Environmental Targets (Fine Particulate Matter) (England) Regulations (2023) (UK Government, 2023) contain the following long-term targets for $PM_{2.5}$:

- an Annual Mean Concentration Target (AMCT) - to reduce maximum annual mean (average) $PM_{2.5}$ concentrations in England to 10 µg m^{-3} by 2040
- a Population Exposure Reduction Target (PERT), to reduce population exposure to $PM_{2.5}$ in England by 35% compared to 2018, by 2040. The PERT is based on an average of measurements from urban background and suburban background monitoring sites.

Compliance with the targets is a legal requirement from 2040 onwards, but there are interim targets which are not legally mandatory. The targets apply only in England.

The AMCT will be considered met if, at every relevant monitoring station, the annual mean (average) concentration of $PM_{2.5}$ in ambient air, rounded to the nearest whole number of µg m^{-3}, is equal to or less than the target level in the year 2040.

One AURN site in England exceeded the AMCT of 10 µg m^{-3} in 2024. This was London Marylebone Road, a roadside site in central London. All AURN sites met the interim AMCT in 2024. This is a maximum of 12 µg m^{-3} to be achieved by January 2028.

Progress towards meeting the PERT is assessed using a ‘Population Exposure Indicator’ (PEIyear) - a measure of average population exposure in the three-year period ending on 31 December in a given year. The reduction in population exposure is found by comparing the PEIyear against the Baseline Population Exposure Indicator (‘PEIbase’) - the average for the three years 2016, 2017 and 2018. PEIbase is 10.09 µg m^{-3}. A statistical method to account for changes in the monitoring network is used in the calculation of the percentage reduction, so the comparison is not direct.

PEI2024 is 7.56 µg m^{-3}. The reduction in population exposure from 2018 to 2024 is 25%: England therefore met the interim PERT of 22% in 2024, though not the long-term target of 35% to be met by December 2040.

How England has progressed towards achieving the AMCT and PERT since 2018 is reported in Section 4.3.

Ozone: in 2024 all zones of the UK met the target values for health and for protection of vegetation, as they have for many years. However, some zones exceeded the more stringent long-term objectives.

For ozone (O_3), the target value for protection of human health is based on the maximum daily 8-hour mean. All 43 zones and agglomerations were compliant with this target value, which is assessed as an average over a three-year period. There is also a more stringent long-term objective for protection of human health, also based on the maximum daily 8-hour mean, assessed over a single year. Twelve of the 43 zones and agglomerations were compliant with the long-term objective (LTO) for health in 2024. The results of the air quality assessment for ozone, in relation to the target value and LTO for human health, are summarised in **Table 4-5**.

The target value for protection of vegetation is based on the AOT40 statistic. This statistic (expressed in µg m^{-3}.hours) is the sum of the difference between hourly concentrations greater than 80 µg m^{-3} (= 40 ppb) over a given period using only the hourly mean values measured between 08:00 and 20:00 Central European Time each day from 1 May to 31 July each year, as an average over a five-year period. All 43 zones and agglomerations met the target value based on the AOT40 statistic. There is also a more stringent long-term objective for protection of vegetation, also based on the AOT40 statistic assessed over a single year; four zones exceeded this long-term objective for vegetation in 2024. The results of the air quality assessment for ozone, in relation to the target value and LTO for vegetation, are summarised in **Table 4-6**.

Ozone concentrations fluctuate from year to year as ozone is a transboundary pollutant (travelling long distances across countries) and its formation is influenced by meteorological factors. This influences the number of zones exceeding the LTOs. Ozone is not emitted from sources in the same way as most other air pollutants. It is the product of chemical reactions between other pollutants in the air, both human-made and from natural sources, that occur more frequently during hot and sunny weather. In 2024 there were relatively few periods of elevated ozone concentration, and fewer exceedances of the LTO for vegetation in 2024 than in 2023.

In 2024 there were no exceedances of the population warning threshold of 240 µg m^{-3} as a 1-hour mean. This is not unusual. However, there were also no measured exceedances of the (lower) ozone population information threshold of 180 µg m^{-3} (which also applies to the 1-hour mean). This is relatively rare, although the number varies from year to year. For comparison, there were 26 exceedances of the population information threshold reported in the previous year, 2023.

Table 4-5 Results of Air Quality Assessment for Ozone in 2024: 8-hour Mean Target Value and Long-Term Objective for Human Health

Zone	O_3 8h Mean Target Value for human health	O_3 8h Mean Long-Term Objective for human health
Greater London Urban Area	Compliant	**Exceedance**
West Midlands Urban Area	Compliant	**Exceedance**
Greater Manchester Urban Area	Compliant [sup]	**Exceedance [sup]**
West Yorkshire Urban Area	Compliant [sup]	**Exceedance [sup]**
Tyneside	Compliant	Compliant
Liverpool Urban Area	Compliant [sup]	**Exceedance [sup]**
Sheffield Urban Area	Compliant [sup]	**Exceedance [sup]**
Nottingham Urban Area	Compliant	**Exceedance**
Bristol Urban Area	Compliant	**Exceedance**
Brighton/Worthing/Littlehampton	Compliant	**Exceedance**
Leicester Urban Area	Compliant	**Exceedance**
Portsmouth Urban Area	Compliant	**Exceedance**
Teesside Urban Area	Compliant	Compliant
The Potteries	Compliant	**Exceedance**
Bournemouth Urban Area	Compliant	**Exceedance**
Reading/Wokingham Urban Area	Compliant	**Exceedance**
Coventry/Bedworth	Compliant	**Exceedance**
Kingston upon Hull	Compliant	Compliant
Southampton Urban Area	Compliant	**Exceedance**
Birkenhead Urban Area	Compliant [sup]	**Exceedance [sup]**
Southend Urban Area	Compliant	**Exceedance**
Blackpool Urban Area	Compliant [sup]	**Exceedance [sup]**
Preston Urban Area	Compliant [sup]	**Exceedance [sup]**
Glasgow Urban Area	Compliant	Compliant
Edinburgh Urban Area	Compliant	Compliant
Cardiff Urban Area	Compliant	**Exceedance**
Swansea Urban Area	Compliant [sup]	**Exceedance [sup]**
Belfast Metropolitan Urban Area	Compliant	Compliant
Eastern	Compliant	**Exceedance**
South West	Compliant	**Exceedance**
South East	Compliant	**Exceedance**
East Midlands	Compliant	**Exceedance**
North West and Merseyside	Compliant	**Exceedance**
Yorkshire and Humberside	Compliant [sup]	**Exceedance [sup]**
West Midlands	Compliant	**Exceedance**
North East	Compliant	Compliant
Central Scotland	Compliant	Compliant
North East Scotland	Compliant	Compliant
Highland	Compliant	Compliant
Scottish Borders	Compliant	Compliant
South Wales	Compliant [sup]	**Exceedance [sup]**
North Wales	Compliant	**Exceedance**
Northern Ireland	Compliant	Compliant

The abbreviation '[sup]' indicates the compliance or exceedance was determined by supplementary assessment only.

Table 4-6 Results of Air Quality Assessment for Ozone in 2024: Target Value and Long-Term Objective Based On AOT40 Statistic, for Vegetation

Zone	O_3 Target Value for vegetation (AOT40)	O_3 Long-Term Objective for vegetation (AOT40)
Greater London Urban Area	Compliant	**Exceedance**
West Midlands Urban Area	Compliant	Compliant
Greater Manchester Urban Area	Compliant [sup]	Compliant
West Yorkshire Urban Area	Compliant [sup]	Compliant
Tyneside	Compliant	Compliant
Liverpool Urban Area	Compliant [sup]	Compliant
Sheffield Urban Area	Compliant [sup]	Compliant
Nottingham Urban Area	Compliant	Compliant
Bristol Urban Area	Compliant	Compliant
Brighton/Worthing/Littlehampton	Compliant	Compliant
Leicester Urban Area	Compliant	Compliant
Portsmouth Urban Area	Compliant	Compliant
Teesside Urban Area	Compliant	Compliant
The Potteries	Compliant	Compliant
Bournemouth Urban Area	Compliant	**Exceedance**
Reading/Wokingham Urban Area	Compliant	Compliant
Coventry/Bedworth	Compliant	Compliant
Kingston upon Hull	Compliant	Compliant
Southampton Urban Area	Compliant	Compliant
Birkenhead Urban Area	Compliant [sup]	Compliant
Southend Urban Area	Compliant	Compliant
Blackpool Urban Area	Compliant [sup]	Compliant
Preston Urban Area	Compliant [sup]	Compliant
Glasgow Urban Area	Compliant	Compliant
Edinburgh Urban Area	Compliant	Compliant [sup]
Cardiff Urban Area	Compliant	Compliant
Swansea Urban Area	Compliant [sup]	Compliant
Belfast Metropolitan Urban Area	Compliant	Compliant
Eastern	Compliant	Compliant
South West	Compliant	**Exceedance**
South East	Compliant	**Exceedance**
East Midlands	Compliant	Compliant
North West and Merseyside	Compliant	Compliant
Yorkshire and Humberside	Compliant [sup]	Compliant
West Midlands	Compliant	Compliant
North East	Compliant	Compliant
Central Scotland	Compliant	Compliant
North East Scotland	Compliant	Compliant
Highland	Compliant	Compliant
Scottish Borders	Compliant	Compliant
South Wales	Compliant [sup]	Compliant
North Wales	Compliant	Compliant
Northern Ireland	Compliant	Compliant

The abbreviation '[sup]' indicates that the compliance or exceedance was determined by supplementary assessment only.

Arsenic, cadmium, nickel and benzo[a]pyrene: the air quality assessments for arsenic (As), cadmium (Cd), nickel (Ni) and benzo[a]pyrene (B[a]P) are summarised in **Table 4-7**. All zones met target values for arsenic and cadmium (as they have for many years). For the first time, all zones also met the target value for benzo[a]pyrene.

Concentrations of Ni exceeded the target value of 20 ng m^{-3} in three zones: Sheffield Urban Area, Yorkshire and Humberside, and South Wales. These exceedances are attributed to emissions from industrial sources.

Table 4-7 Results of Air Quality Assessment for As, Cd, Ni and B[a]P in 2024

Zone	As Target Value	Cd Target Value	Ni Target Value	B[a]P Target Value
Greater London Urban Area	Compliant	Compliant	Compliant	Compliant
West Midlands Urban Area	Compliant	Compliant	Compliant	Compliant
Greater Manchester Urban Area	Compliant [sup]	Compliant [sup]	Compliant [sup]	Compliant
West Yorkshire Urban Area	Compliant [sup]	Compliant [sup]	Compliant [sup]	Compliant
Tyneside	Compliant [sup]	Compliant [sup]	Compliant [sup]	Compliant
Liverpool Urban Area	Compliant [sup]	Compliant [sup]	Compliant [sup]	Compliant
Sheffield Urban Area	Compliant	Compliant	**Exceedance [sup]**	Compliant
Nottingham Urban Area	Compliant [sup]	Compliant [sup]	Compliant [sup]	Compliant
Bristol Urban Area	Compliant [sup]	Compliant [sup]	Compliant [sup]	Compliant
Brighton/Worthing/Littlehampton	Compliant [sup]	Compliant [sup]	Compliant [sup]	Compliant [sup]
Leicester Urban Area	Compliant [sup]	Compliant [sup]	Compliant [sup]	Compliant [sup]
Portsmouth Urban Area	Compliant [sup]	Compliant [sup]	Compliant [sup]	Compliant
Teesside Urban Area	Compliant [sup]	Compliant [sup]	Compliant [sup]	Compliant
The Potteries	Compliant [sup]	Compliant [sup]	Compliant [sup]	Compliant [sup]
Bournemouth Urban Area	Compliant [sup]	Compliant [sup]	Compliant [sup]	Compliant [sup]
Reading/Wokingham Urban Area	Compliant [sup]	Compliant [sup]	Compliant [sup]	Compliant [sup]
Coventry/Bedworth	Compliant [sup]	Compliant [sup]	Compliant [sup]	Compliant [sup]
Kingston upon Hull	Compliant [sup]	Compliant [sup]	Compliant [sup]	Compliant [sup]
Southampton Urban Area	Compliant [sup]	Compliant [sup]	Compliant [sup]	Compliant
Birkenhead Urban Area	Compliant [sup]	Compliant [sup]	Compliant [sup]	Compliant [sup]
Southend Urban Area	Compliant [sup]	Compliant [sup]	Compliant [sup]	Compliant [sup]
Blackpool Urban Area	Compliant [sup]	Compliant [sup]	Compliant [sup]	Compliant [sup]
Preston Urban Area	Compliant [sup]	Compliant [sup]	Compliant [sup]	Compliant
Glasgow Urban Area	Compliant [sup]	Compliant [sup]	Compliant [sup]	Compliant
Edinburgh Urban Area	Compliant [sup]	Compliant [sup]	Compliant [sup]	Compliant
Cardiff Urban Area	Compliant [sup]	Compliant [sup]	Compliant [sup]	Compliant
Swansea Urban Area	Compliant	Compliant	Compliant	Compliant
Belfast Urban Area	Compliant	Compliant	Compliant	Compliant
Eastern	Compliant [sup]	Compliant [sup]	Compliant [sup]	Compliant
South West	Compliant	Compliant	Compliant	Compliant
South East	Compliant	Compliant	Compliant	Compliant
East Midlands	Compliant	Compliant	Compliant	Compliant
North West and Merseyside	Compliant [sup]	Compliant [sup]	Compliant [sup]	Compliant
Yorkshire and Humberside	Compliant	Compliant	**Exceedance [sup]**	Compliant
West Midlands	Compliant	Compliant	Compliant	Compliant [sup]
North East	Compliant [sup]	Compliant [sup]	Compliant [sup]	Compliant [sup]
Central Scotland	Compliant	Compliant	Compliant	Compliant
North East Scotland	Compliant [sup]	Compliant [sup]	Compliant [sup]	Compliant [sup]
Highland	Compliant [sup]	Compliant [sup]	Compliant [sup]	Compliant
Scottish Borders	Compliant	Compliant	Compliant	Compliant [sup]
South Wales	Compliant	Compliant	**Exceedance [sup]**	Compliant
North Wales	Compliant [sup]	Compliant [sup]	Compliant [sup]	Compliant [sup]
Northern Ireland	Compliant [sup]	Compliant [sup]	Compliant [sup]	Compliant

‘[sup]’ indicates the compliance or exceedance was determined by supplementary assessment only.

4.3 Comparison with Previous Years

This section provides information on non-compliances in previous years from 2008 onwards. 2008 is the year that the Air Quality Directive came into force, which was subsequently transposed into UK legislation by The Air Quality Standards Regulations (AQSR) (2010).

For SO_2, Pb, benzene and CO, the UK has been compliant with all limit values set in the AQSR (2010) since 2008. For $PM_{2.5}$, the UK has been compliant with the limit value (20 µg m^{-3} to have been achieved by 1 Jan 2020) since 2015. 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 Pb 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 and the AQSR (2010) superseded.

For nitrogen dioxide, **Table 4-8** summarises the results of the air quality assessment in years from 2008 to 2024. This table shows the numbers of zones exceeding the limit value in each year. In years up to 2014 inclusive, some zones were granted a time extension. In these cases, the zone was deemed compliant so long as the limit value plus an agreed margin of tolerance (MOT) was not exceeded. The right-hand column of this table lists the number of zones which exceeded the limit value but were compliant within the provisions of the agreed time extension and MOT. The last time extension ended on 1 January 2015.

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 2024. Time extensions were in place up to the end of 2011 for some zones.

For $PM_{2.5}$, **Table 4-10** shows no zones in exceedance of the annual mean limit value (20 µg m^{-3}).

Table 4-8 Non-Compliances with Limit Values for Nitrogen Dioxide, 2008 to 2024

Year	Zones Exceeding NO_2 LV for health (1hr mean)	Zones Exceeding NO_2 LV for health (annual mean)	Additional zones which exceeded the annual mean LV but were covered by time extensions and were within the LV + MOT therefore compliant
2008	3 zones (London, Glasgow, N.E. Scotland)	40 zones	Not applicable
2009	2 zones (London, Glasgow)	40 zones	Not applicable
2010	3 zones (London, Teesside, Glasgow)	40 zones	Not applicable
2011	3 zones (London, Glasgow, South East)	35 zones	5 zones
2012	2 zones (London, South East)	34 zones	4 zones
2013	1 zone (London)	31 zones	7 zones
2014	2 zones (London, South Wales)	30 zones	8 zones
2015	2 zones (London, South Wales)	37 zones	2015 was the first year with no time extensions for NO_2: hence the apparent increase in zones exceeding in 2015.
2016	2 zones (London, South Wales)	37 zones	All time extensions ended.
2017	2 zones (London, South Wales)	37 zones	All time extensions ended.
2018	2 zones (London, South Wales)	36 zones	All time extensions ended.
2019	1 zone (South Wales)	33 zones	All time extensions ended.
2020	None	5 zones	All time extensions ended.
2021	None	10 zones	All time extensions ended.
2022	None	9 zones	All time extensions ended.
2023	None	9 zones	All time extensions ended.
2024	None	5 zones	All time extensions ended.

Table 4-9 Non-Compliances with the Limit Values for PM_{10}, 2008 to 2024

Year	PM_{10} LV (annual mean)	PM_{10} LV (daily mean)	Additional Zones with Time Extensions, Compliant with AM LV + MOT after Subtraction of Natural Contribution
2008	None	2 zones (1 zone after subtraction of natural contribution)	Not applicable
2009	None	3 zones (1 zone after subtraction of natural contribution)	Not applicable
2010	None	None (after subtraction of natural contribution)	1 zone
2011	None	None (after subtraction of natural contribution)	1 zone
2012	None	None (after subtraction of natural contribution)	All time extensions ended.
2013	None	None (after subtraction of natural contribution)	All time extensions ended.
2014	None	None (after subtraction of natural contribution)	All time extensions ended.
2015	None	None (after subtraction of natural contribution)	All time extensions ended.
2016	None	None	All time extensions ended.
2017	None	None	All time extensions ended.
2018	None	None	All time extensions ended.
2019	None	None	All time extensions ended.
2020	None	None	All time extensions ended.
2021	None	None	All time extensions ended.
2022	None	None	All time extensions ended.
2023	None	None	All time extensions ended.
2024	None	None	All time extensions ended.

Table 4-10 Non-Compliances with the $PM_{2.5}$ Annual Mean Limit Value 2008 to 2024

Year	$PM_{2.5}$ Annual Mean Limit Value (20 µg m^{-3}): number of non-compliant zones
2008	None
2009	None
2010	None
2011	None
2012	None
2013	None
2014	None
2015	None
2016	None
2017	None
2018	None
2019	None
2020	None
2021	None
2022	None
2023	None
2024	None

Figure 4-2 shows how measured concentrations of $PM_{2.5}$ are changing over time and compares them to the long-term (2040 target) and interim (2028 target) Annual Mean Concentration Target (AMCT).

This figure illustrates the gradual decrease in measured concentrations, from the situation in 2010 when the majority of sites had annual mean concentrations above the interim 2028 target, to 2024 when all sites were within the interim 2028 target and most also met the target for 2040. One AURN site in England exceeded the 2040 target of 10 µg m^{-3} in 2024. This was London Marylebone Road, a roadside site in central London. All AURN sites met the interim 2028 target in 2024.

Figure 4-2 AMCT for $PM_{2.5}$: progress from 2009 to 2024, sites by status (per cent of total sites)

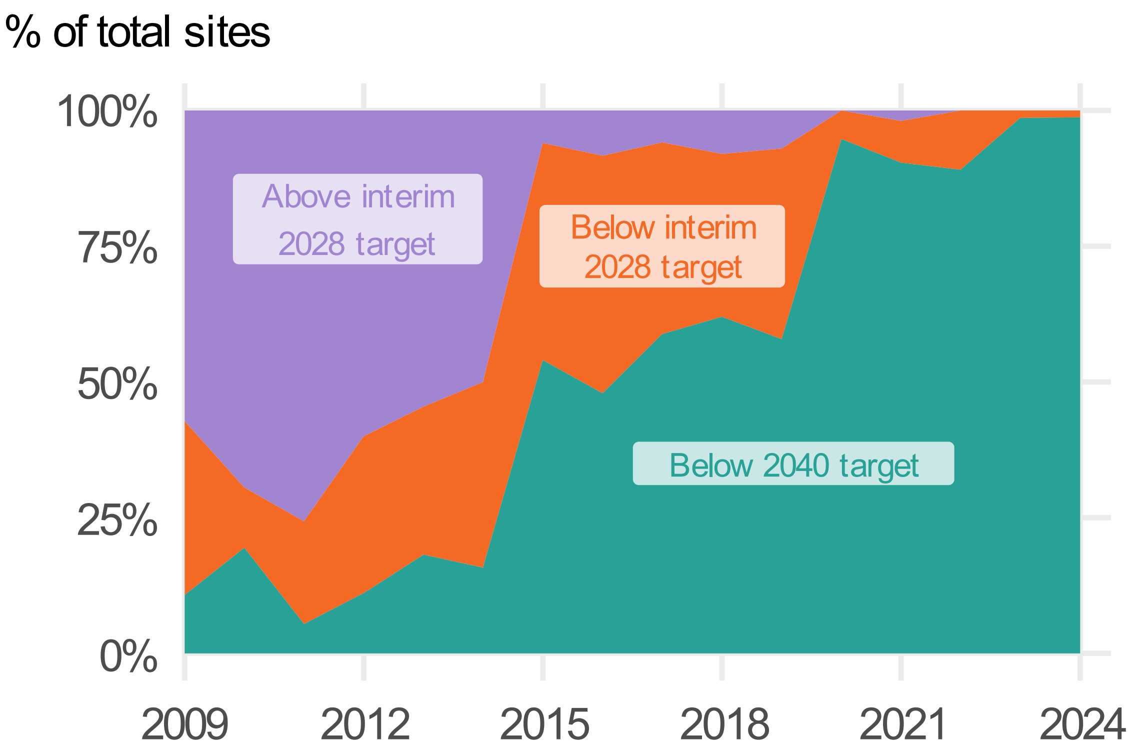
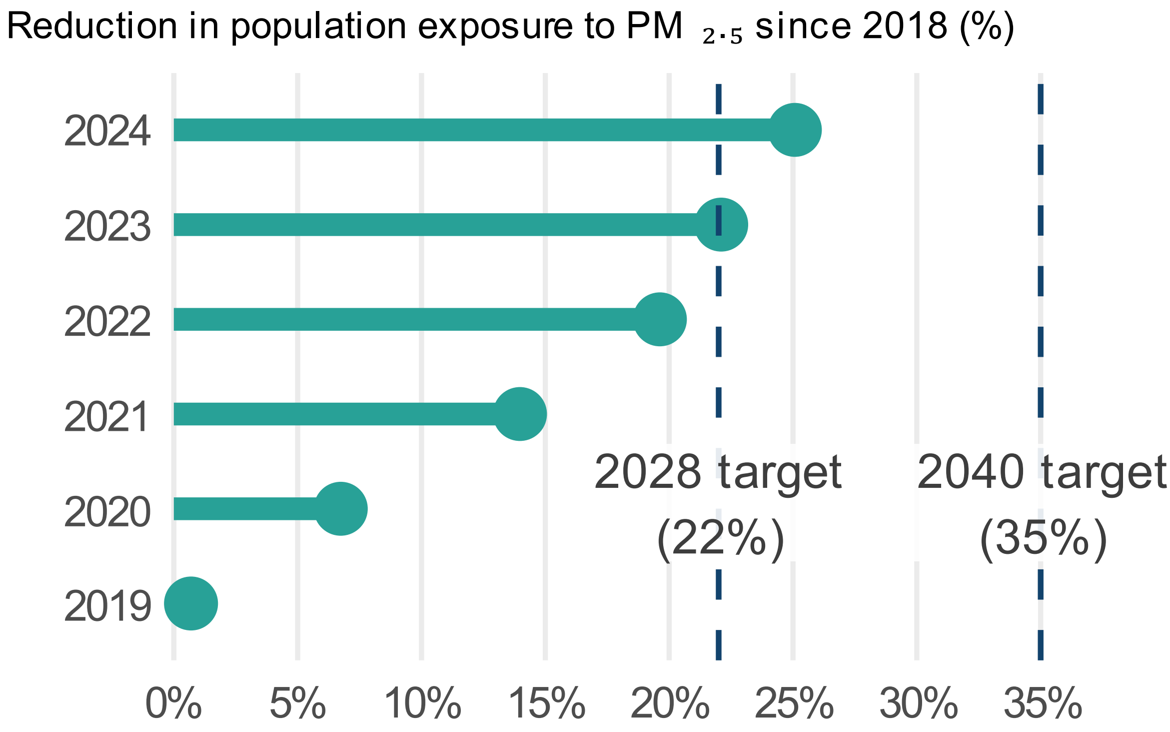


Figure 4-3 illustrates progress towards meeting the PERT (i.e. the 2040 target of a 35 per cent reduction compared to 2018) and its interim target (i.e. the 2028 target of a 22 per cent reduction compared to 2018). The bars indicate the percentage decrease in population exposure since 2018. This illustrates that in 2024, population exposure to $PM_{2.5}$ across England had reduced by 25 per cent since 2018.

Figure 4-3 PERT for $PM_{2.5}$: progress, per cent reduction in population exposure to $PM_{2.5}$ from 2018 to 2024



Information on progress towards meeting the $PM_{2.5}$ targets is available on the UK-AIR website's progress page and the methodology for the PERT and AMCT can be found on the UK-AIR website's calculation page.

For ozone, **Table 4-11** summarises annual exceedances of the target value for human health (based on the maximum daily 8-hour mean), the target value for protection of vegetation (based on the AOT40 statistic), and the two long-term objectives (LTOs) based on these two metrics.

For the pollutants formerly covered by the Fourth Daughter Directive, the UK has been compliant with the target values for As and Cd since 2008 or earlier. **Table 4-12** summarises the numbers of zones with exceedances of target values for Ni and benzo[a]pyrene (B[a]P) in previous years.

Table 4-11 Exceedances of Target Values for Ozone (Health) and Long-Term Objectives, 2008 to 2024

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
2019	None	None	43 zones	6 zones
2020	None	None	40 zones	16 zones
2021	None	None	39 zones	1 zone
2022	None	None	43 zones	11 zones
2023	None	None	42 zones	30 zones
2024	None	None	31 zones	4 zones

Table 4-12 Zones Exceeding Target Values for Ni and B[a]P, 2008 to 2024

Year	Ni	B[a]P
2008	2 (Swansea, South Wales)	6 (Yorks & Humberside, Teesside, Northern Ireland, Swansea, South Wales, Belfast)
2009	2 (Swansea, South Wales)	6 (Yorks & Humberside, Northern Ireland, Teesside, Swansea, North East, South Wales)
2010	2 (Swansea, South Wales)	8 (Yorks & Humber, N. Ireland, Teesside, Belfast, W Midlands, North East, South Wales, North Wales.)
2011	2 (Swansea, South Wales)	7 (Yorks & Humberside, N. Ireland, Teesside, Swansea, Belfast, North East, South Wales)
2012	2 (Swansea, South Wales)	8 (Yorks & Humberside, Teesside, Swansea, Belfast, North East, South Wales, North Wales, N. Ireland.)
2013	2 (Swansea, South Wales)	6 (Yorks & Humberside, Teesside, Swansea, East Midlands, North East, South Wales.)
2014	3 (Sheffield, Swansea, South Wales)	6 (Yorks & Humberside, Teesside, Swansea, East Midlands, North East, and South Wales).
2015	2 (Swansea, South Wales)	5 (Yorks & Humberside, Teesside, Swansea, North East and South Wales).
2016	3 (Sheffield, Swansea, South Wales)	4 (Yorks & Humberside, Swansea, South Wales and Northern Ireland).
2017	None	3 (Yorks. & Humberside, Swansea, South Wales)
2018	4 (Sheffield, Yorks. & Humber., Swansea, South Wales)	3 (Yorks. & Humberside, Swansea, South Wales)
2019	4 (Sheffield, Yorks. & Humber., Swansea, South Wales)	3 (Yorks. & Humberside, Swansea, South Wales)
2020	4 (Sheffield, Yorks. & Humber., Swansea, South Wales)	3 (Yorks. & Humberside, Swansea, South Wales)
2021	4 (Sheffield, Yorks. & Humber., Swansea, South Wales)	2 (Swansea and South Wales)
2022	3 (Sheffield, Yorks. & Humberside, South Wales)	2 (Swansea and South Wales)
2023	3 (Sheffield, Yorks. & Humberside, South Wales)	2 (Swansea and South Wales)
2024	3 (Sheffield, Yorks & Humberside, South Wales)	None

5 Spatial Variation and Changes Over Time

5.1 About the Maps and Charts in this Section

5.1.1 Maps of Modelled Pollutant Concentration

This section looks at the spatial distribution of pollutants across the UK, based upon the modelled maps of ambient pollutant concentration discussed in Section 3.3 of this report, “Modelling”.

Modelled maps are included in this section to illustrate how background (i.e. non-roadside) concentrations of various pollutants vary across the UK. However, here they can only show general patterns and limited detail. To see modelled maps in more detail, and to zoom in on specific areas, it is recommended to view the UK Ambient Air Quality Interactive Maps, provided by the UK-AIR website.

Please note, the online interactive versions of the maps are not all identical to the versions used in this report. In some cases, the concentration bands may be different, and in the case of lead (Pb), different units are used. Also, the online interactive maps use a different default colour scale from the one used in this report. To view the online maps in the ‘Viridis’ colour scale used in this report, please change this via the accessibility settings as follows:

(i) When accessing the UK Ambient Air Quality Interactive Maps, click on the link to “*About this ambient air quality map*” in the top right corner of the page.
(ii) Scroll down to the ‘Accessibility Version’ heading.
(iii) Select the ‘Viridis’ colour scale from the list.

Please note that these modelled concentration maps show the modelled average background concentration in each 1 km^2 grid square. Within the grid squares, there may be local areas of higher concentration (so-called ‘hot spots’), for example around road junctions or other specific emission sources. These will not be visible in these maps.

Reports in this series for years up to and including 2020 have also included maps of modelled roadside concentrations of some traffic-related pollutants: NO_2, PM_{10}, $PM_{2.5}$ and benzene. However, these are no longer included, due to the difficulty of showing the modelled roadside concentrations in a clear and accessible way. Instead, the reader is recommended to refer to the interactive maps on UK-AIR using the link above. These interactive maps will allow the viewer to see the modelled roadside concentrations in detail and zoom in on individual road links.

5.1.2 Trend and Time Series Charts

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 Polycyclic Aromatic Hydrocarbons (PAH) Network.

5.1.3 Estimated UK Emission Charts

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. The most recent year for which NAEI emission estimates are available is 2023. The NAEI dataset shows emissions split between various emission source categories, which are different for different pollutants.

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 or groups of long-running sites. Patterns for specific regions or individual sites may be different.

5.2 Nitrogen Dioxide

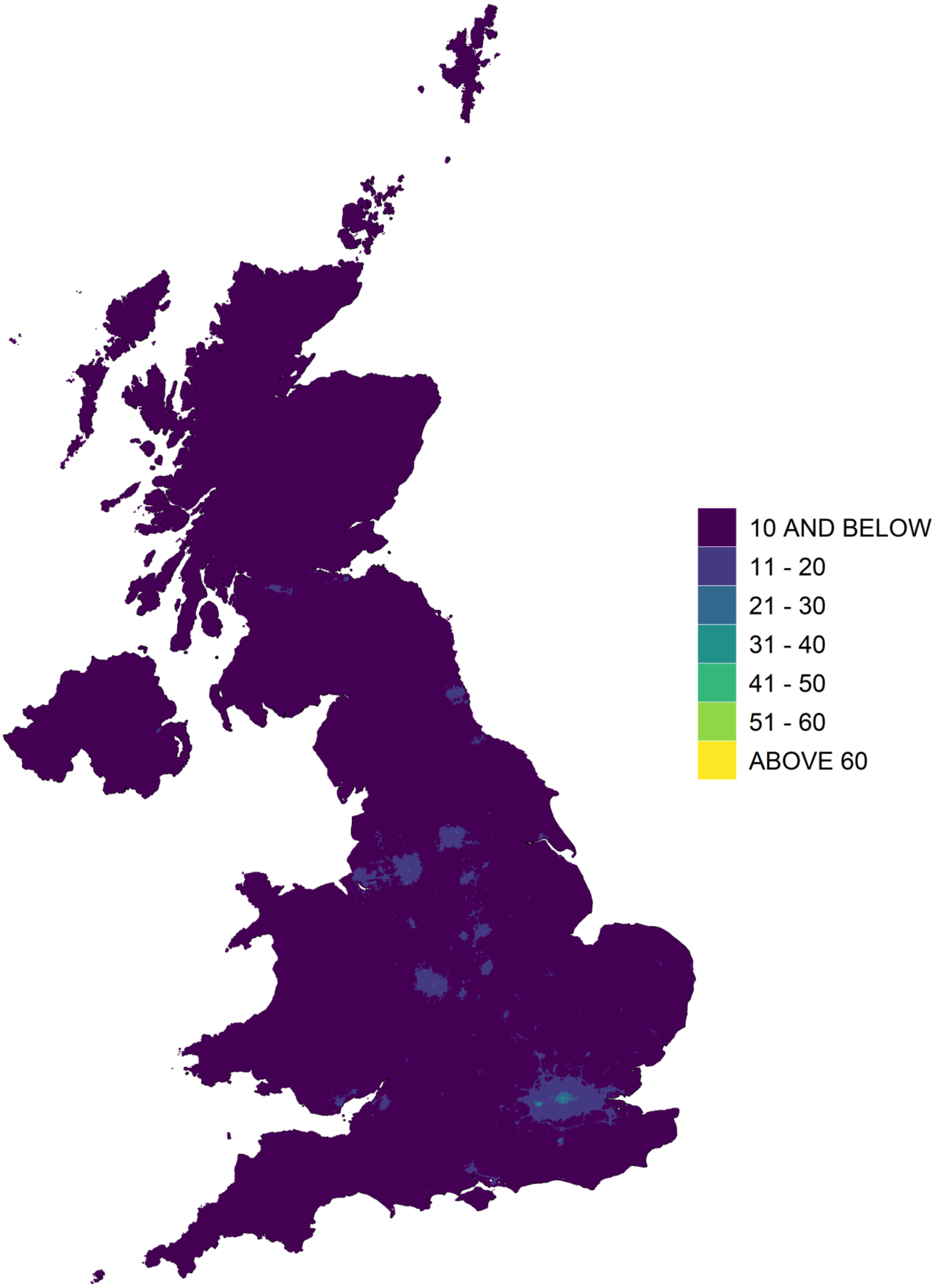
5.2.1 NO_2: Spatial Distribution in the UK

Figure 5-1 shows the modelled annual mean NO_2 concentrations for 2024, at all urban, suburban and rural background locations. This modelled map shows the modelled mean concentration for each 1 km^2 grid square. Outside of major towns and cities, modelled annual mean concentrations of NO_2 were mostly 10 µg m^{-3} or below (shown as dark blue). In the UK's urban areas, modelled concentrations were higher (indicated by lighter colours). The highest modelled annual mean concentrations were in the range 31 – 40 µg m^{-3}, and occurred in two small areas: central London, and the area around Heathrow Airport. However, all background locations were within the limit value of 40 µg m^{-3}.

To see detail for specific areas, and maps of modelled roadside concentrations, please use the UK Ambient Air Quality Interactive Maps provided by the UK-AIR website.

As explained above, previous reports in this series (up to and including 2020) have also included maps of modelled roadside concentrations of NO_2 and other traffic-related pollutants. However, these are no longer included, due to the difficulty of showing the modelled roadside concentrations in a clear and accessible way. Instead, the reader is referred to the online Interactive Maps to see the modelled roadside concentrations.

Figure 5-1 Annual Mean Background NO_2 Concentration, 2024 (µg m^{-3})



More detail is available on the UK-AIR website's interactive map.

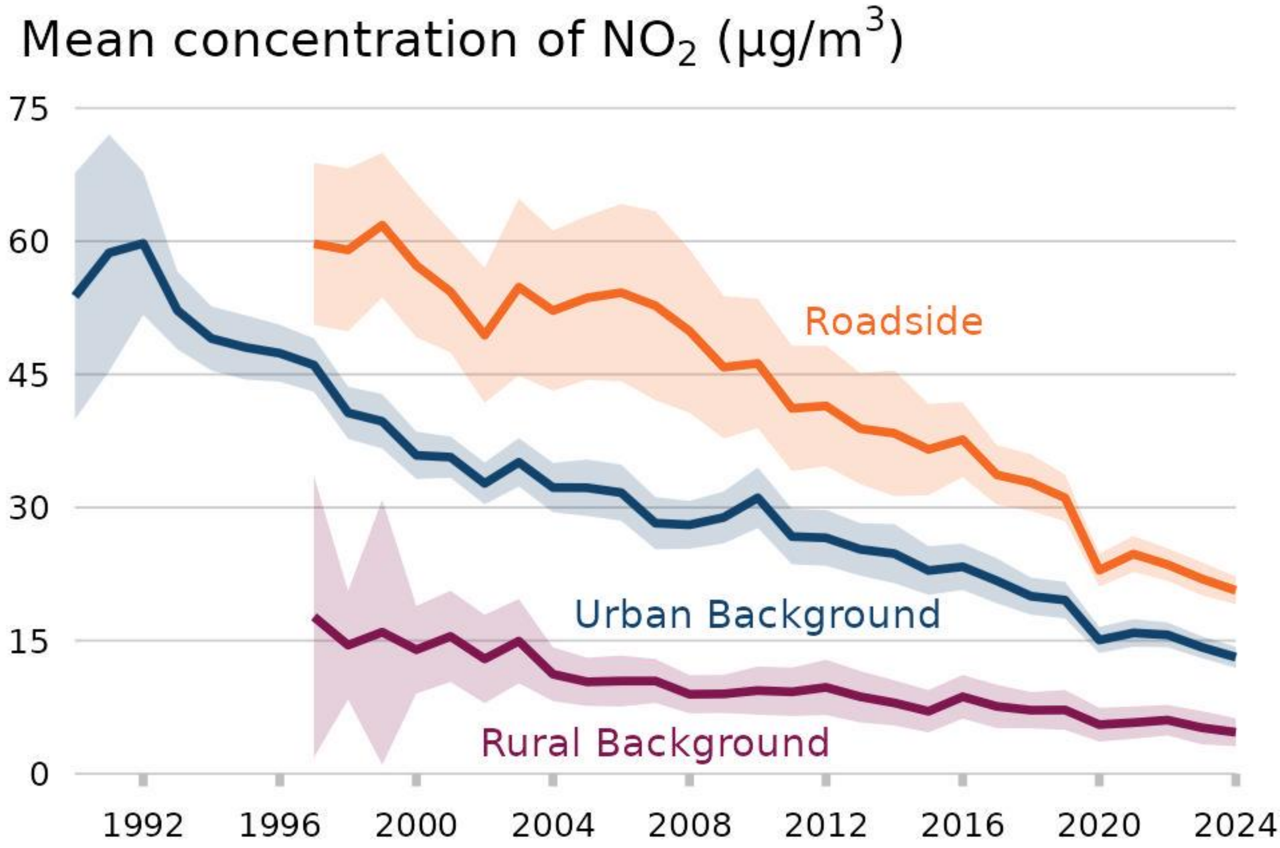
5.2.2 NO_2: Changes Over Time

Figure 5-2 is taken from Defra's Accredited Official Statistics (Defra, 2025b). This shows annual mean NO_2 concentrations averaged over all included sites that had annual data capture greater than or equal to 75% in the relevant year. Roadside (i.e. urban traffic), urban background and rural sites are shown by separate, labelled, lines.

The number of sites in the network has increased substantially over the years. This introduces uncertainty when considering trends for the whole network. Therefore, this graph shows the 95% confidence interval of the annual mean for each site classification, as a shaded area either side of each line. The confidence intervals narrow over time because of an increase in the number of monitoring sites and a reduction in the variation between annual means at monitoring sites for NO_2.

All site types show strong decreases. For both urban traffic and urban background sites, there appears to be a dip in 2020, which is likely to be due at least in part to the reduction in traffic emissions caused by the COVID-19 pandemic restrictions in that year.

Figure 5-2 Annual mean concentrations of NO_2 in the UK, by AURN Site Classification, 1990 to 2024.



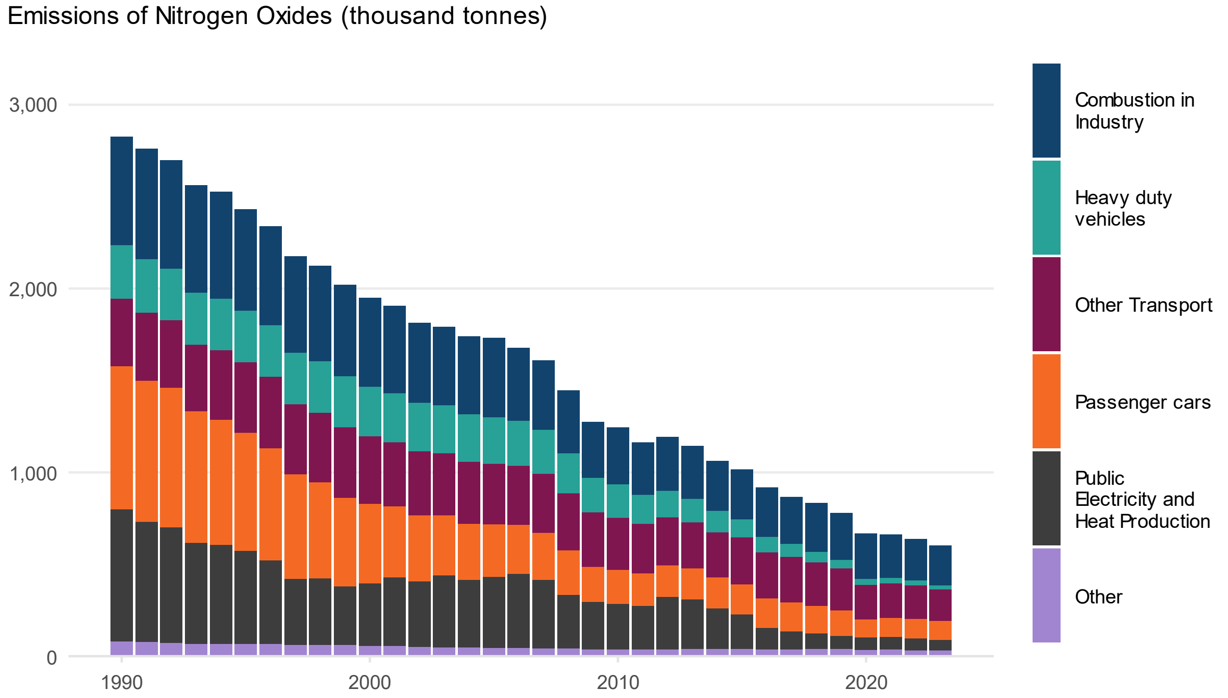
Shaded areas either side of each line show the 95% confidence interval of the mean.

Source: Accredited Official Statistics - Air Quality in the UK

Figure 5-3 shows estimates of total UK annual emission of nitrogen oxides (NOx), in kilotonnes, from 1990 to 2023 (the most recent year for which emission estimates are available). The data are from the National Atmospheric Emissions Inventory (NAEI) website. This shows that total NOx emissions have decreased substantially over this period and are now less than one third of the total emissions in 1990. Emissions from several specific sources, notably public energy and heat production, passenger cars and heavy-duty vehicles, have also shown substantial decreases over the same period.

For more information on UK emissions of NOx please visit the Accredited Official Statistics publication Emissions of Air Pollutants.

Figure 5-3 Estimated Annual UK Emissions of Nitrogen Oxides (kt), 1990 to 2023 (Source: NAEI 2025)



5.3 PM_{10} Particulate Matter

5.3.1 PM_{10}: Spatial Distribution

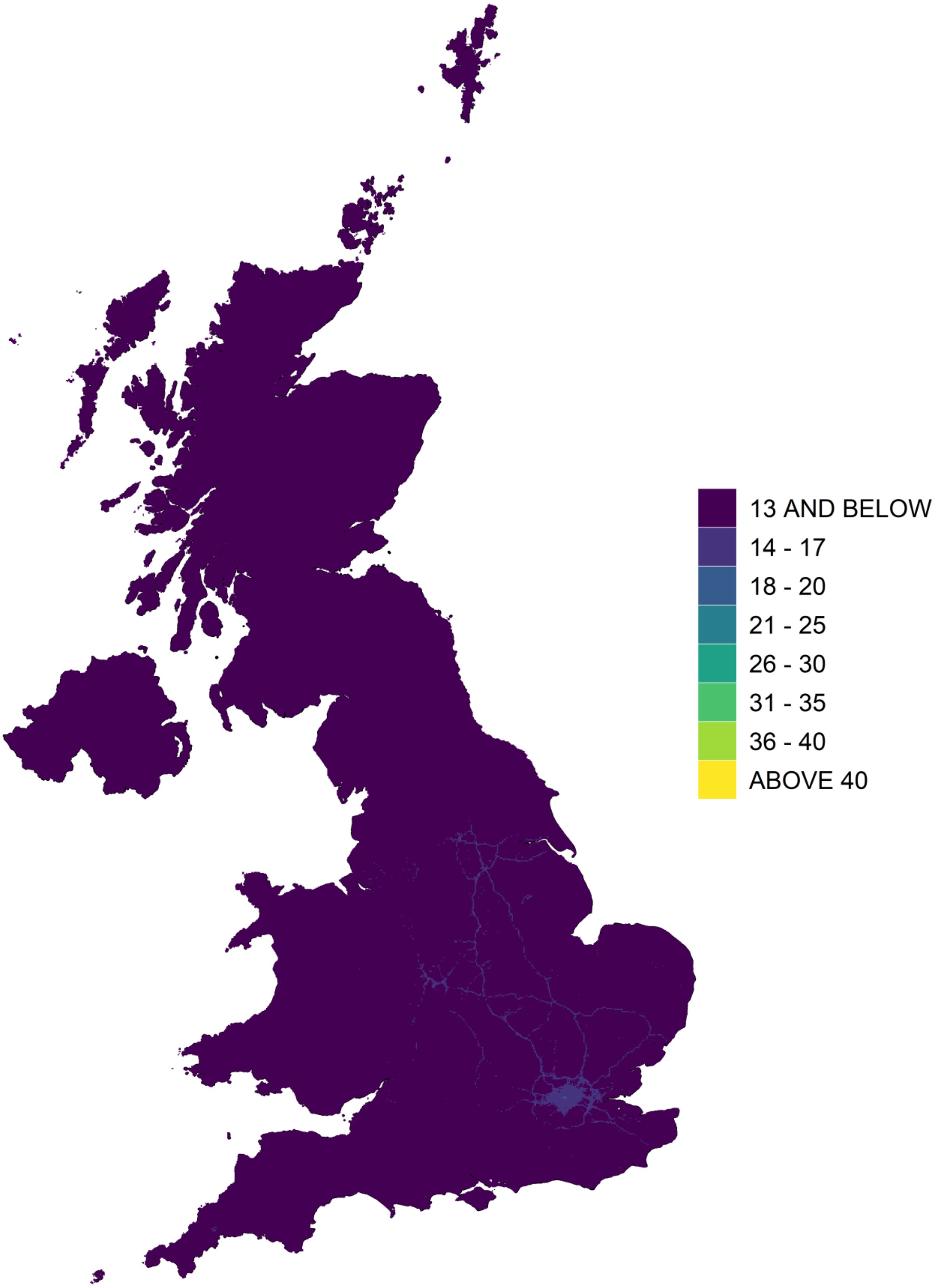
Figure 5-4 shows modelled annual mean background PM_{10} concentrations in 2024, based on modelled mean concentrations for 1 km^2 grid squares. An interactive map is available on the UK-AIR website.

The majority of the UK, even in major cities apart from London, had modelled annual mean PM_{10} concentrations of 13 µg m^{-3} or less. An interesting feature of the 2024 modelled map is that the routes of some major roads and motorways are clearly visible, including the M1, M18, M180, M25 and parts of the M62, M6 and M40. Along these major routes, modelled annual mean background PM_{10} concentrations are higher - in the range 14 to 17 µg m^{-3} - due to the influence of PM_{10} emissions associated with the road traffic. These include both exhaust emissions, tyre and brake wear, and road abrasion.

No urban background locations had a modelled annual mean concentration greater than the limit value of 40 µg m^{-3}.

As in the case of NO_2 and other traffic-related pollutants, roadside concentrations are also modelled, but maps are no longer included in this report because of the difficulty of showing the information clearly. Instead, the reader is referred to the interactive maps of modelled concentrations of both roadside and background PM_{10} (at) which allow the detail to be seen more clearly.

Figure 5-4 Annual Mean Background PM_{10} Concentration, 2024 ($\mu g\ m^{-3}$)



More detail is available on the UK-AIR website's interactive map.

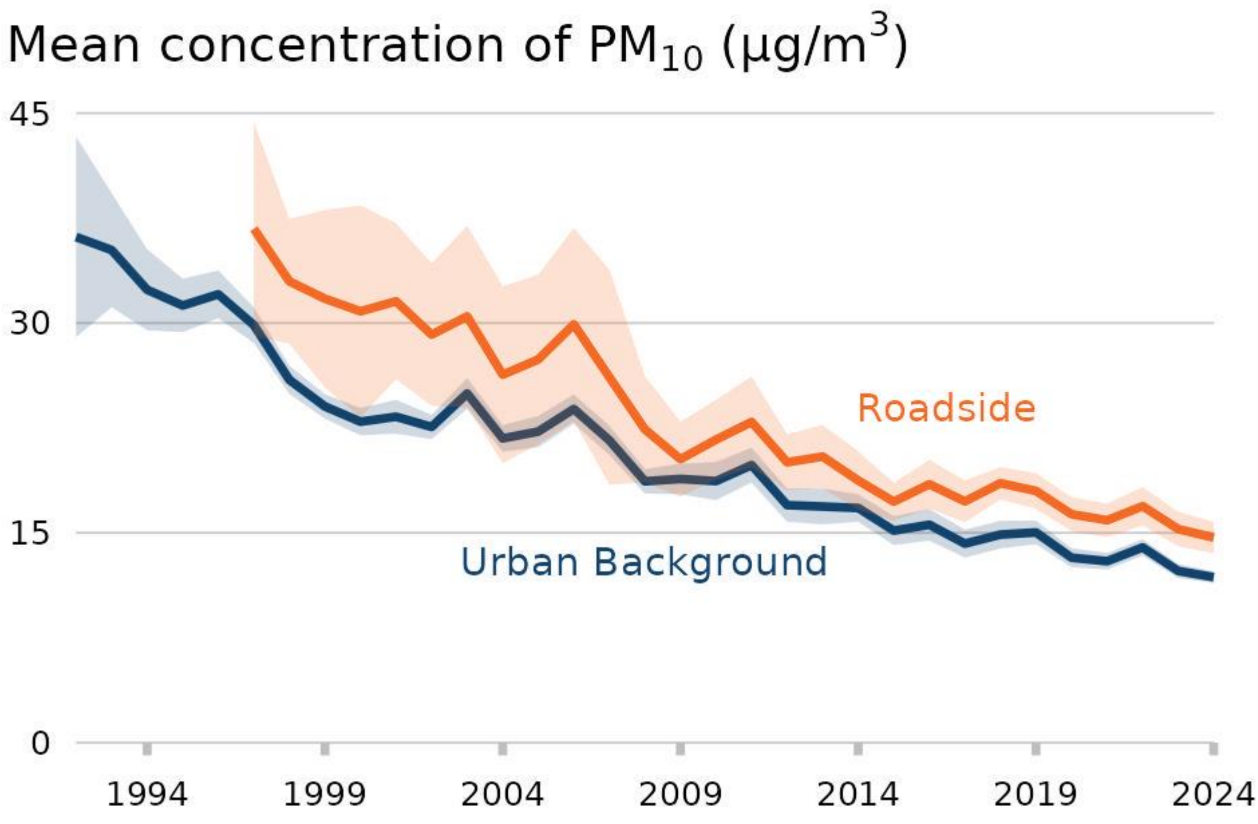
5.3.2 PM_{10} Changes Over Time

Figure 5-5 is taken from Defra's National Air Quality Statistics web page for PM_{10} and $PM_{2.5}$, at https://www.gov.uk/government/statistics/air-quality-statistics/concentrations-of-particulate-matter-pm10-and-pm25, (Defra, 2025c). This shows annual mean PM_{10} concentrations averaged over all included AURN sites that had annual data capture greater than or equal to 75% in the relevant year. Roadside (urban traffic) and urban background sites are shown by separate, labelled, lines.

Shaded areas surrounding the lines show the 95% confidence interval of the annual mean for each site classification. The confidence intervals narrow over time, as the number of monitoring sites has increased: this is particularly the case for urban traffic (roadside) PM_{10} monitoring sites, which have almost doubled in number since 2008.

It is notable that the difference between roadside and background concentrations (the roadside increment) is much smaller relative to the background concentrations than is the case for NO_2.

Figure 5-5 Annual mean concentrations of PM_{10} in the UK, by AURN Site Classification, 1992 to 2024.



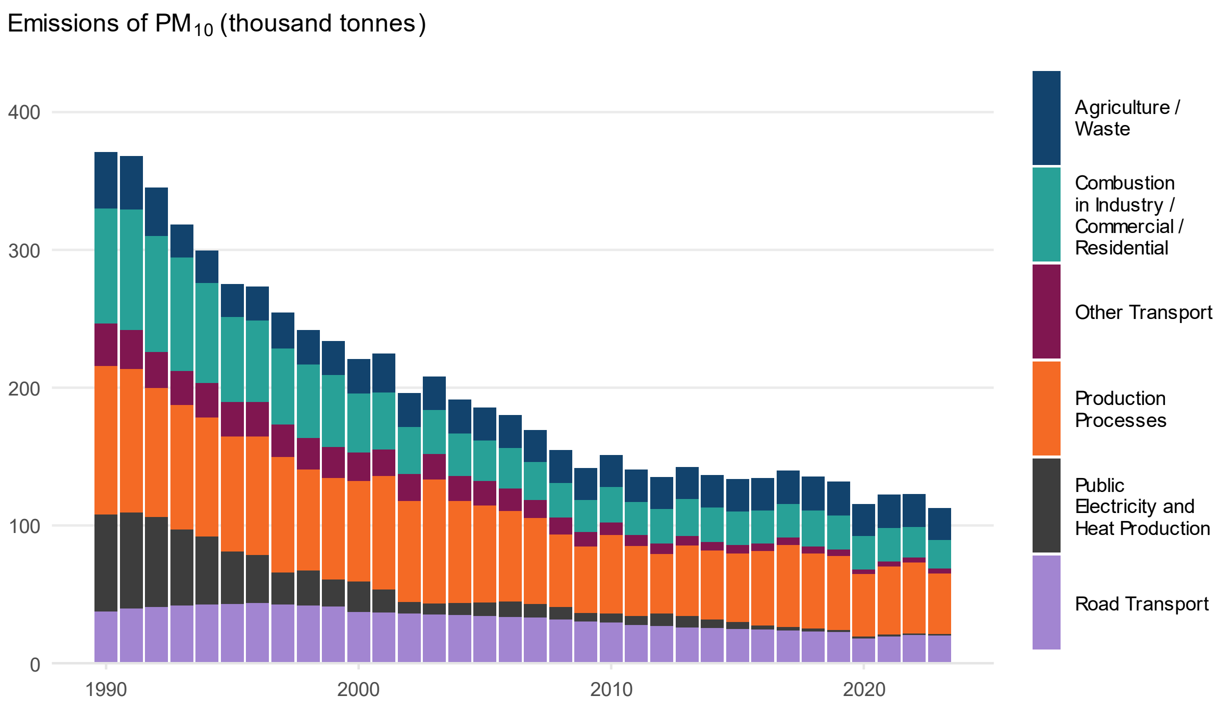
Shaded areas either side of each line show the 95% confidence interval of the mean.

Source: Accredited Official Statistics - Air Quality in the UK

Figure 5-6 shows NAEI estimates of total UK annual emission of PM_{10} in kilotonnes, from 1990 to 2023 (the most recent year for which emission estimates are available). 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 2010. Emissions from the *'combustion in industry, commercial and residential*' sector appears to have increased slightly over the past decade. The NAEI says *"Emissions from residential sector combustion have grown both in real terms and in terms of the contribution to the UK total. This is because of strong growth in the use of wood as a domestic fuel, which has offset reductions that have occurred due to decreasing use of coal and other solid mineral fuels."* (https://naei.energysecurity.gov.uk/node/51). By contrast, estimated emissions from road traffic alone have continued to decrease steadily. The graph shows a sharp decrease in estimated emissions from road traffic and other traffic in 2020, as a result of the COVID-19 pandemic restrictions.

For more information on UK emissions of PM_{10} please visit the Accredited Official Statistics publication available here: https://www.gov.uk/government/statistics/emissions-of-air-pollutants.

Figure 5-6 Estimated Annual UK Emissions of PM_{10} (kt), 1990 to 2023 (Source: NAEI 2025)



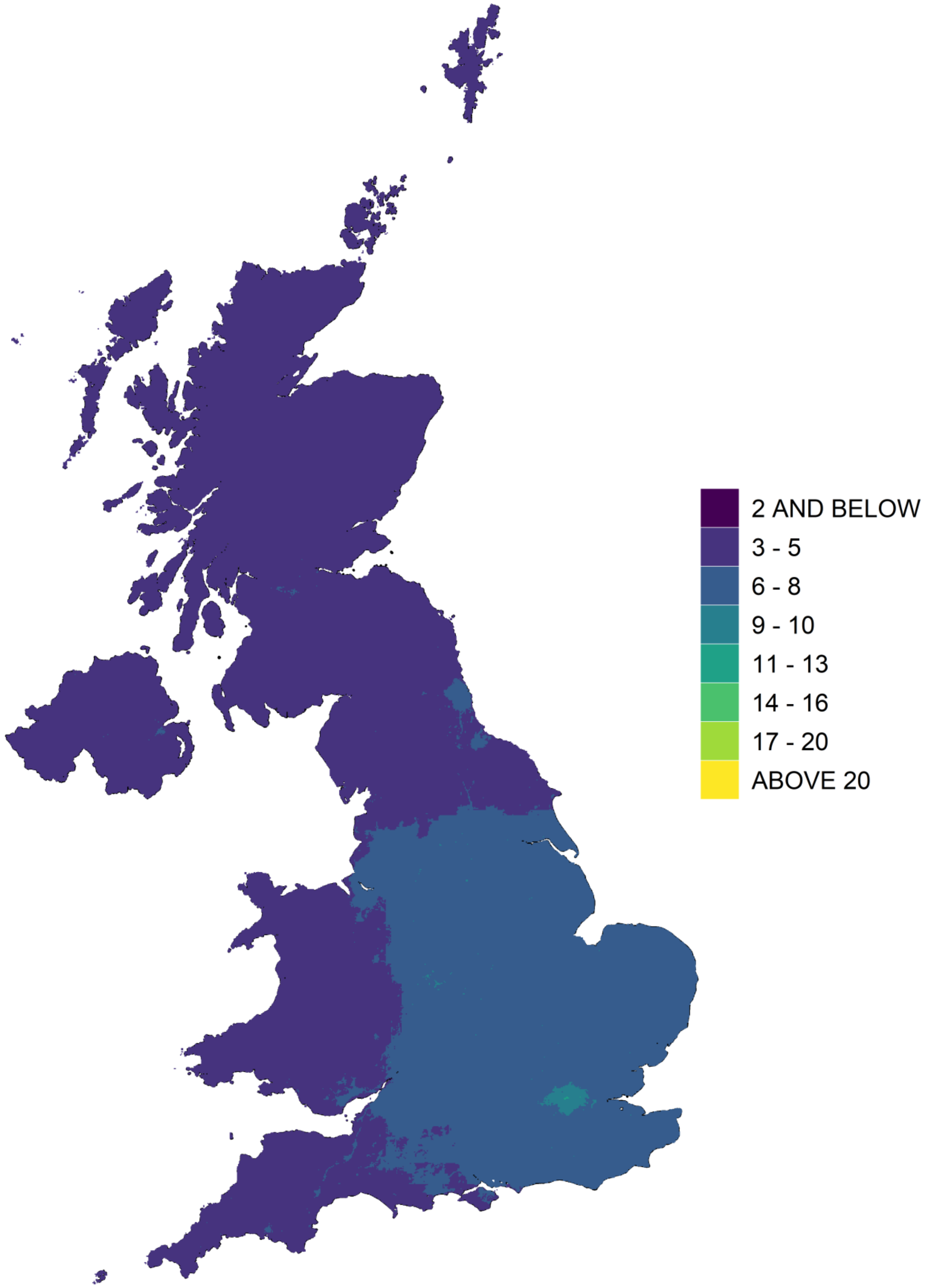
5.4 $PM_{2.5}$ Particulate Matter

5.4.1 $PM_{2.5}$: Spatial Distribution

Figure 5-7 shows modelled annual mean background $PM_{2.5}$ concentrations for 2024. In most of Scotland, Northern Ireland, Wales, the South West peninsula, and England north of a line running roughly through Preston and York, modelled concentrations were in the range 3 to 5 µg m^{-3}. In the rest of England, as well as small areas within Belfast, Glasgow, Cardiff and the Tyneside conurbation, modelled concentrations were higher, in the range 6 to 8 µg m^{-3}. Concentrations in the range 9 to 10 µg m^{-3} are visible in Greater London and small areas elsewhere in England, and a small area of central London had modelled concentrations in the range 11 to 13 µg m^{-3}. However, everywhere in the UK was well within the annual mean limit value of 20 µg m^{-3}, and as reported in Section 4.

As in the case of other traffic-related pollutants, maps of modelled annual mean roadside concentrations are also produced. However, they are no longer included in this series of reports because the detail can be seen much more clearly in the interactive versions of the maps, available on UK-AIR at https://uk-air.defra.gov.uk/data/gis-mapping/.

Figure 5-7 Annual Mean Background $PM_{2.5}$ Concentration, 2024 ($\mu g\ m^{-3}$)



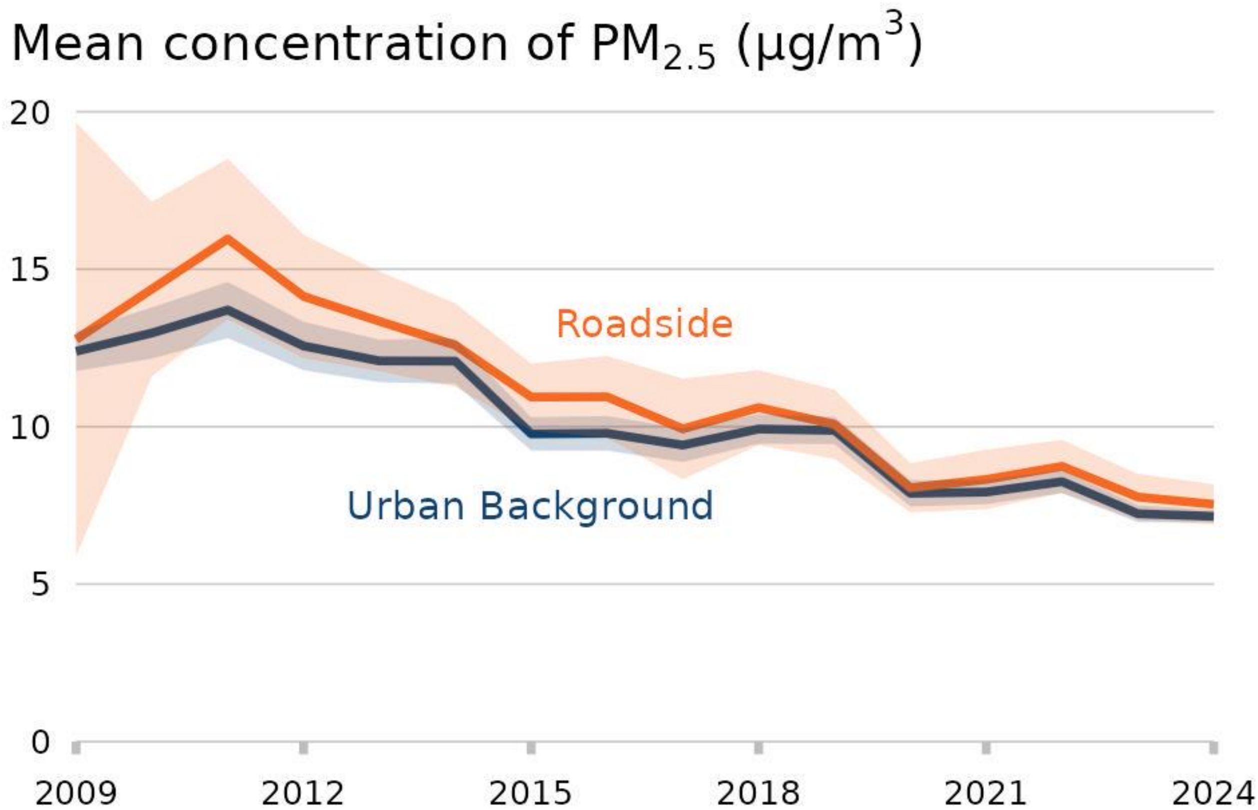
More detail is available on the UK-AIR website's interactive map.

5.4.2 $PM_{2.5}$: Changes Over Time

Figure 5-8 is taken from Defra's Air Quality Accredited Official Statistics web page for particulate matter (Defra, 2025c). This shows annual mean $PM_{2.5}$ concentrations averaged over all included AURN sites that had annual data capture greater than or equal to 75% in the relevant year. Roadside (urban traffic) and urban background sites are shown by separate, labelled, lines.

This graph shows years from 2009 onwards: although there was some $PM_{2.5}$ monitoring before then, the number of sites was very small. Shaded areas surrounding the lines show the 95% confidence interval of the annual mean for each site classification. The very wide confidence intervals in years 2009 to 2011, especially for roadside sites, reflect the small number of sites measuring $PM_{2.5}$ in these early years.

Figure 5-8 Annual mean concentrations of $PM_{2.5}$ in the UK, by AURN Site Classification, 2009 to 2024.



Shaded areas either side of each line show the 95% confidence interval of the mean.

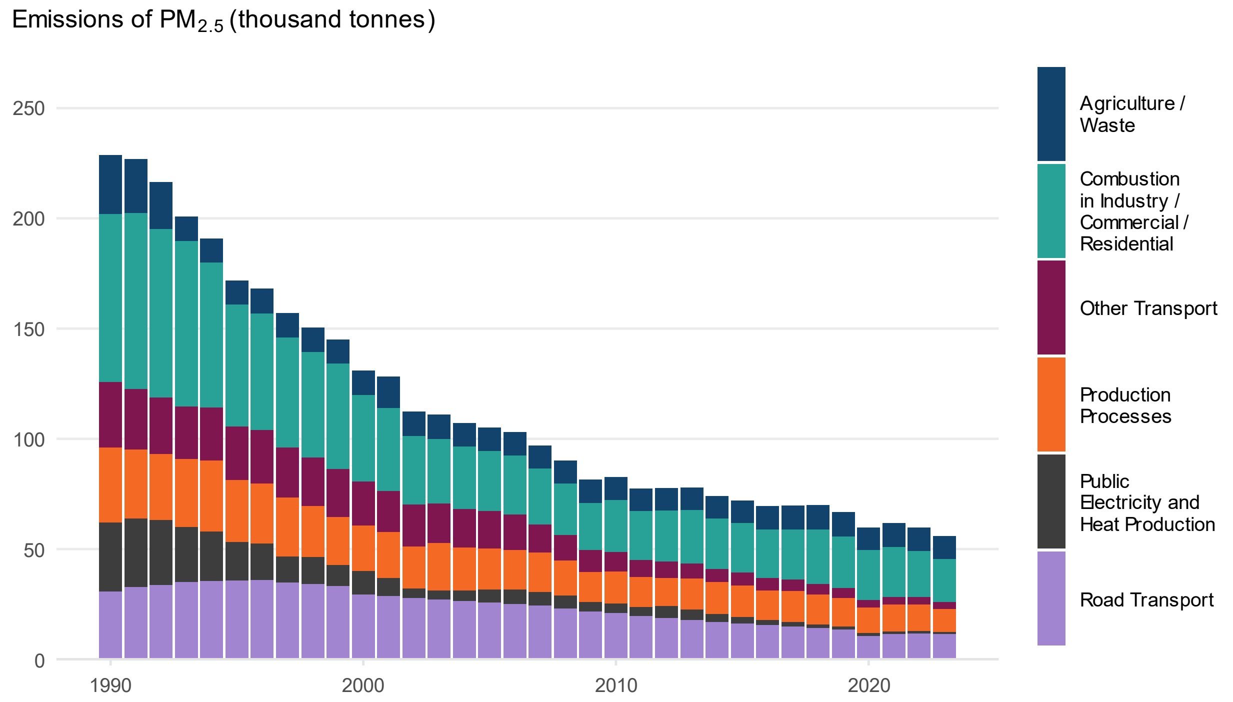
Source: Accredited Official Statistics - Air Quality in the UK

Figure 5-9 shows the estimated annual emission of $PM_{2.5}$, from 1990 to 2023 (the most recent year for which estimates are available). The graph shows that emissions have decreased in a similar manner to emissions of PM_{10}, with a steady decrease from the early 1990s, and a clear levelling off around 2010 with no further consistent decrease until 2020.

Estimated UK emissions of $PM_{2.5}$ have declined by 66% since 1990 due mainly to a reduction in coal use, and the banning of crop residue burning in 1993. Emissions from coal-fired power stations have also fallen by 99.9% since 1990. The largest source category for $PM_{2.5}$ is combustion in industry, residential and commercial premises. Estimated emissions from this source have increased over the past decade, both in real terms and as a proportion of the UK total. Residential and industrial combustion of wood and other biomass fuels have increased since 2000 and have become a substantial source of total $PM_{2.5}$ emissions.

Estimated $PM_{2.5}$ emissions from both road transport and other transport showed a dip in 2020, similar to what is observed for PM_{10}, attributed to the travel restrictions resulting from the COVID-19 pandemic. For more information on UK emissions of $PM_{2.5}$ please visit the Accredited Official Statistics publication available here: https://www.gov.uk/government/statistics/emissions-of-air-pollutants.

Figure 5-9 Estimated Annual UK Emissions of $PM_{2.5}$ (kt), 1990 to 2023. (Source: NAEI 2025)



5.5 Ozone

5.5.1 O_3: Spatial Distribution

Figure 5-10 shows the average number of days per year with maximum daily running 8-hour mean ozone concentration greater than 120 µg m^{-3}, over the **three** years 2022 to 2024. The number of such days is highest in the southern parts of the UK: the south east, south west of England, the east and west Midlands and Wales. Only in parts of Central Scotland and Scotland's Northern Isles were there no such days in 2024.

This map shows slightly lower values around some major conurbations including Greater London, Birmingham, Cardiff, Nottingham, Derby and the West Yorkshire urban area. Ozone concentrations tend to be lower in built-up areas, due to the ‘scavenging’ effect of nitric oxide (NO), which reacts with ozone. Therefore, the pattern shown in these modelled for ozone is often in some respects the opposite to that shown for e.g. NO_2 or PM_{10}.

Figure 5-11 shows the number of days per year with maximum daily running 8-hour mean ozone concentration greater than 120 µg m^{-3}, for 2024 only. These values are lower for 2024 alone than for the three years 2022 to 2024, with no such days modelled for Scotland, Northern Ireland or parts of northern England: this reflects the generally low ozone concentrations measured in 2024.

Figure 5-12 shows the AOT40 statistic, averaged over the past **five** complete years, 2020 to 2024. 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 between 1 May and 31 July. The pattern shown is fairly typical in that the values are highest in the southern part of the UK, although the highest areas are East Anglia and the South West. Lower values are visible around some urban areas (Greater London, the West Midlands conurbation) and along parts of some motorway routes.

Figure 5-13 shows the same statistic, for 2024 only. Values are lower, reflecting the generally lower ozone concentrations in 2024 compared to previous recent years: the pattern shown is similar however, with highest concentrations in the south of the UK.

Figure 5-10 Average Number of days with Maximum Daily Running 8h Mean O_3 Concentration > 120 µg m^{-3} 2020 to 2024

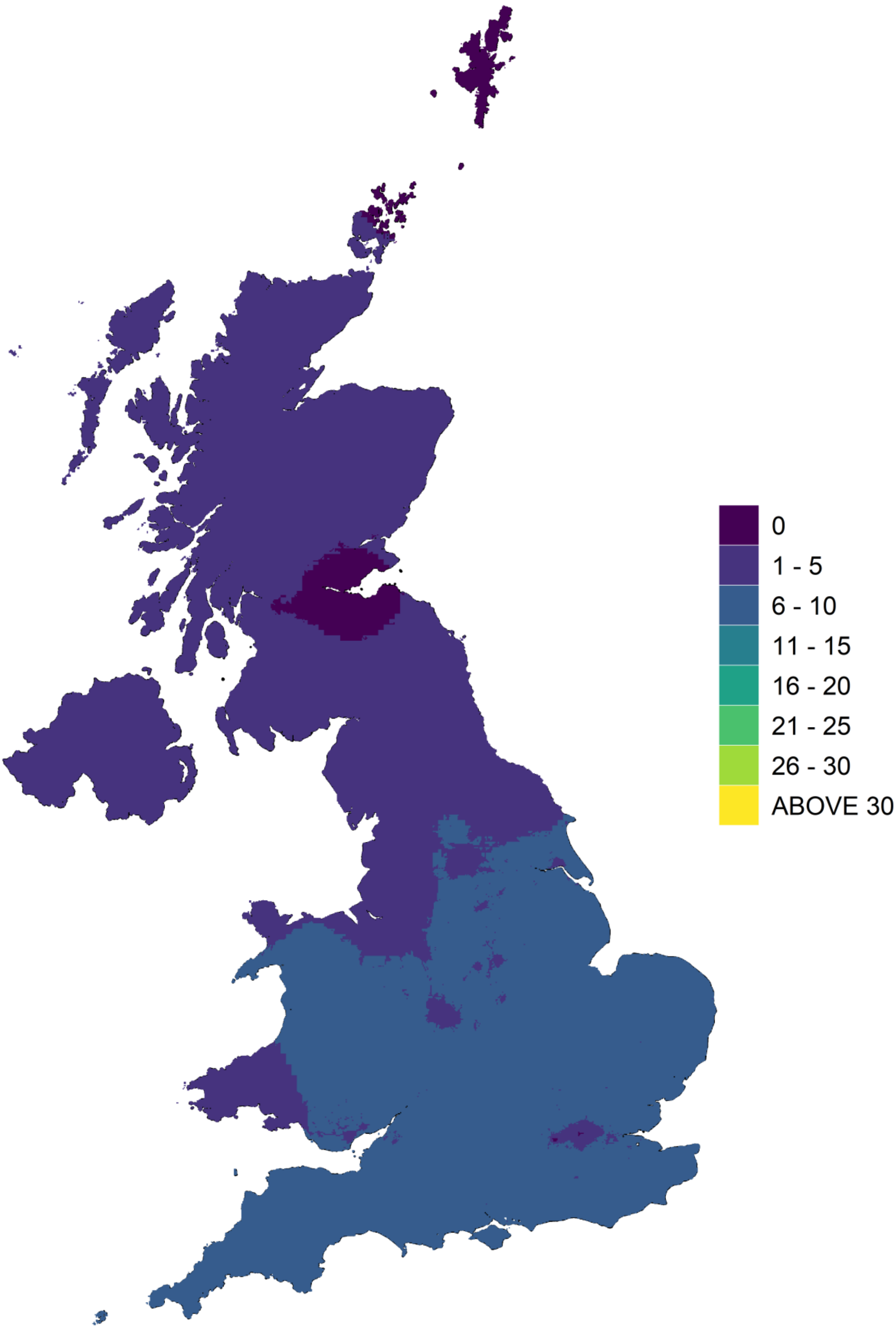
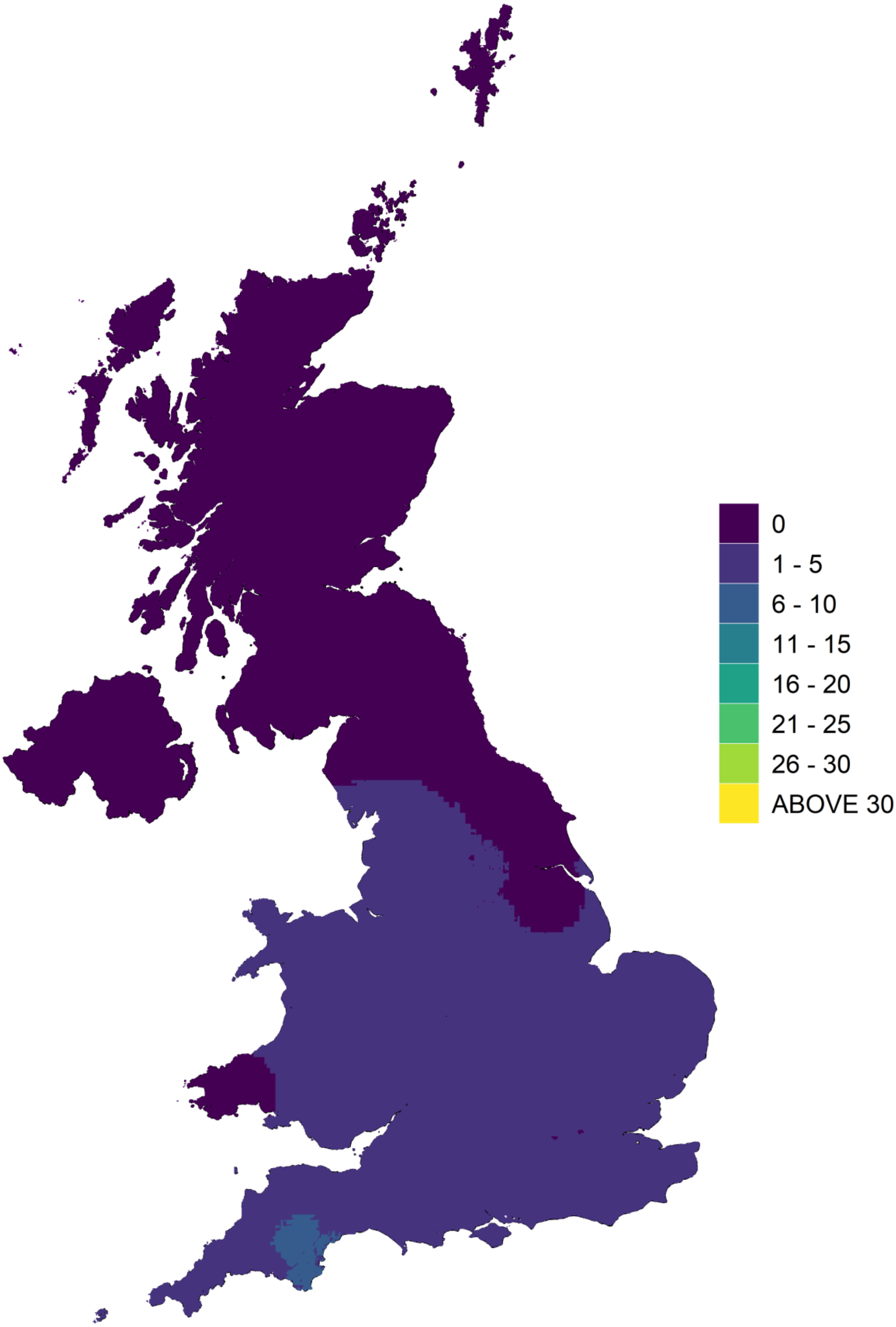


Figure 5-11 Days with Maximum Daily Running 8h Mean O_3 Concentration > 120 µg m^{-3}, 2024



More detail is available on [the UK-AIR website's interactive map](#).

Figure 5-12 Average AOT40, 2018 to 2024 (µg m^{-3}.hours)

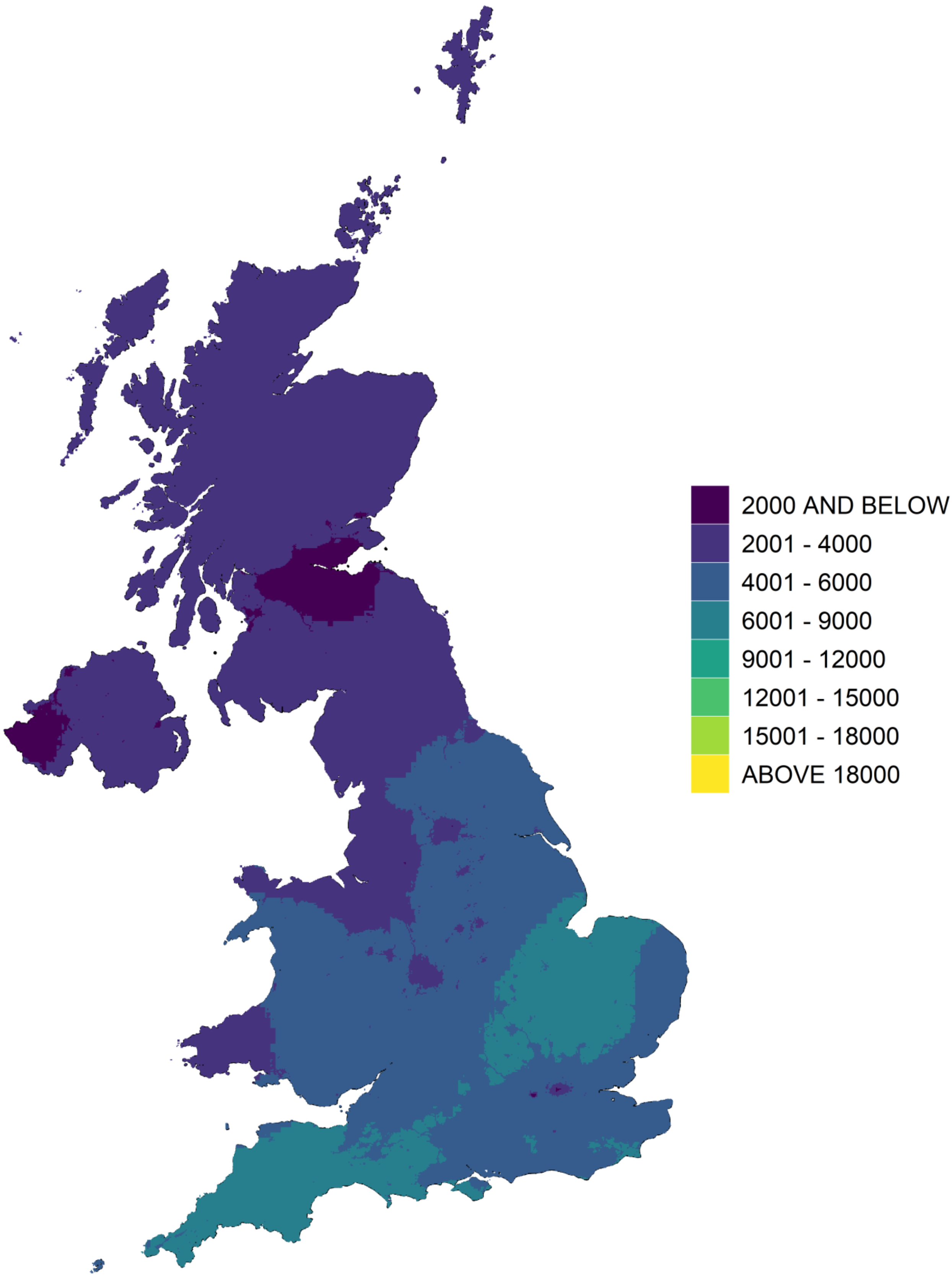
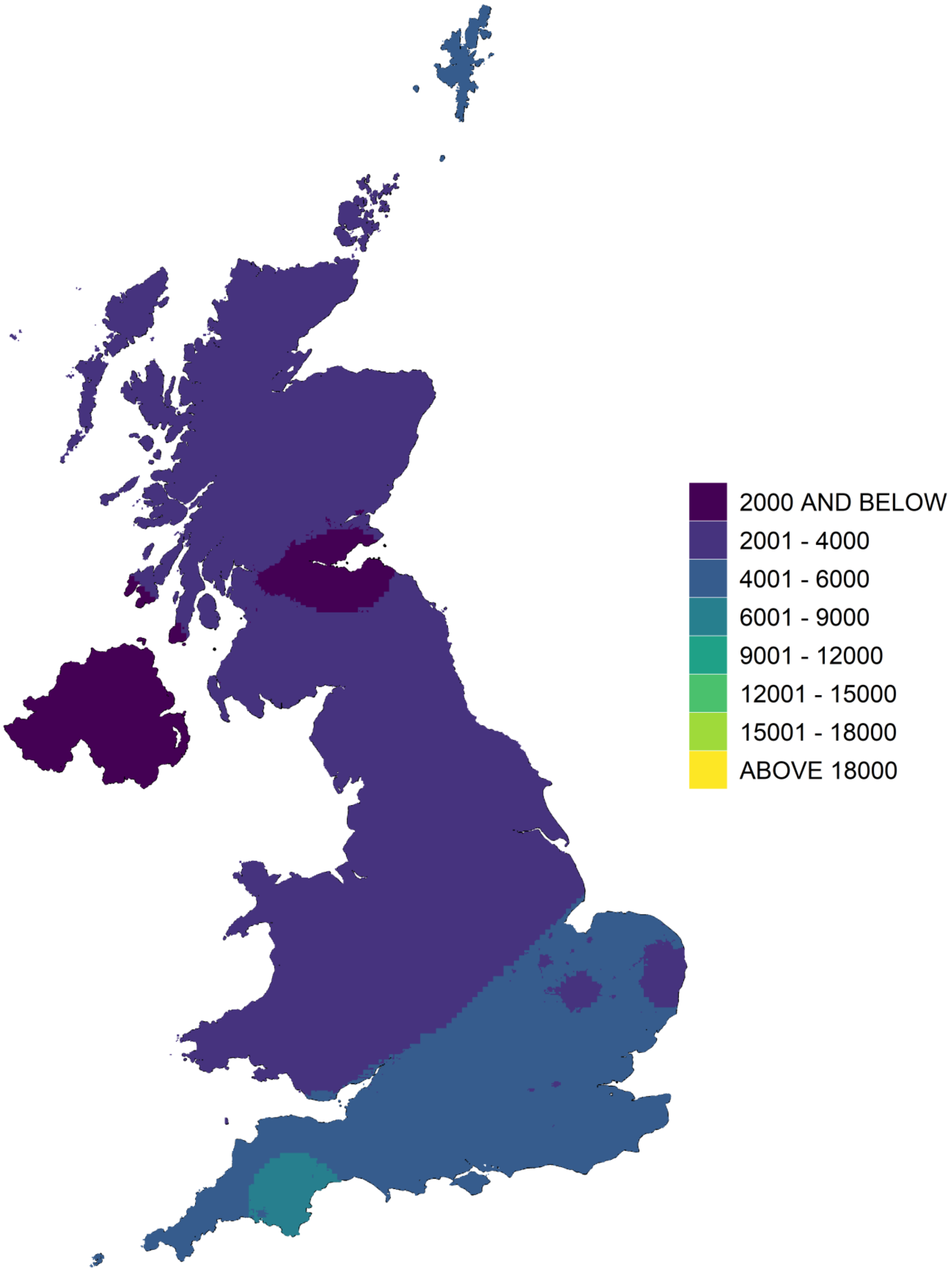


Figure 5-13 Average AOT40, 2024 (µg m^{-3}.hours)

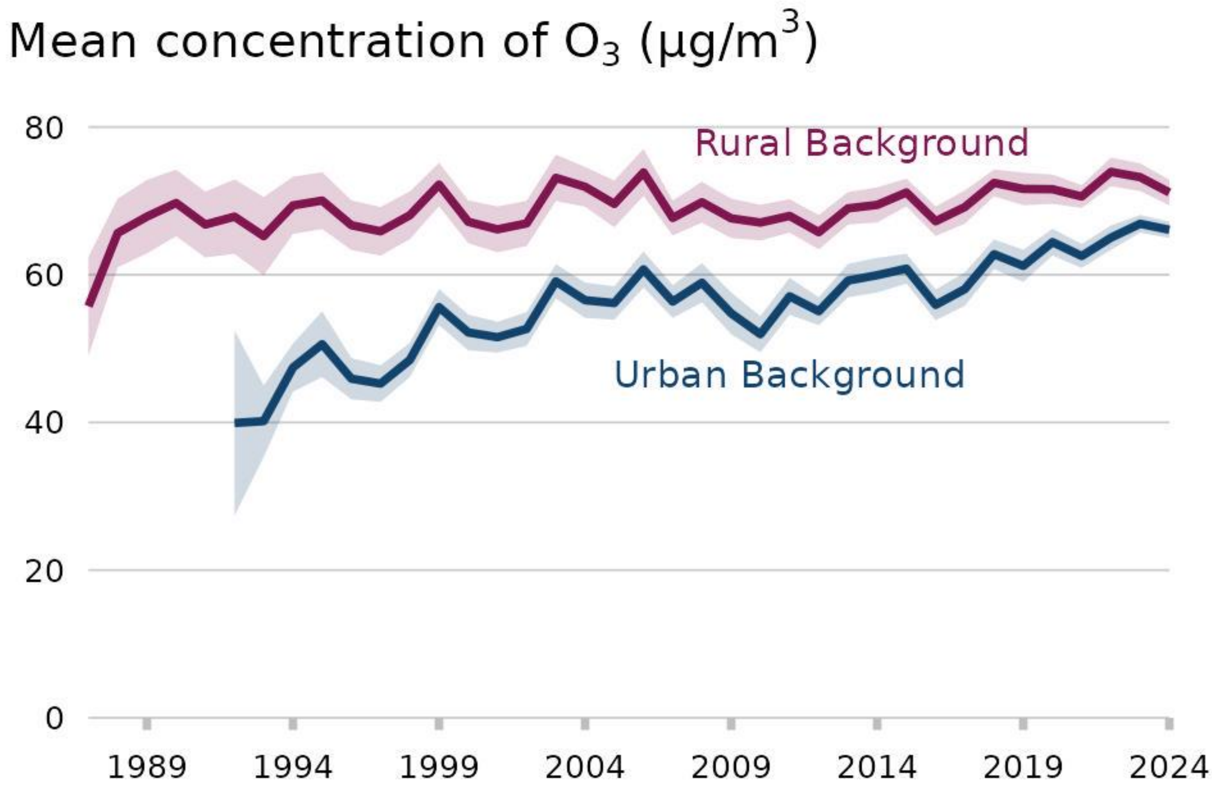


5.5.2 O_3: Changes Over Time

An increasing trend in background ozone concentrations is illustrated by **Figure 5-14**, taken from Defra's Accredited Official Statistics, Air Quality in the UK (Defra, 2025d).

This shows the annual mean of the daily maximum 8-hour mean, averaged over all sites that had annual data capture greater than or equal to 75%. Separate lines are shown for urban background sites and rural background sites, with the 95% confidence intervals shown as shaded areas either side of each line. Ozone has been monitored in the UK since the 1980s, and this graph shows years from 1987 onwards.

Figure 5-14 Annual mean daily maximum 8-hour mean O_3 concentrations in the UK, 1987 to 2024.



Shaded areas either side of each line show the 95% confidence interval of the mean.

Source: Accredited Official Statistics, Air Quality in the UK

The concentration in urban background areas shows a gradual increase, which is the opposite trend to that observed for NO_2 in urban areas. The complexity of the reactions producing ozone, their reliance on sunlight, and the interdependence between ozone and various precursor pollutants means that assessing and tackling exposure to ozone and its precursor pollutants is difficult. For example, when sunlight levels are low, nitric oxide (NO), which is an ozone precursor, can contribute to the removal of ozone from the atmosphere, known as a titration effect. Indeed, studies have shown that, as NOx concentrations decrease in urban areas, there may be an associated increase in ozone concentrations. Another layer of complexity in assessing exposure to ozone is that once formed, ozone can persist in the air for several days and thus can travel long distances (e.g. between mainland Europe and the UK), so contributing to elevated concentrations far from where it was formed. There is evidence that the ‘hemispheric background’ ozone concentration has increased since the 1950s, and the observed trends may reflect this (Vinzargan, 2004).

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.

5.6 Sulphur Dioxide

5.6.1 SO_2: Spatial Distribution in the UK

Figure 5-15 shows how the modelled 99.73rd percentile[7] of hourly mean sulphur dioxide concentration varied across the UK during 2024. 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. The 99.73rd percentile of hourly means was 25 µg m^{3} or less over most of the UK: although it was higher in some urban areas, there were no areas in which this statistic exceeded the limit value of 350 µg m^{-3}.

Figure 5-16 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 2024. The modelled 99.18th percentile was 10 µg m^{-3} or less over most of the UK: it was higher in some small areas due to specific local industrial and other emissions, but still well below 125 µg m^{-3} throughout the UK.

The online interactive maps include annual mean background SO_2 concentrations but not maps of the above metrics.

[7] Where the AQSR 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.

Figure 5-15 99.73rd Percentile of 1-hour Mean SO_2 Concentration, 2024 ($\mu g\ m^{-3}$)

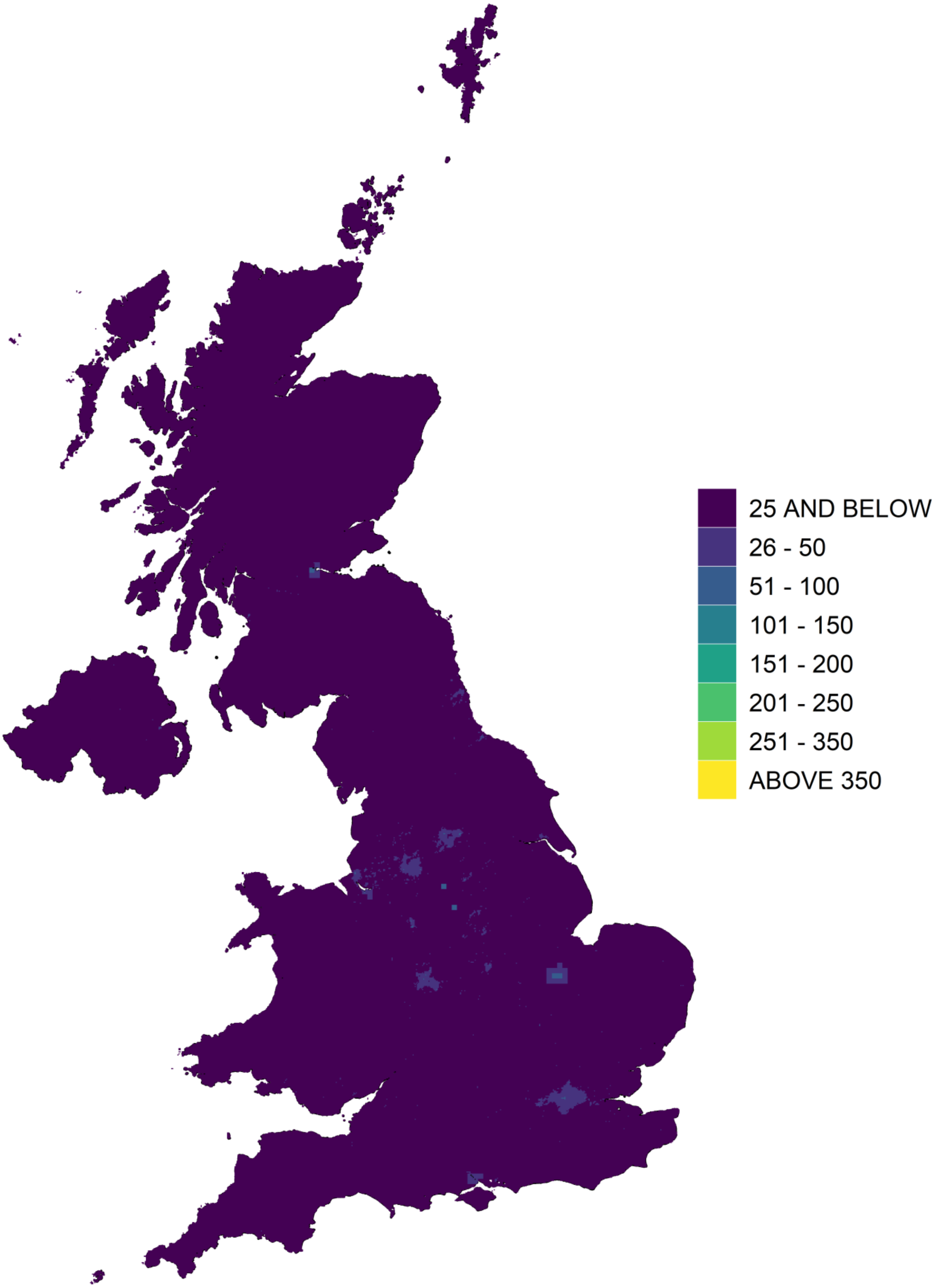
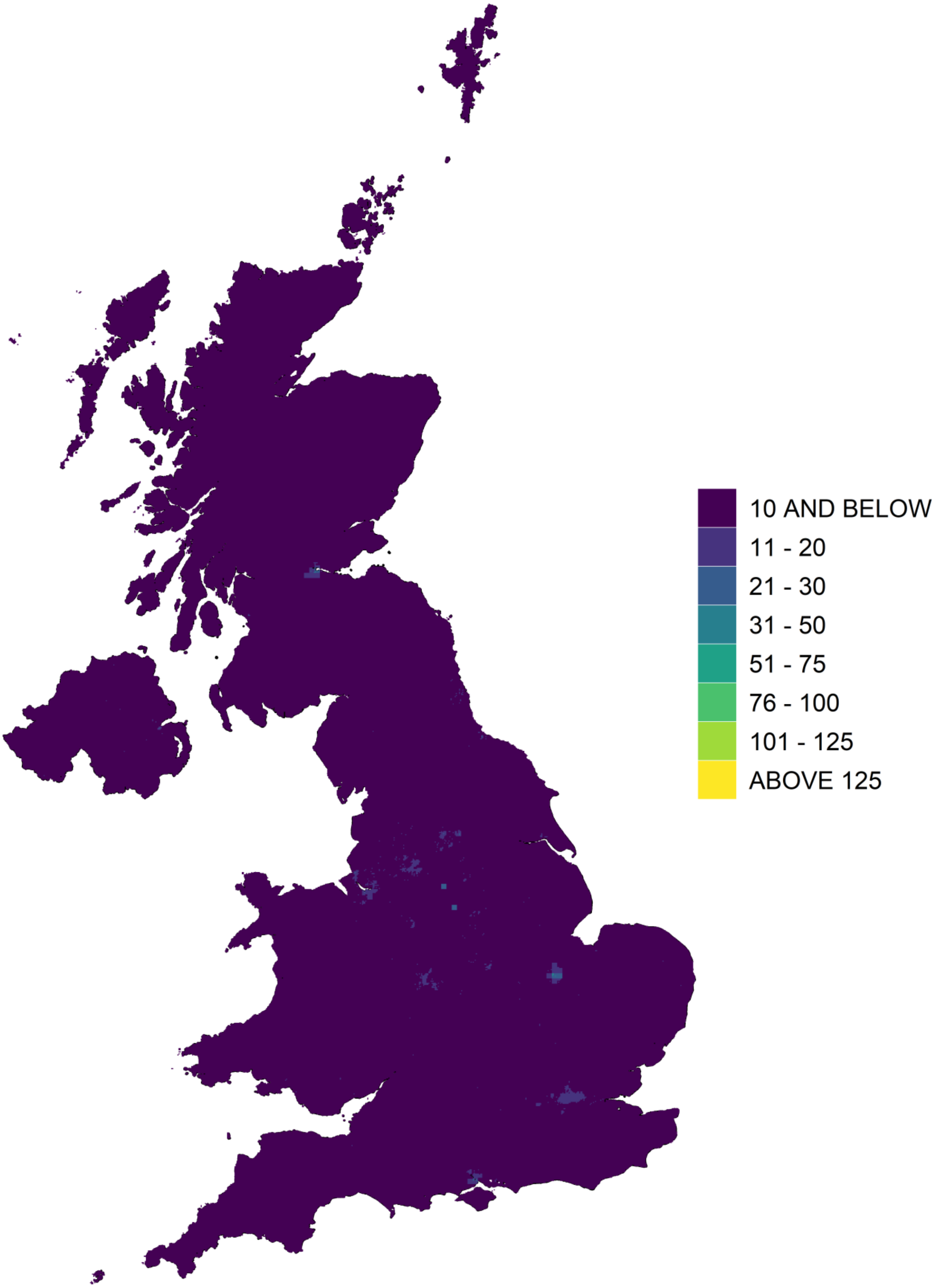


Figure 5-16 99.18th Percentile of 24-hour Mean SO_2 Concentration, 2024 ($\mu g\ m^{-3}$)



5.6.2 SO_2: Changes Over Time

Figure 5-17 shows how ambient concentrations have changed over the period 1992 to 2024. This shows annual mean SO_2 concentrations averaged over all included AURN sites that had annual data capture greater than or equal to 75% in the relevant year. The average of all urban sites is shown here: urban background, urban industrial and urban traffic. Of these, the majority are urban background.

The shaded area surrounding the line shows the 95% confidence interval of the annual mean. This is shown for all years, but for years from the early 2000s it is very small compared to the mean itself, therefore becomes invisible in the graph. This graph shows ambient concentrations of SO_2 have decreased over the period shown. However, the decrease has not been linear. The downward trend is steepest for the 1990s and early 2000s: there is a clear flattening-off in more recent years from around 2009.The pattern observed in ambient SO_2 concentrations appears to reflect changes in national emissions.

Figure 5-17 Annual mean concentrations of SO_2 in the UK, AURN Urban Site Classifications, 2009 to 2024

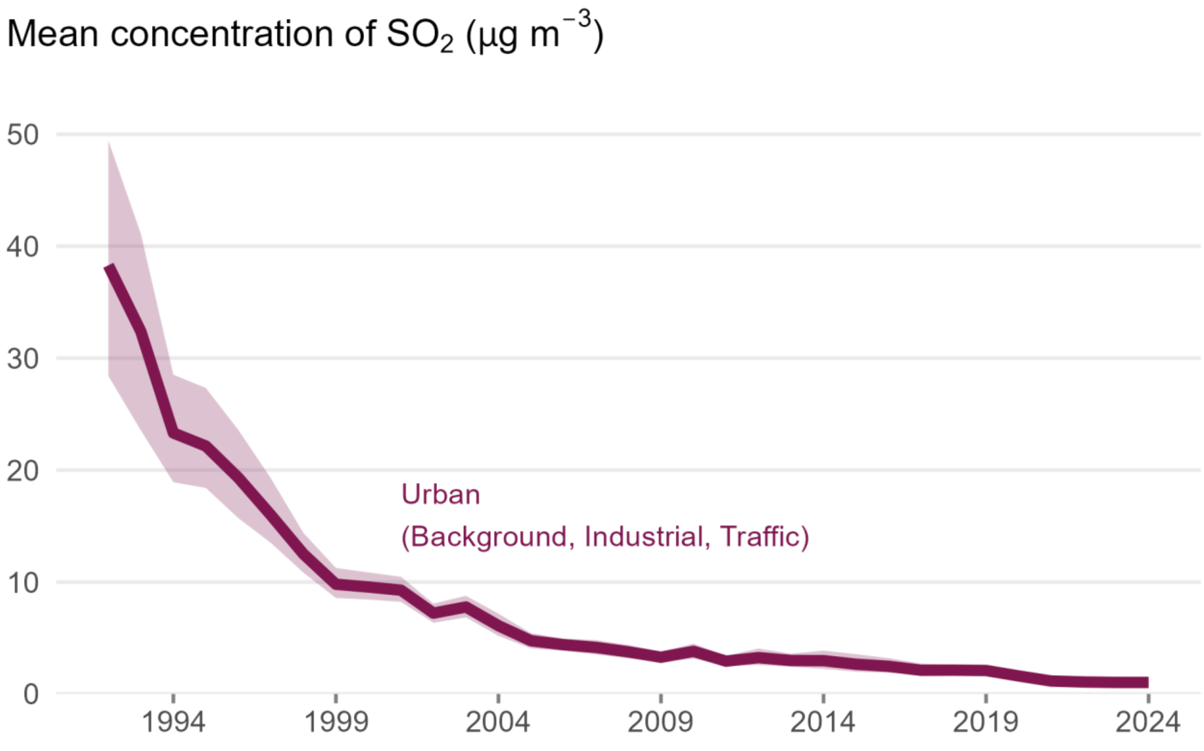


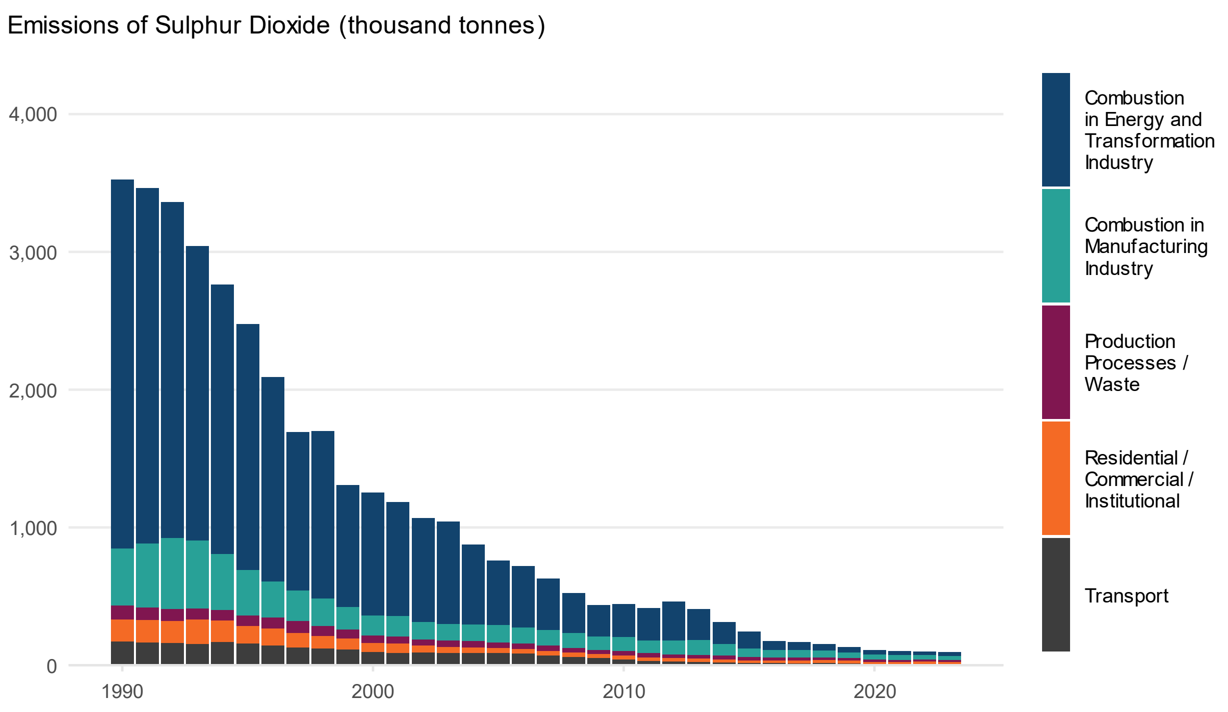
Figure 5-18 is based on data from the NAEI and shows the UK's estimated annual emissions of sulphur dioxide from 1990 to 2023 (the most recent year for which estimates are available). The decrease in emissions over time shown here is the continuation of an on-going trend observed by the NAEI throughout 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 1990, due to reductions in the use of coal and oil. A contributing factor is the decline in use of coal for power generation. 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] 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 NAEI pollutant information attributes the decrease between 2012 and 2018 to a decrease of over 40% in coal combustion in power stations.

For more information on UK emissions of SO_2 please visit the Accredited Official Statistics publication [Emissions of Air Pollutants].

Figure 5-18 Estimated Annual UK Emissions of SO_2 (kt), 1990 to 2023 (Source: NAEI 2025)



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 five (Belfast Centre, Cardiff Centre, Edinburgh St Leonards, Leeds Centre, and London North Kensington) are urban background, one (London Marylebone Road) is urban traffic, and one (Port Talbot Margam) is urban industrial. All have been operating for at least 10 years.

Figure 5-19 shows how average concentrations at these long-running AURN sites have changed over the years from 1992 to 2024. This graph shows a clear, though not consistent, decrease over the years. There is a sharp increase in 1997: this reflects a change in the composition of the monitoring network, when a number of new sites were added. The new sites were mostly at roadside locations with relatively high CO concentrations compared to the previously existing sites. Subsequently the decrease continued through the 1990s and 2000s but has subsequently flattened off to some extent.

Figure 5-19 Annual mean concentrations of CO in the UK 1992 to 2024

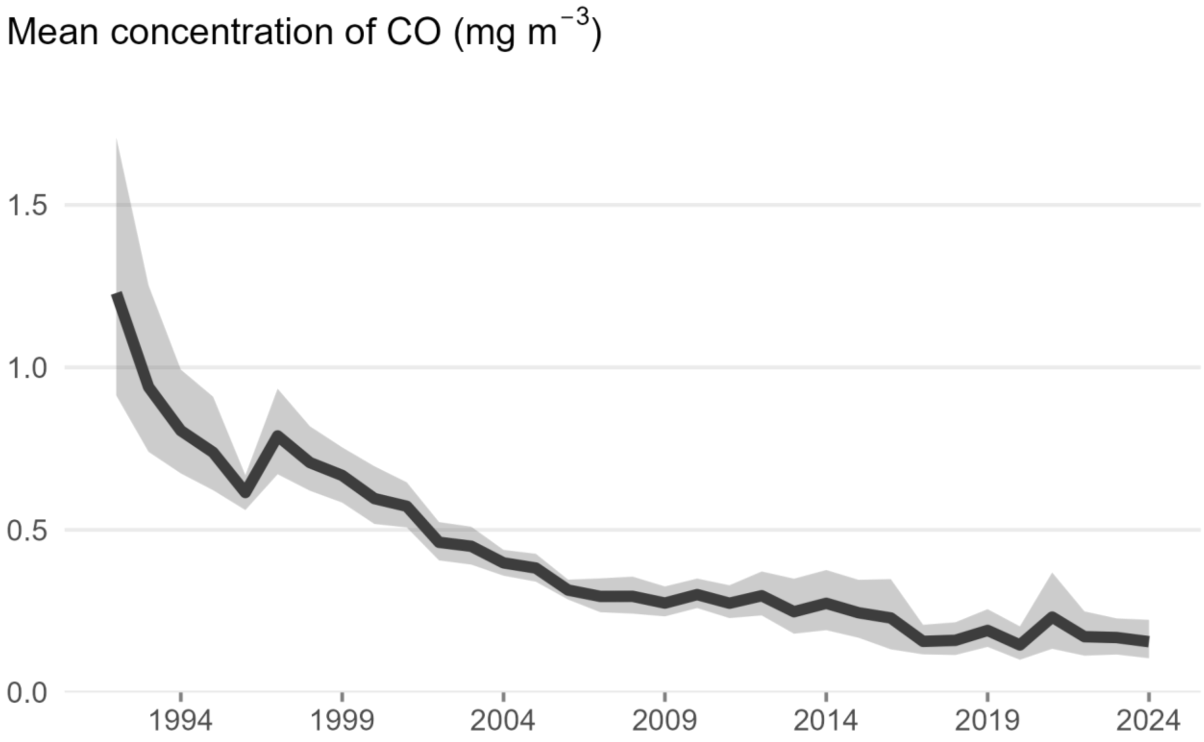
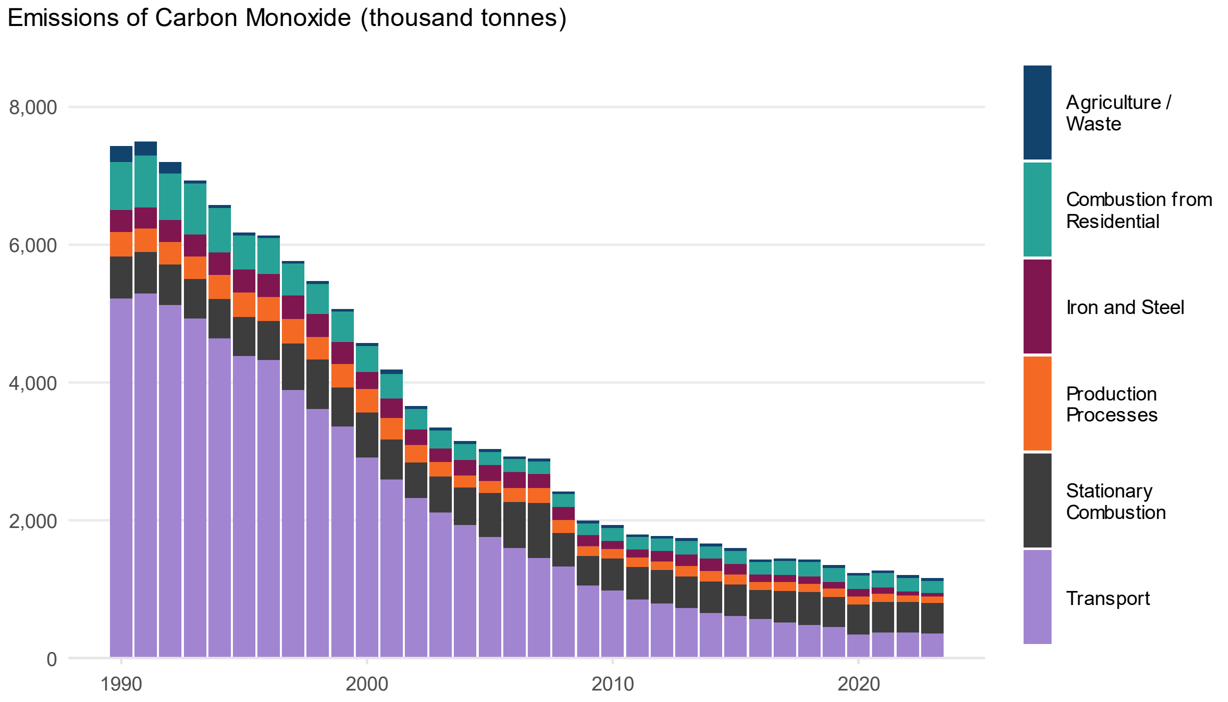


Figure 5-20 shows the estimated annual emissions of CO over the same period. The decreasing ambient concentrations reflect declining emissions over the last 25 years. The NAEI attributes the decrease in CO emissions to factors including EU-wide emission standards for road vehicles, a decline in industrial use of solid fuels, and a decline in the production of steel and non-ferrous metals.

Source: NAEI website

Figure 5-20 Estimated Annual UK Emissions of CO (kt), 1990 to 2023 (Source: NAEI 2025)



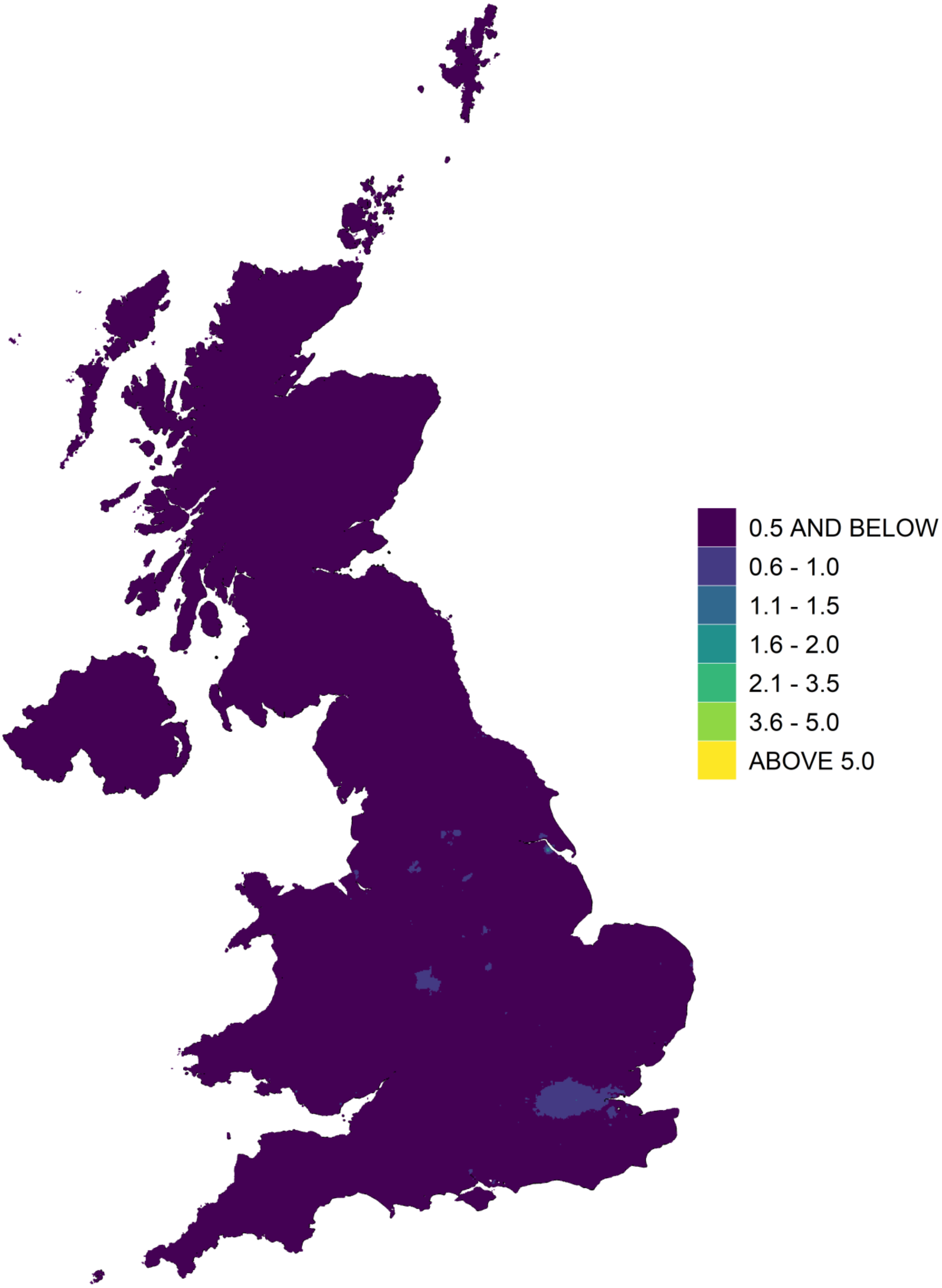
5.8 Benzene

5.8.1 Benzene: Spatial Distribution

Figure 5-21 shows the modelled annual mean background concentrations of benzene in 2024. Most areas outside major towns and cities had modelled benzene concentrations of 0.5 µg m^{-3} or below. Most urban areas had modelled concentrations of 1.0 µg m^{-3} or less, with the exception of a few very small industrial areas. No locations in the UK exceeded the annual mean limit value of 5.0 µg m^{-3}.

Benzene is found in petrol and in vehicle emissions, although the maximum benzene content in petrol has been 1% since 2000 (UK Government, 1999). Therefore higher levels may be expected at roadside locations, so maps of modelled annual mean roadside benzene concentration are also produced. However, as for other traffic-related pollutants, the detail in such maps can be difficult to see clearly, so these are no longer included in this series of reports. Instead, the reader is recommended to use the interactive version of the modelled roadside map, available on UK-AIR at https://uk-air.defra.gov.uk/data/gis-mapping/.

Figure 5-21 Annual Mean Background Benzene Concentration, 2024 (µg m^{-3})



More detail is available on the UK-AIR website's interactive map.

5.8.2 Benzene: Changes Over Time

Figure 5-22 shows how benzene concentrations have changed over time, based on the combined dataset from the Non-Automatic Hydrocarbon Network, which has operated since 2002.

The graph shows a steep decrease between around 2005 and 2008. From then on, the graph is much flatter, showing little further fall in ambient concentrations of benzene until 2012 to 2013 when there is a slight rise, followed by a further decrease in subsequent years, to around 2021 after which the graph shows little further change.

Figure 5-22 Annual Mean Concentration of Benzene as measured by the Non-Automatic Hydrocarbon Network Sites, 2002 to 2024

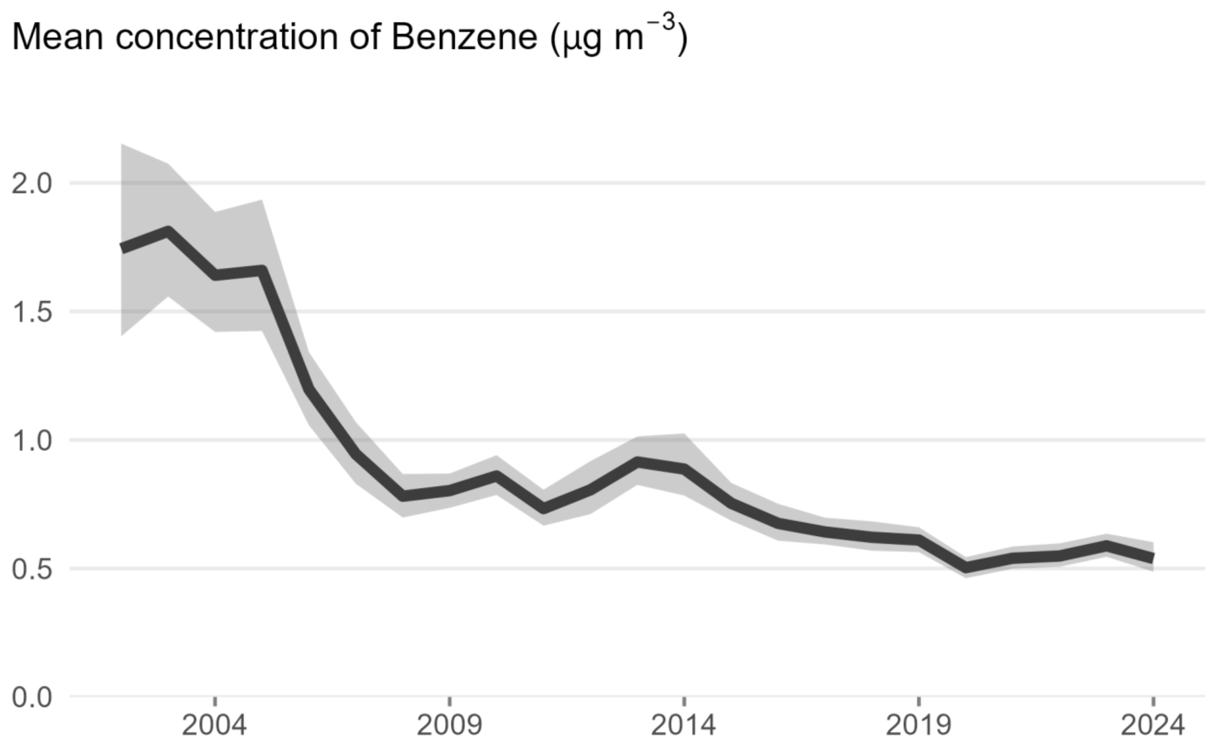
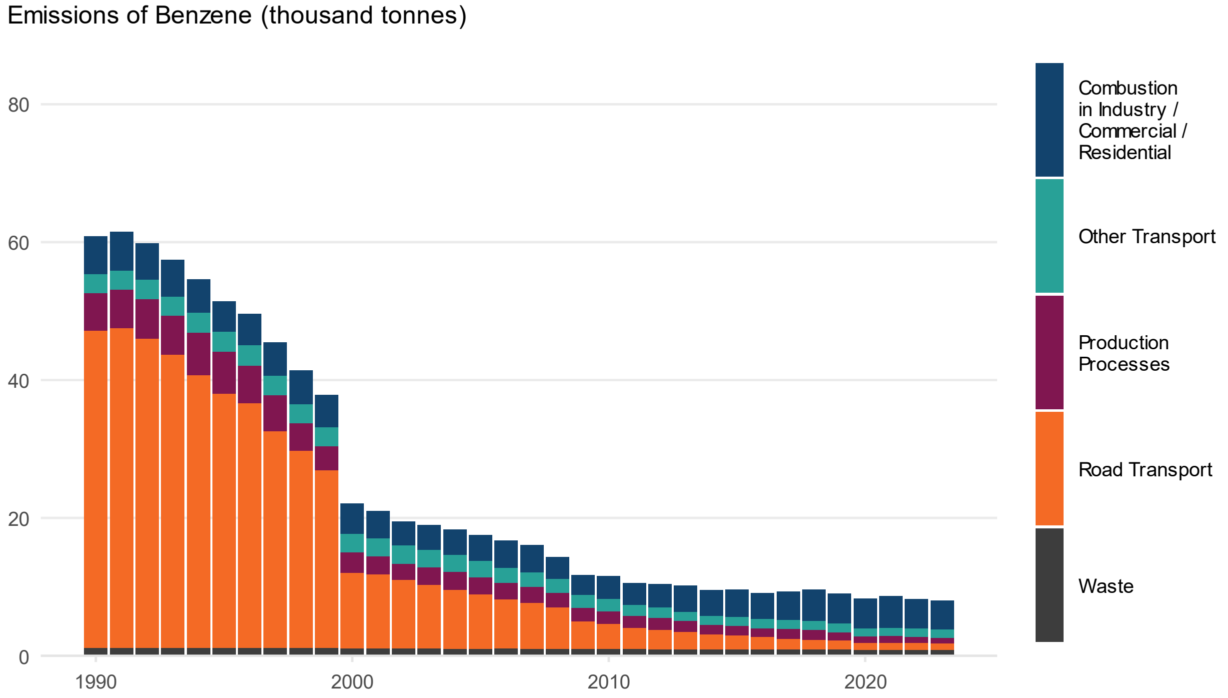


Figure 5-23 shows the estimated total annual UK emission of benzene (in kilotonnes), 1990 to 2023. The data are from the NAEI. The largest UK source of benzene is fuel combustion. Like the ambient concentrations, the estimated annual emissions also appear to have decreased over the period 2000 to 2020 but subsequently flattened off. There is a downward step-change in benzene emissions from road transport in 2000: this is primarily attributed to reduction in benzene emissions from petrol vehicles, resulting from regulations that reduced the maximum benzene content of petrol to 1%.

Figure 5-23 Estimated Annual UK Emissions of Benzene (kt), 1990 to 2023 (Source: NAEI 2025)



5.9 1,3-Butadiene

5.9.1 1,3-Butadiene: Compliance with AQS Objective

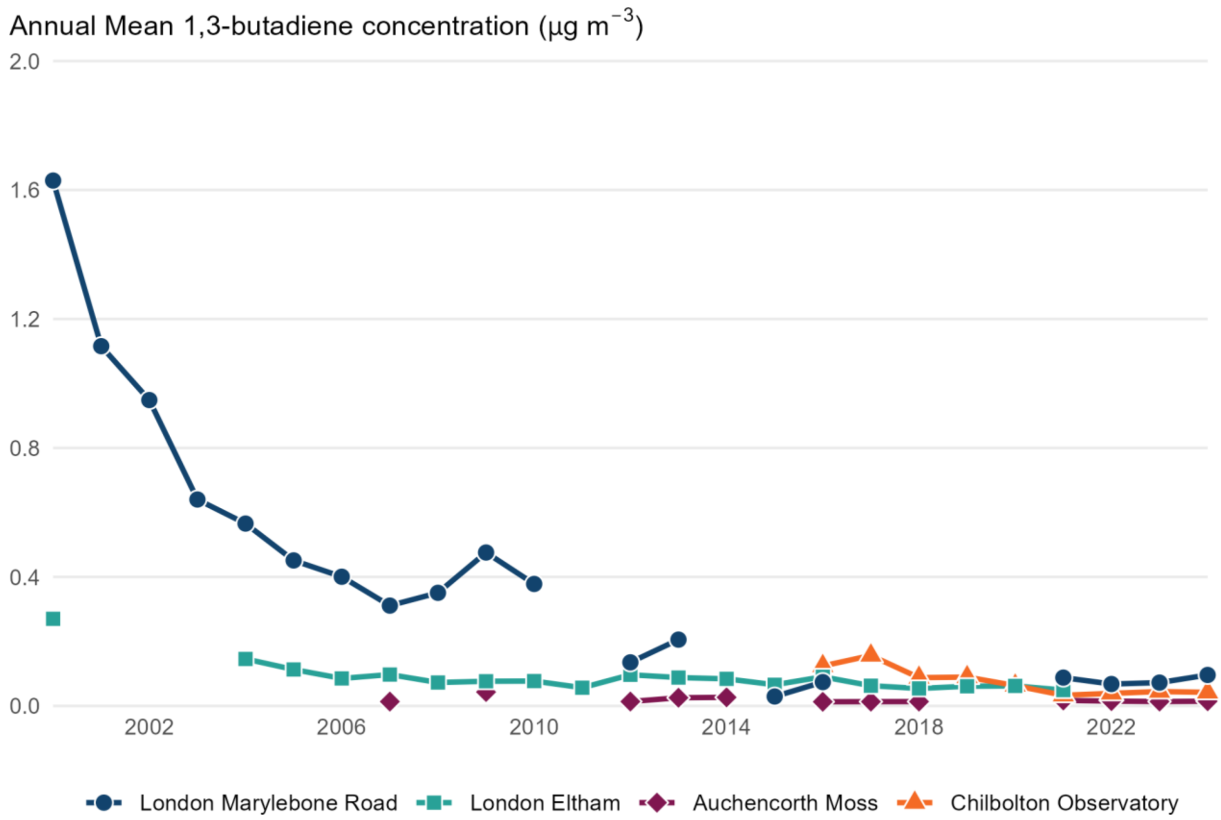
The UK Air Quality Strategy objective for 1,3-butadiene is 2.25 µg m^{-3}, as a maximum running annual mean. This objective was met throughout the UK by the due date of 31 December 2003. Modelled maps are not routinely produced for this pollutant.

The Automatic Hydrocarbon Network monitors 1,3-butadiene at four sites: London Marylebone Road (urban traffic), London Eltham (urban background – currently out of action awaiting relocation), Auchencorth Moss in Midlothian (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 all three sites were well within the AQS objective in 2024.

5.9.2 1,3-Butadiene: Changes Over Time

Figure 5-24 shows a time series chart of ambient annual mean 1,3-butadiene concentration between 2000 and 2024 at the four automatic sites. (Minimum annual data capture for inclusion is 50% in this case.)

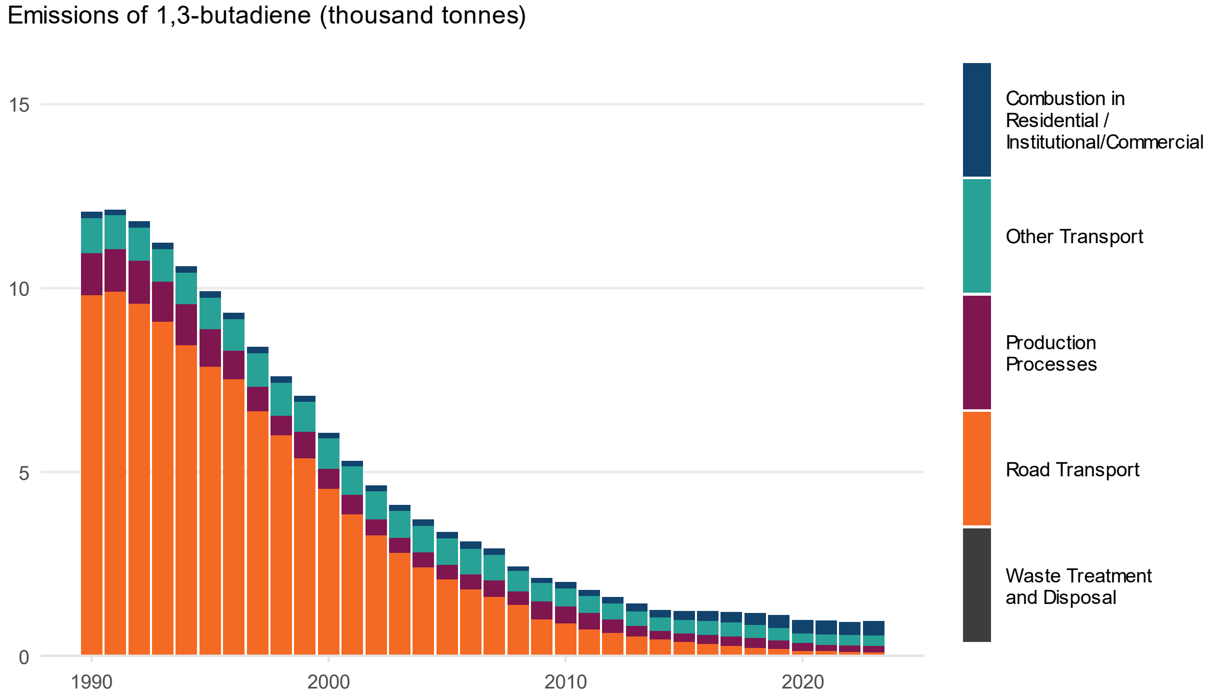
Figure 5-24 Time Series Graph of 1,3-Butadiene Concentration, 2000 to 2024



London Marylebone Road has historically had the highest concentrations of 1,3-butadiene, but these decreased substantially between 2000 and 2015. Chilbolton Observatory has also exhibited a decrease, although concentrations have always been lower than at London Marylebone. Chilbolton Observatory, despite its rural location, has typically reported slightly higher concentrations than London Eltham (though the latter did not meet the data capture target in 2022, 2023 or 2024 and is currently out of action awaiting a relocation). All four sites, both urban and rural, are now measuring annual mean 1,3-butadiene concentrations of less than 0.1 µg m^{-3}.

Figure 5-25 shows the total estimated UK annual emission of this compound, in kilotonnes, between 1990 and 2023. 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. However, emissions from the ‘Combustion in Residential/Institutional//Commercial’ category have increased over the past decade: this is attributed to an increase in the use of wood as a domestic fuel.

Figure 5-25 Estimated Annual UK Emissions of 1,3-Butadiene (kt), 1990 to 2023 (Source: NAEI 2025)



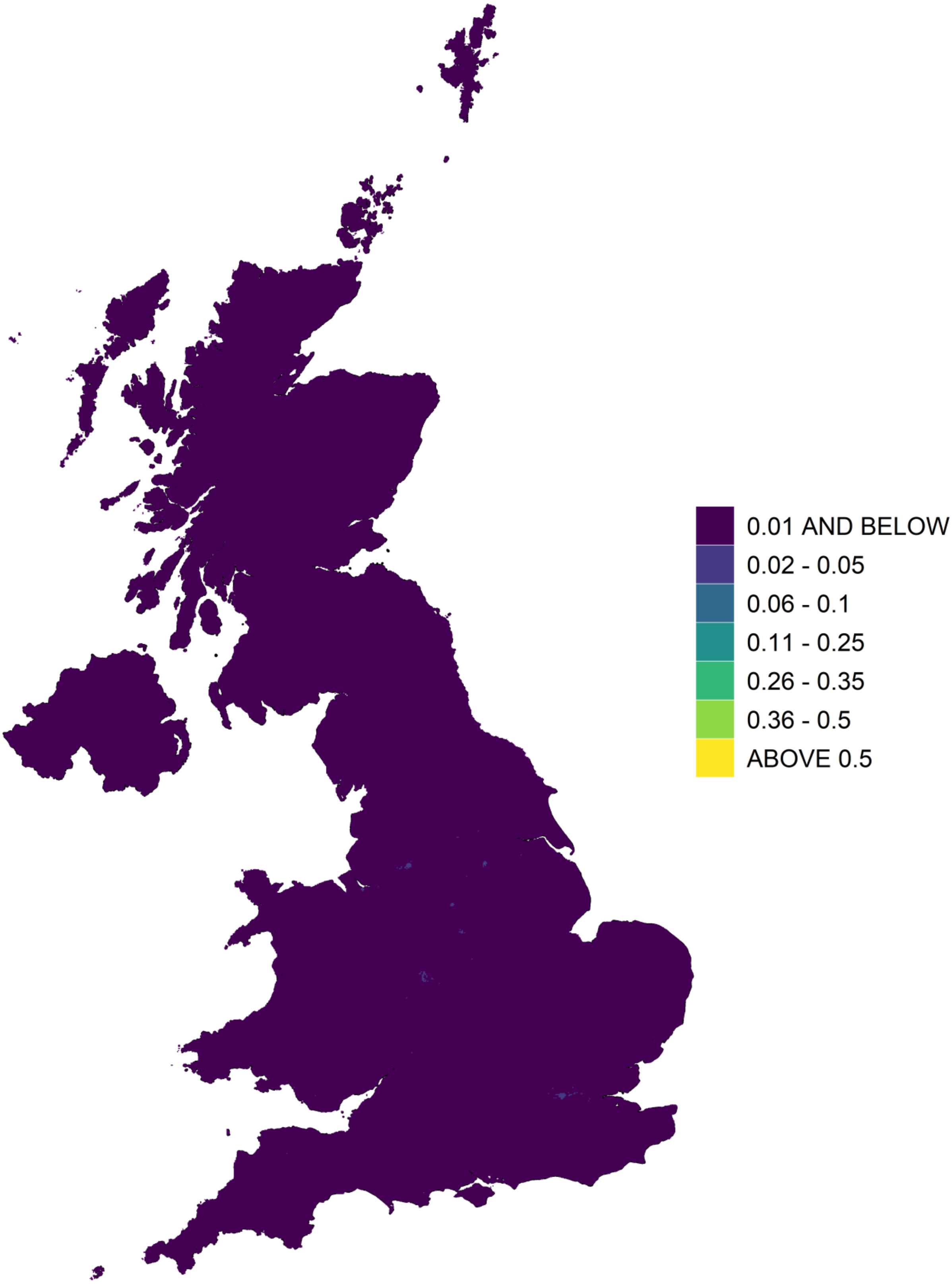
5.10 Metallic Elements

5.10.1 Metallic Elements: Spatial Distribution

Figure 5-26, Figure 5-27, **Figure 5-28** and **Figure 5-36** show modelled annual mean background concentrations of lead (Pb), arsenic (As), cadmium (Cd) and nickel (Ni) respectively in 2024. The spatial distribution patterns are discussed below.

Pb: background concentrations were 0.01 µg m^{-3} (that is, 10 ng m^{-3}) or less over almost all the UK. The map shows concentrations in micrograms per cubic metre, as this is the unit used for The Air Quality Standards Regulations (2010) limit value). Some small areas around major cities had concentrations in the 0.02 to 0.05 µg m^{-3} range. Modelled concentrations were well within the limit value of 0.5 µg m^{-3} throughout the UK.

Figure 5-26 Annual Mean Background Lead Concentration, 2024 (μg m^{-3})



More detail is available on the UK-AIR website's interactive map.

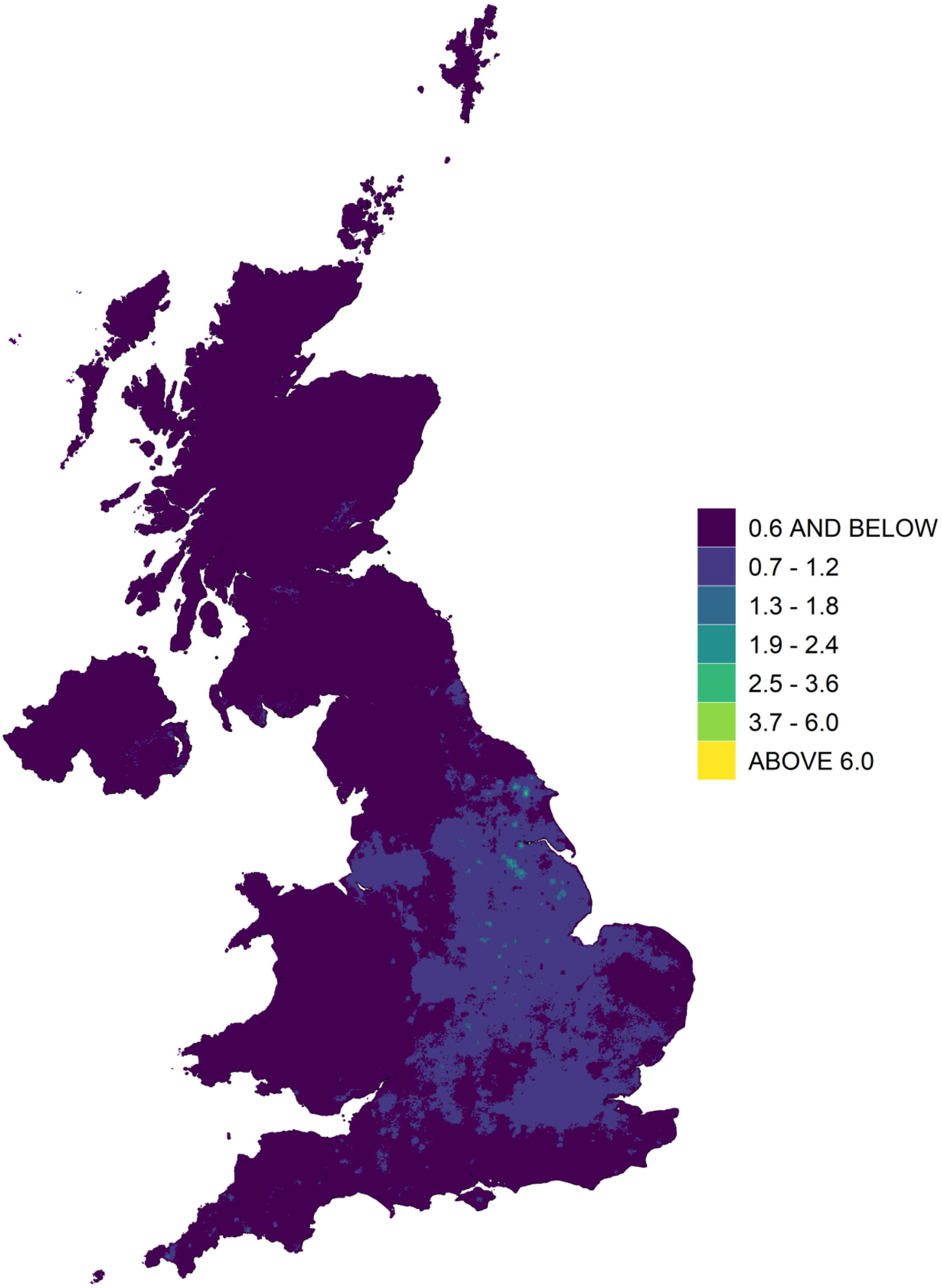
As: this toxic element is a metalloid rather than a metal but is nevertheless measured by the Heavy Metals Network. **Figure 5-27** shows that modelled annual mean background concentrations were 1.2 ng m^{-3} or less throughout most of the UK. Modelled concentrations were well within the limit value of 6 ng m^{-3} throughout the UK.

However, concentrations in the range 1.9 to 2.4 ng m^{-3} occurred in some small 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.

Cd: background concentrations were less than 0.3 ng m^{-3} over most of the UK, as shown by **Figure 5-28**. Higher concentrations can be seen at numerous urban and industrial areas around the UK, which reflects the sources of cadmium which are primarily industrial. Higher concentrations are also visible along some major road routes: like lead, cadmium is a constituent of re-suspended road dust. In the 2024 map, this feature is clearly visible for cadmium. However, no parts of the UK had modelled concentrations greater than the annual mean limit value of 5 ng m^{-3}.

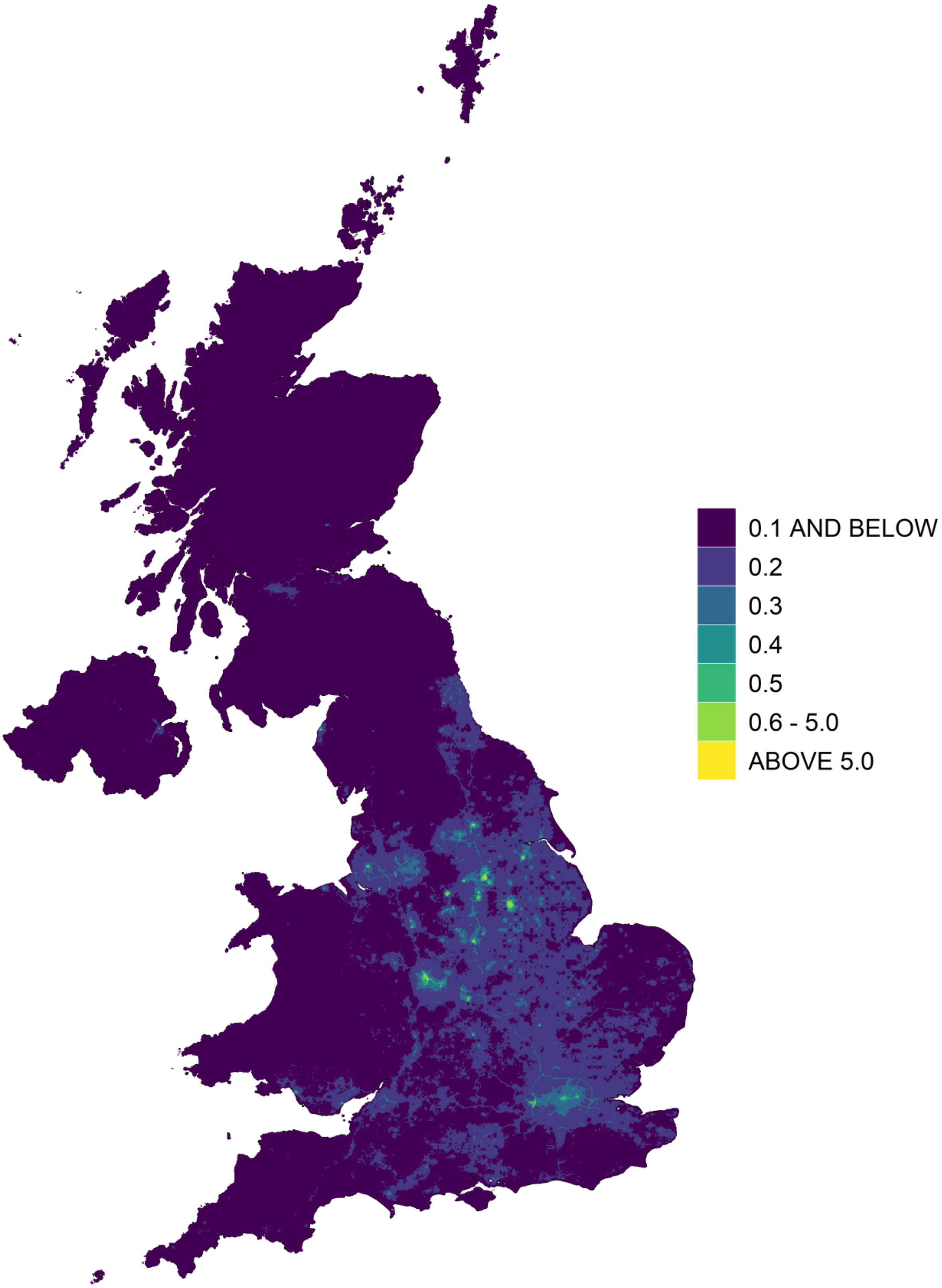
Ni: background concentrations of Ni were typically 2 ng m^{-3} or less, and usually 1 ng m^{-3} or less, away from urban areas (**Figure 5-29**). There were also a few small areas with higher concentrations due to industrial activity, including two locations where modelled concentration exceeded the Ni target value of 20 ng m^{-3} in 2024: one in the Sheffield Urban Area, and one (very small) in South Wales. The highest measured annual mean Ni concentration in 2024 was within the target value: 15 ng m^{-3} at Sheffield Tinsley. As reported in Section 4, three zones exceeded the target value for Ni in 2024: Sheffield Urban Area, Yorkshire and Humberside, and South Wales.

Figure 5-27 Annual Mean Background Arsenic Concentration, 2024 (ng m^{-3})



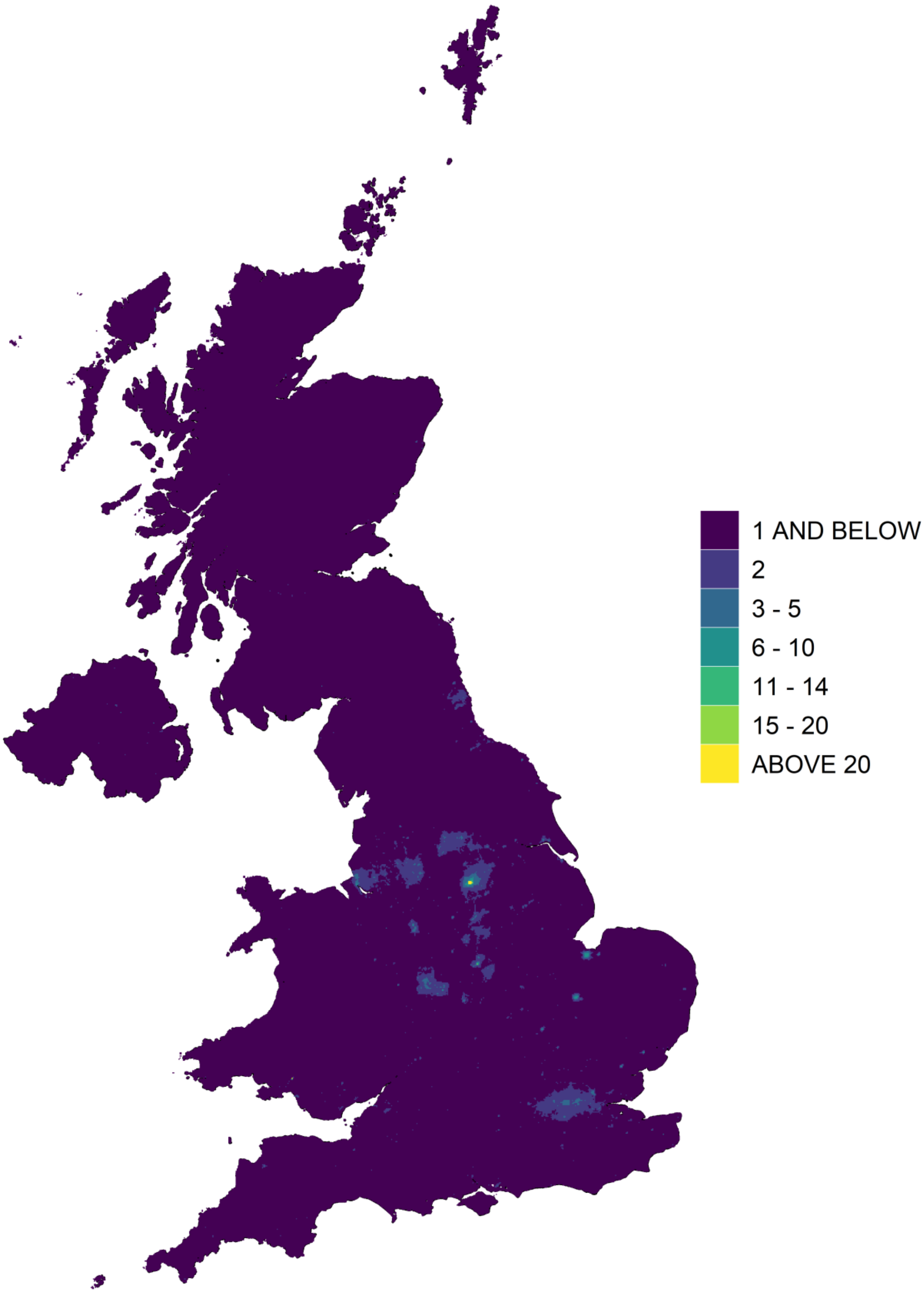
More detail is available on the UK-AIR website's interactive map.

Figure 5-28 Annual Mean Background Cadmium Concentration, 2024 (ng m^{-3})



More detail is available on [the UK-AIR website's interactive map](#).

Figure 5-29 Annual Mean Background Nickel Concentration, 2024 (ng m^{-3})



More detail is available on [the UK-AIR website's interactive map](#).

5.10.2 Metals: 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 (NPL, 2020). 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.) 24 sites were in operation during 2024.

5.10.2.1 Lead: Changes Over Time

Figure 5-30 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 3.1. (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 Heavy Metals Network sites, both urban and rural, is shown. (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). **Please also note that for clarity, this graph uses units of ng m^{-3}, rather than µg m^{-3} as used in the modelled maps.** Ambient concentrations of Pb have decreased substantially, though not consistently, since 2004.

Figure 5-31 shows NAEI estimated total annual UK emissions of this metal from 1990 to 2023. The phasing-out of lead in petrol in the 1990s greatly reduced emissions of Pb from transport, which had previously been the largest UK source. However, Pb is a constituent of dust from tyre and brake wear, so transport remains a significant source, though emissions are now much lower. Production processes are also a significant source.

Figure 5-30 Ambient Concentrations of Pb in PM_{10}, 2004 to 2024

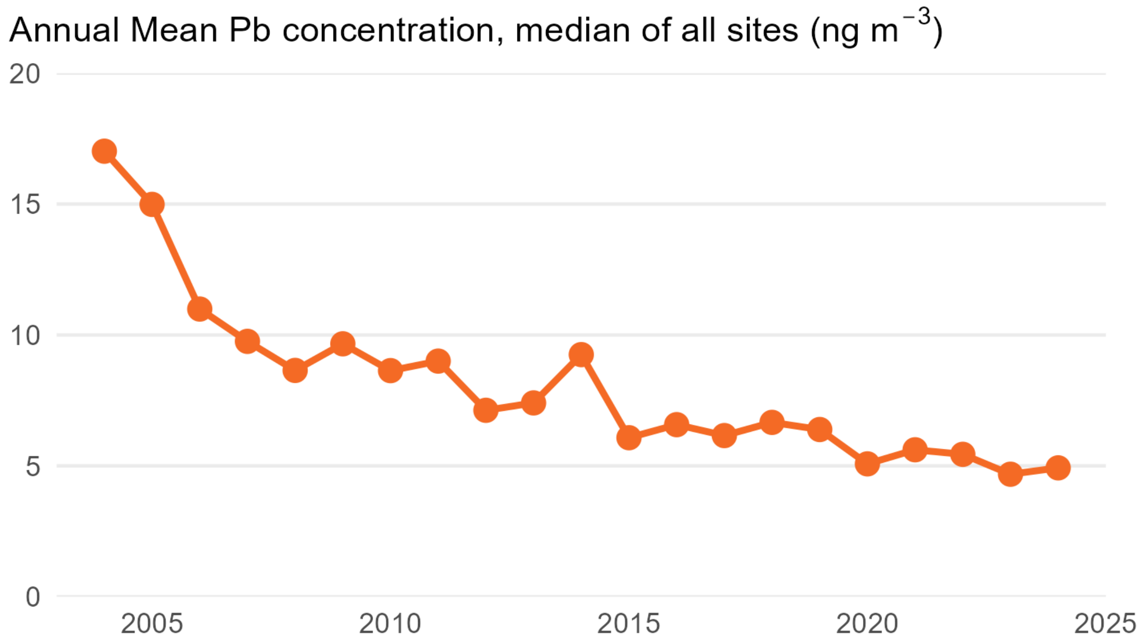
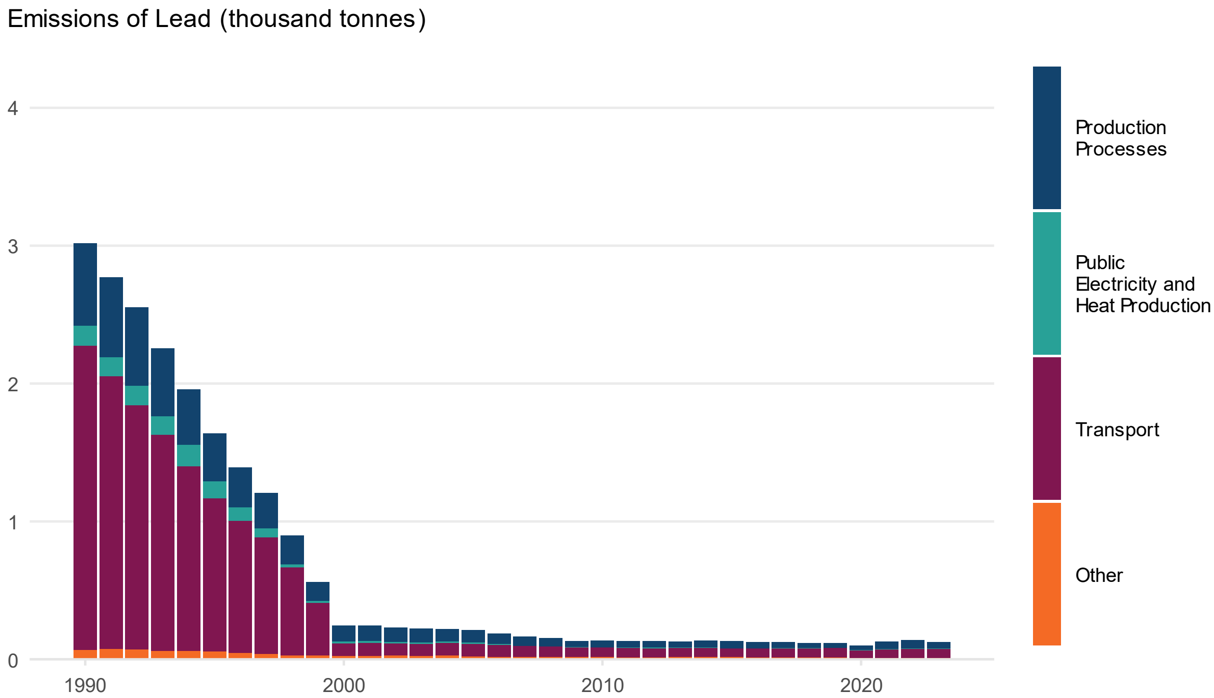


Figure 5-31 Estimated Annual UK Emissions of Pb (kt), 1990 to 2023 (Source: NAEI 2025)



5.10.2.2 Arsenic: Changes Over Time

Figure 5-32 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. Ambient concentrations of As appear to have decreased substantially between 2004 and 2008, since when they have been variable, but remained within the range 0.6 to 0.8 ng m^{-3}.

Figure 5-32 Ambient Concentrations of As in PM_{10}, 2004 to 2024

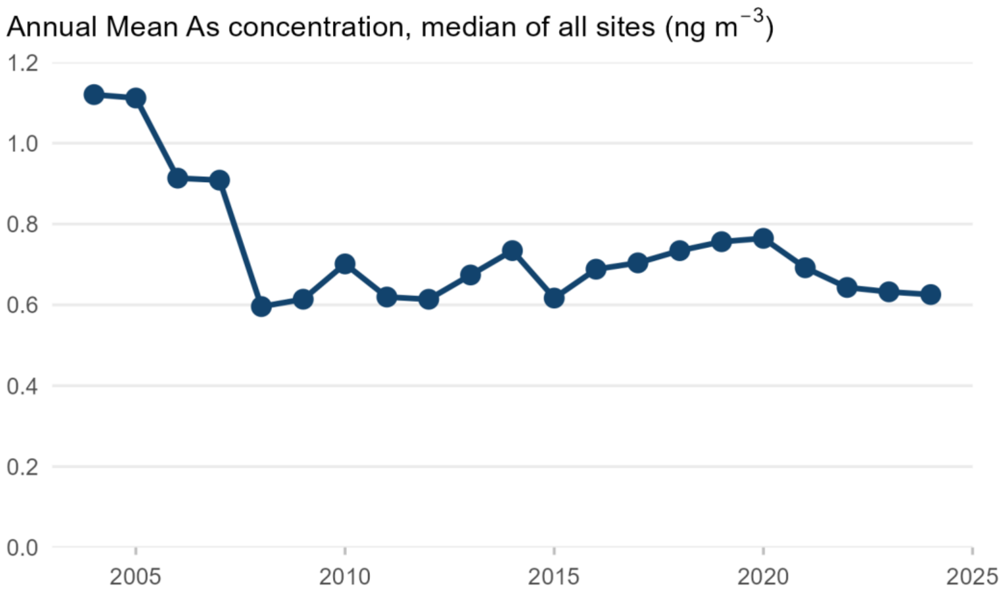
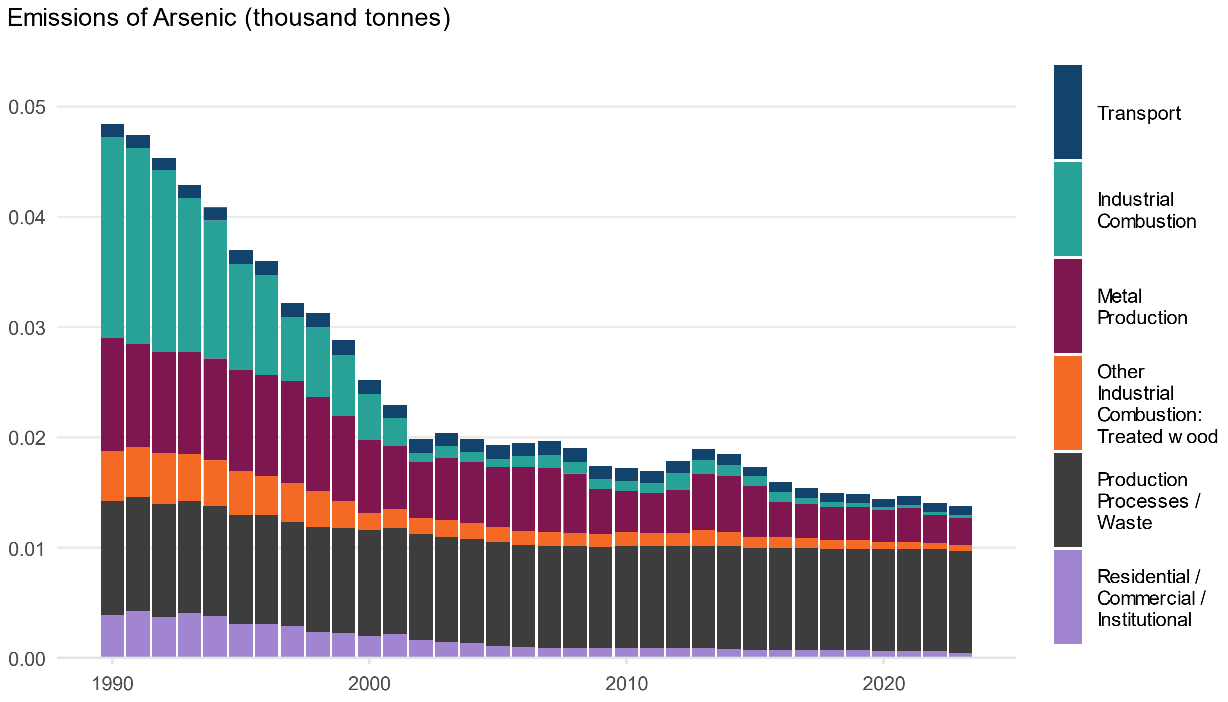


Figure 5-33 shows the UK's estimated total annual emission of As (from the NAEI), in kilotonnes, from 1990 to 2023. The largest human-made source of As emissions in the UK is the open burning of waste wood which has been treated with products containing As. This falls within the 'Production processes/Waste' category. Metal (iron and steel) production processes also give rise to some emissions.

Changes in measured ambient As concentrations (since 2004) do not appear to reflect 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 5.10.1 above – wind-blown dust is a major natural source of airborne arsenic in some areas.

Figure 5-33 Estimated Annual UK Emissions of As (kt), 1990 to 2023 (Source: NAEI 2025)



5.10.2.3 Cadmium: Changes Over Time

Figure 5-34 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.

Again, the graph shows 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 24 sites – both urban and rural – have been included. Over the network's years of operation there has been a decrease in ambient Cd concentrations, but it has not been consistent (for example, Cd shows an apparent increase in 2014, as does Pb).

Figure 5-35 shows the UK's estimated total annual emission of Cd (in kilotonnes), 1990 to 2023, from the NAEI. The main human-made sources of Cd are combustion in manufacturing industry and production processes. Waste incineration was once a large source until control of this source was improved in the 1990s: it now accounts for only 3% of the UK total.

Figure 5-34 Ambient Concentrations of Cd in PM_{10}, 2004 to 2024

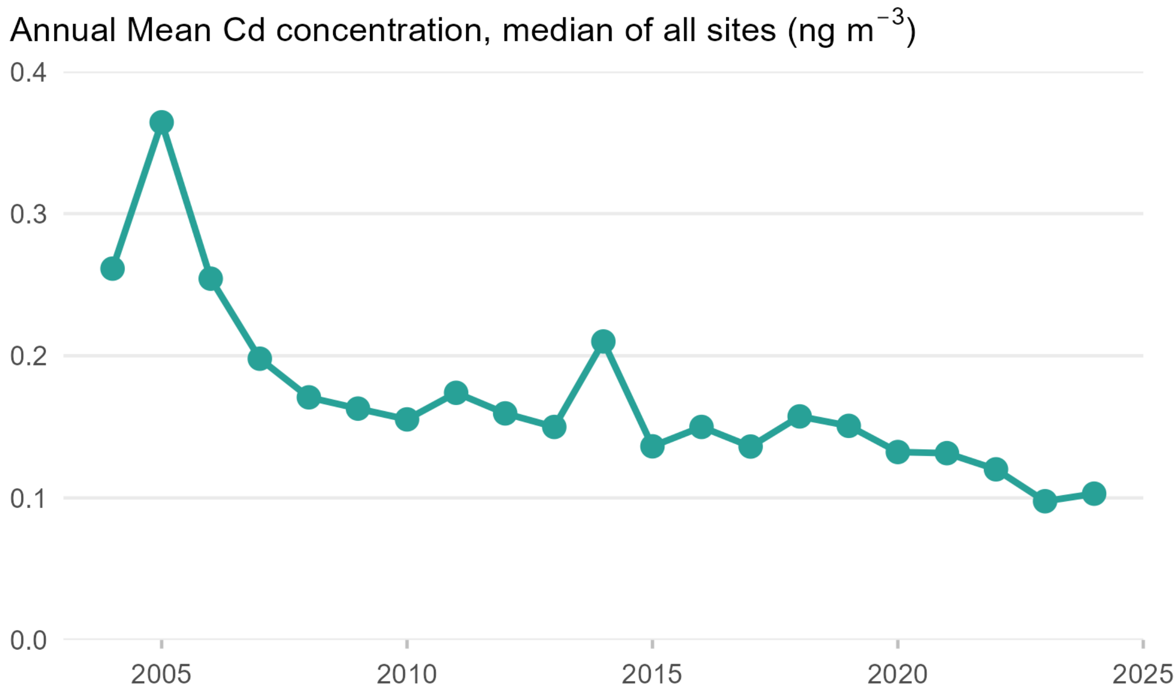
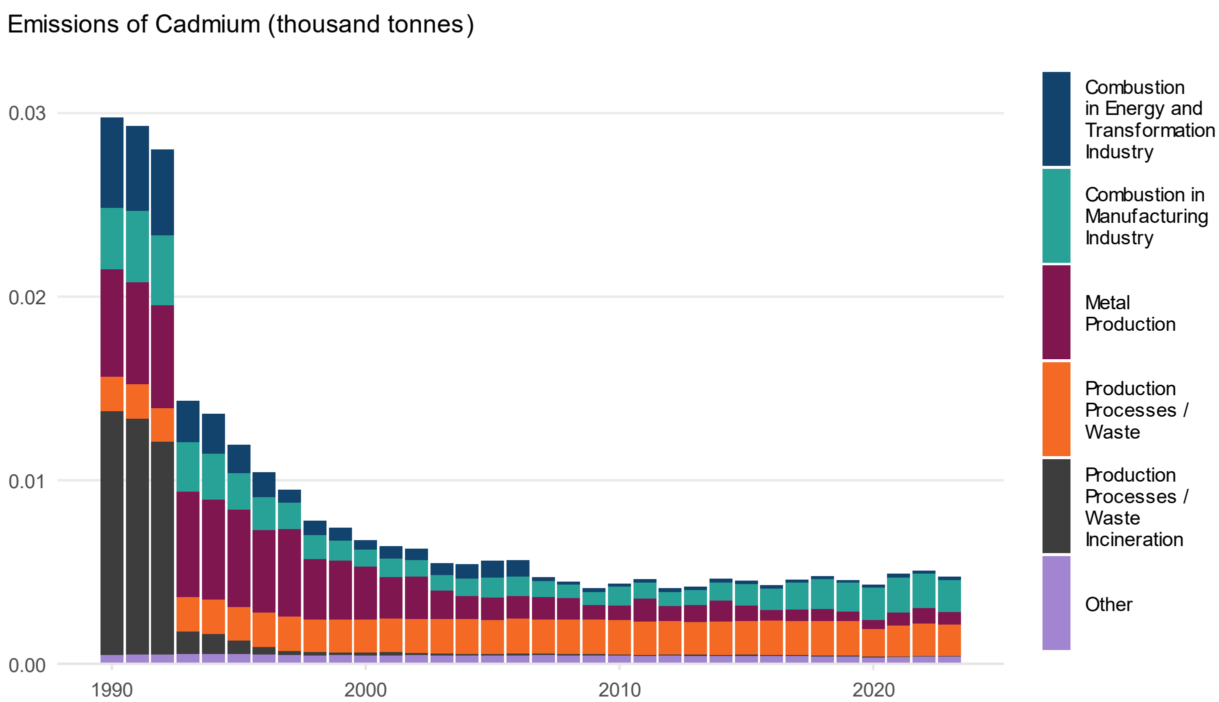


Figure 5-35 Estimated Annual UK Emissions of Cd (kt), 1990 to 2023 (Source: NAEI 2025)



5.10.2.4 Nickel: Changes Over Time

Figure 5-36 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.

Again, the graph shows the median, rather than the arithmetic mean, of annual mean concentrations at all 24 sites. This avoids confounding effects due to a small number of sites which measure ambient Ni concentrations very much higher than the others. Ambient concentrations also show a general (though not consistent) decrease over the period of operation of the network: the pattern is similar to that for Cd.

Figure 5-36 Ambient Concentrations of Ni in PM_{10}, 2004 to 2024

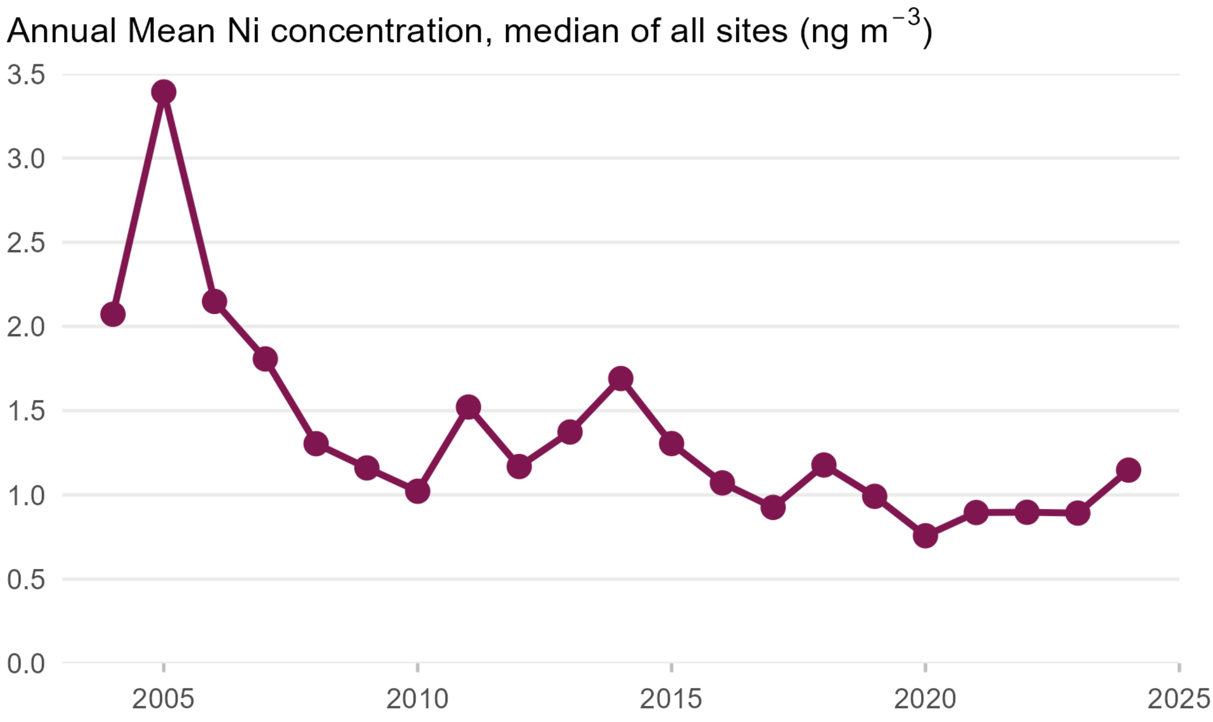
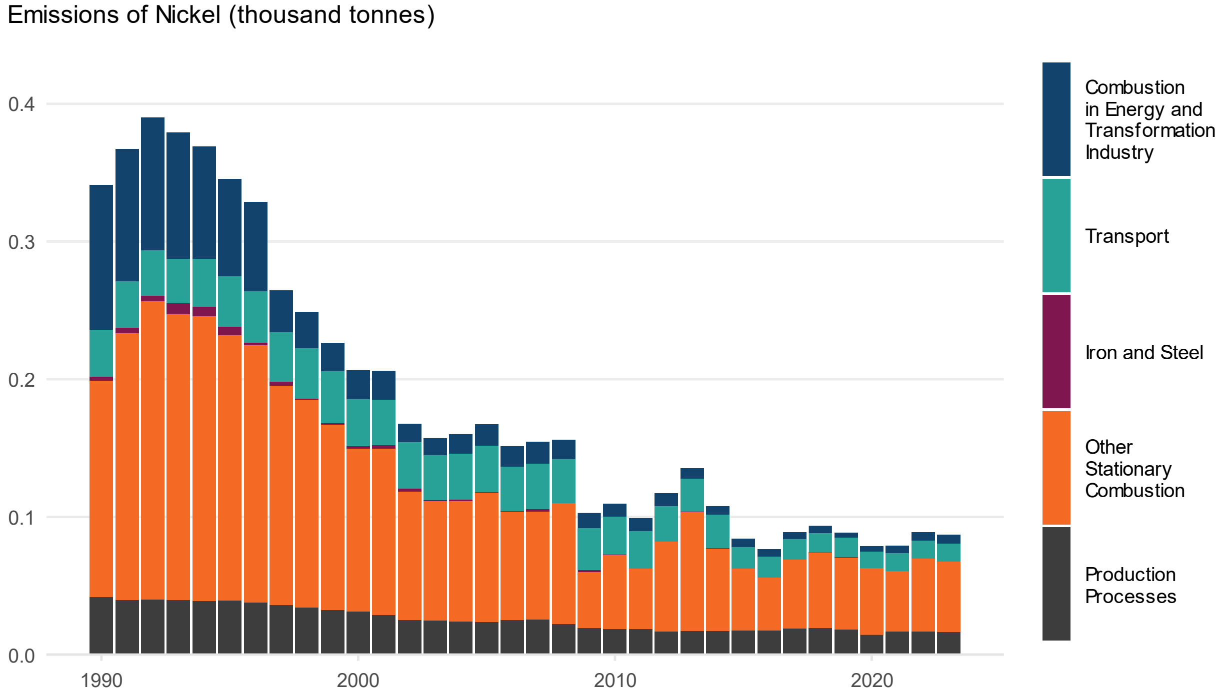


Figure 5-37 shows total estimated annual UK emissions of Ni, from the NAEI, from 1990 to 2024. Stationary combustion in industry (other than the energy production and transformation industry) is the major source. The NAEI data show a general – though not consistent - decrease in Ni emissions since 1990.

Figure 5-37 Estimated Annual UK Emissions of Ni (kt), 1990 to 2023 (Source: NAEI 2025)



5.10.2.5 Mercury: Changes Over Time

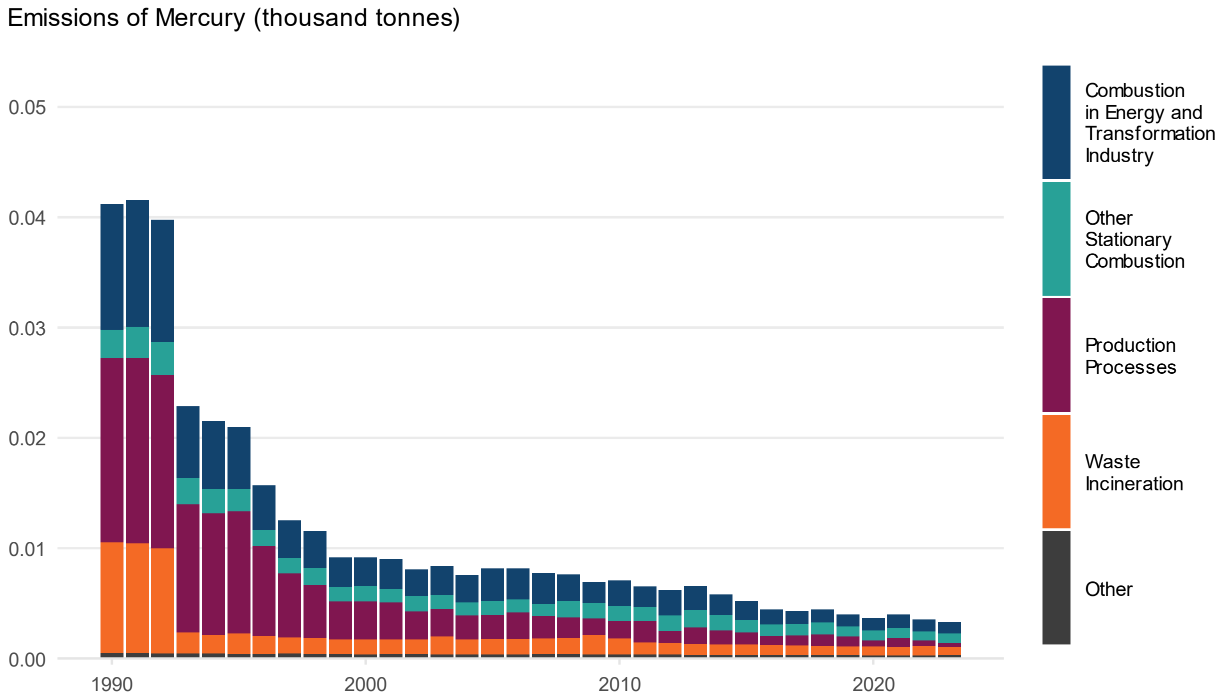
The Heavy Metals Network ceased measuring mercury (Hg) in PM_{10} at the end of 2013. Monitoring of Total Gaseous Mercury (TGM) continued at two sites (London Westminster and Runcorn Weston Point) until 2018. For information on previous years' measurements of mercury carried out by the Heavy Metals Network and its predecessors from 2004 to 2018, please refer to reports in the "*Air Pollution in the UK*" series for years 2018 and earlier.

Mercury deposition (dry deposition and deposition in precipitation) is still carried out at several rural sites (see Section 3). However, ambient concentrations of Hg in air are now only measured at two rural sites: Chilbolton Observatory in Hampshire (which measures TGM), and Auchencorth Moss in Midlothian. The latter site measures Hg in $PM_{2.5}$, Elemental Gaseous Mercury and Reactive Hg in air. These measurements are carried out using the Tekran instrument, as part of the Rural Mercury Network (see Section 3.3.12).

Annual mean concentrations of elemental mercury at Auchencorth Moss from 2010 onwards and TGM at Chilbolton Observatory from 2016 onwards are available from UK-AIR. Annual mean elemental mercury concentrations at Auchencorth Moss have consistently been in the range 1.3 to 1.4 ng m^{-3} since monitoring of this metric began in 2010. Annual mean TGM concentrations at Chilbolton Observatory have consistently been in the range 1.3 to 1.6 ng m^{-3} since monitoring of this metric began in 2016. However, in both cases data capture has been very low (less than 50%) in several years, and there is no clear trend at either site.

Figure 5-38 shows estimated annual UK emissions of Hg, from 1990 to 2023. The main sources are combustion in industry, waste incineration and production processes. Mercury emissions have steadily decreased between 2006 and 2016, though the decrease appears to have flattened off in more recent years. The main sources are industrial, therefore trends in ambient Hg concentrations at the rural sites where monitoring of this element has continued would not necessarily be expected to reflect these emission trends.

Figure 5-38 Estimated Annual UK Emissions of Hg, 1990 to 2023 (Source: NAEI 2025)

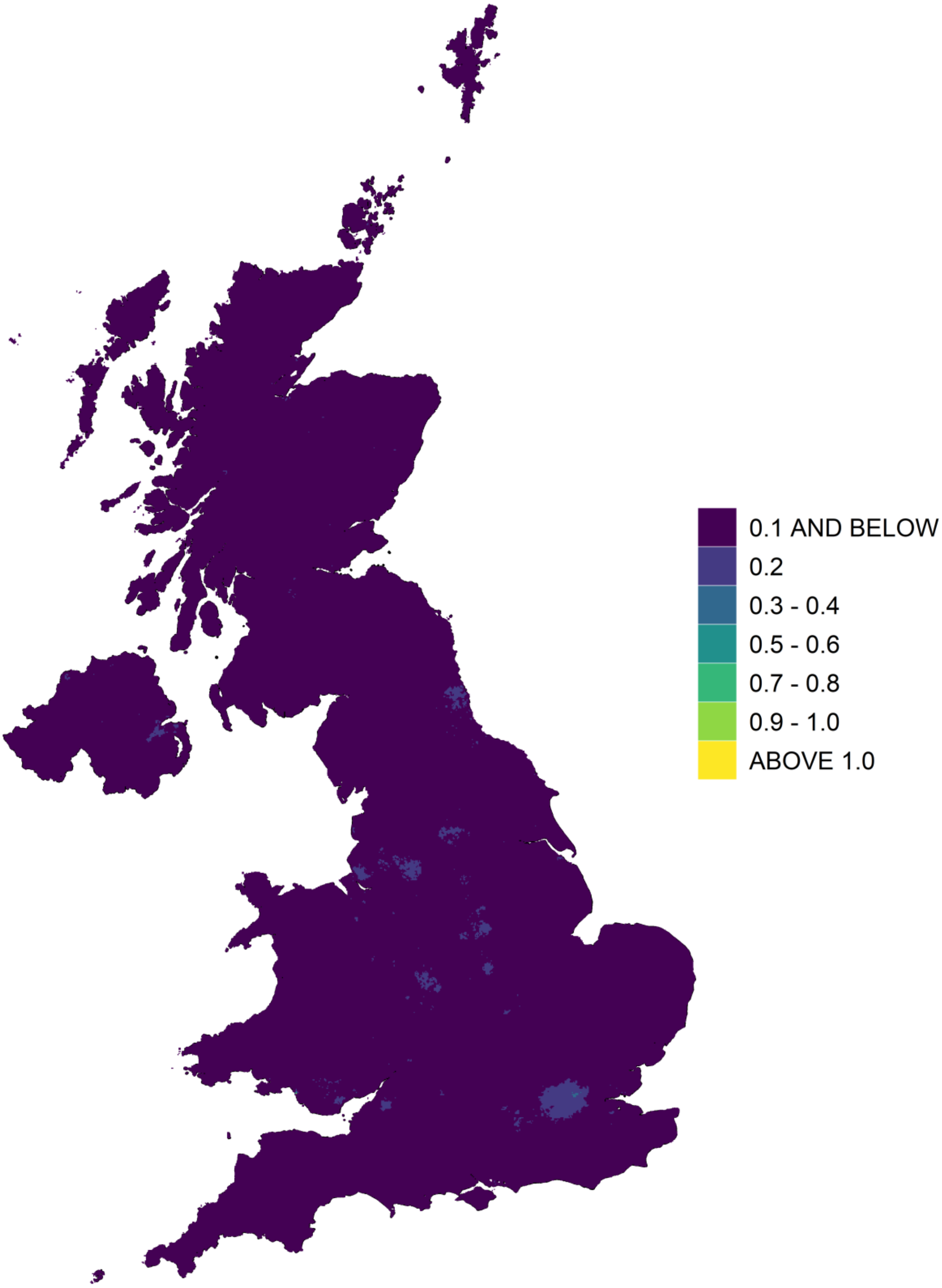


5.11 Benzo[a]pyrene

5.11.1 B[a]P: Spatial Distribution

Figure 5-39 shows the modelled annual mean background concentration of the polycyclic aromatic hydrocarbon compound, benzo[a]pyrene (B[a]P). This shows the average modelled annual mean concentration in each 1 km^2 grid square. Most of the UK had modelled concentrations of 0.1 ng m^{-3} or less in 2024. There were some areas of higher concentration, reflecting the distribution of industrial sources, and/or areas where there is widespread domestic use of coal and other solid fuels for heating. However, no areas had modelled annual mean B[a]P concentrations above the target value of 1 ng m^{-3} in 2024. This is the first year when the UK has been fully compliant with this target value.

Figure 5-39 Annual mean background B[a]P concentration, 2024 (ng m^{-3})



More detail is available on the UK-AIR website's interactive map.

5.11.2 B[a]P: Changes Over Time

The Polycyclic Aromatic Hydrocarbon (PAH) monitoring network began operation in 1991. At that time, it comprised just a small number of sites, but increased in size to over 20 in the late 1990s. Later, during the years 2007 to 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 Digitel™ samplers' shorter collection period. The shorter collection period is likely to decrease the degradation of the PAHs by ozone or other oxidative species (Sarantiridis, 2014).

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 5-40** shows how the mean B[a]P concentration has changed in the years since 2008. This graph is based on combined data from all sites in the PAH Network. The solid line shows the mean, and the shaded area either side of the line shows the 95% confidence interval of the mean for all sites. The 95% confidence intervals are large in the case of B[a]P as there is considerable variation in the concentrations measured by the various sites. In recent years, results less than the limit of detection (LoD) have occurred at some sites: these results have been treated as half the LoD, for the purpose of calculating the averages shown here.

Following a sharp drop in measured concentrations of B[a]P between 2008 and 2009, there has been a further decrease in B[a]P concentrations, although this decrease has not been consistent over time.

Figure 5-41 shows estimated total UK emissions of B[a]P, 1990 to 2023. Emissions have decreased substantially in recent decades compared to the early 1990s, due in part to measures such as the banning of stubble burning in agriculture.

At present, emissions of B[a]P are dominated by combustion of solid fuels in the home, and the NAEI data indicate that this source (part of the category described as "residential/commercial/institutional") is increasing slightly year-on-year, in recent years. The NAEI notes that increases in residential wood burning are partly offsetting decreases in B[a]P emissions from other sources.

Figure 5-40 Annual Mean Concentrations of Particulate Phase B[a]P, 2008 to 2024

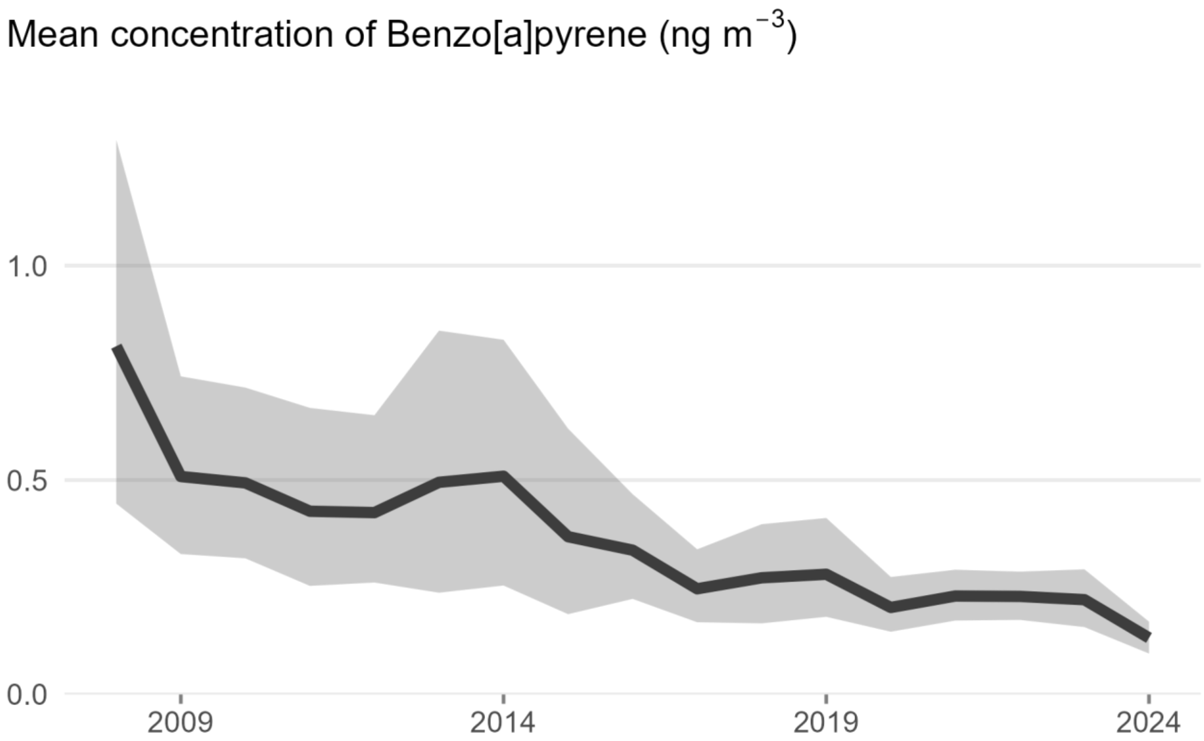
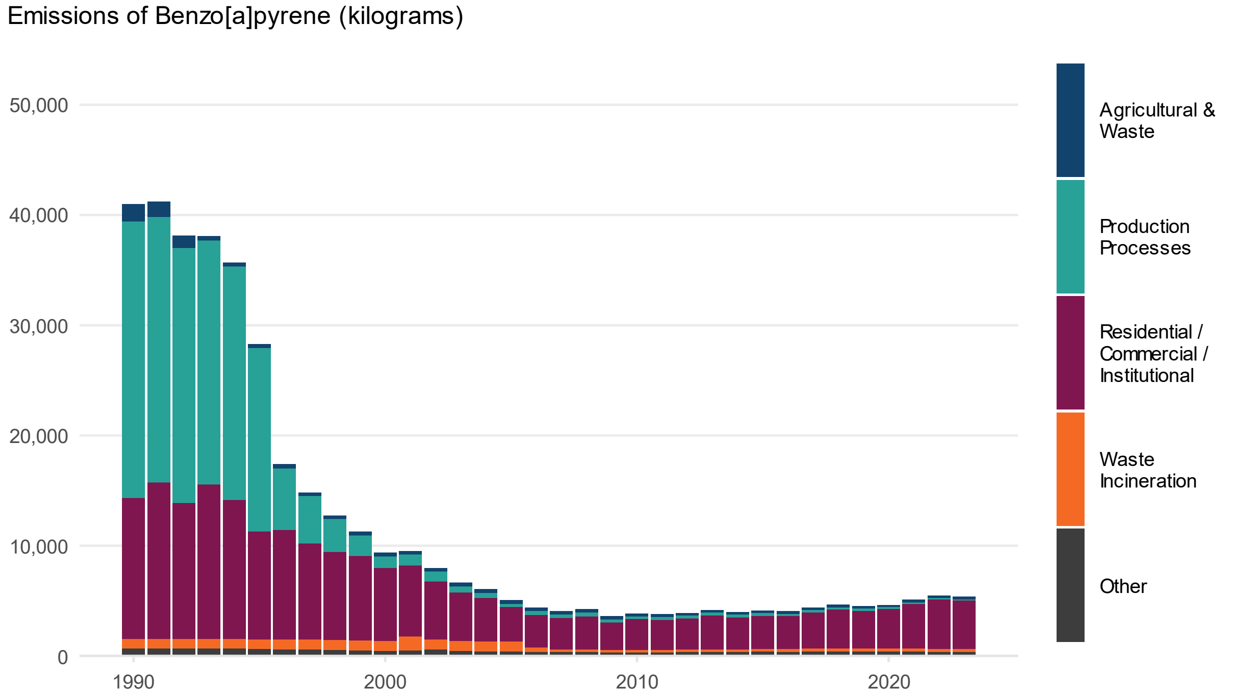


Figure 5-41 Estimated Annual UK Emissions of Benzo[a]pyrene (kg), 1990 to 2023 (Source: NAEI 2025)



6 Air Pollution Episodes in 2024

6.1 Overview of Pollution Episodes and the Daily Air Quality Index

In this section we use the Daily Air Quality Index to quantify periods of elevated pollutant concentration that occurred during 2024. The Daily Air Quality Index (DAQI) tells you about levels of air pollution and provides recommended actions and health advice. The index is numbered 1 to 10 and divided into four bands: Low (1 to 3), Moderate (4 to 6), High (7 to 9) and Very High (10). These bands provide detail about air pollution levels in a simple way, like the sun index or pollen index. More information about the Daily Air Quality Index is available on the UK-AIR website's DAQI page.

Figure 6-1, Figure 6-2, Figure 6-3, Figure 6-4 and **Figure 6-5** each show a visual summary of the DAQI over 2024 for the five DAQI pollutants: nitrogen dioxide (NO_2), ozone (O_3), PM_{10} particulate matter, $PM_{2.5}$ particulate matter, and sulphur dioxide (SO_2) respectively. In these figures, each day in the year is represented by a coloured 'tile'. The colour of each tile represents the maximum DAQI across the network and the numeric label the number of stations at 'Moderate', 'High' or 'Very High' level. There were three specific pollutants of interest in 2024.

- SO_2: unusually for the UK, sulphur dioxide entered the High and Very High bands; this has only occurred on one other occasion since 2000, when the former Harwell monitoring station in Oxfordshire reached 'High' in March of 2012. Elevated SO_2 in 2024 was due to volcanic activity in the Sundhnúkur system of Iceland's Reykjanes Peninsula.
- Ozone: as commonly occurs in the UK, ozone entered the 'Moderate' band on many occasions throughout summer 2024, particularly in May, June and July but also March and September. These periods of elevated ozone can be attributed to sunny, warm weather speeding up ozone-producing reactions in the atmosphere. However, ozone concentrations were relatively low in 2024, with no occasions on which the UK's population information threshold of 180 µg m^{-3} (as an hourly mean) was breached.
- Particulate matter: there were some instances of elevated particulate matter throughout the year. Many of these were local incidents, except for short periods in September and November in which particulate matter concentrations entered the 'Moderate' or 'High' bands. The latter coincided with Bonfire Night (5 November), whereas evidence suggests that the September period of elevated PM_{10} arose from PM-emitting activity in mainland Europe.

In this chapter, each of these occasions will be discussed in turn in greater detail.

Figure 6-1 Visual summary of the daily air quality index for NO_2 in the AURN in 2024. Numbers show number of monitoring sites recording a DAQI 'Moderate' level or above.

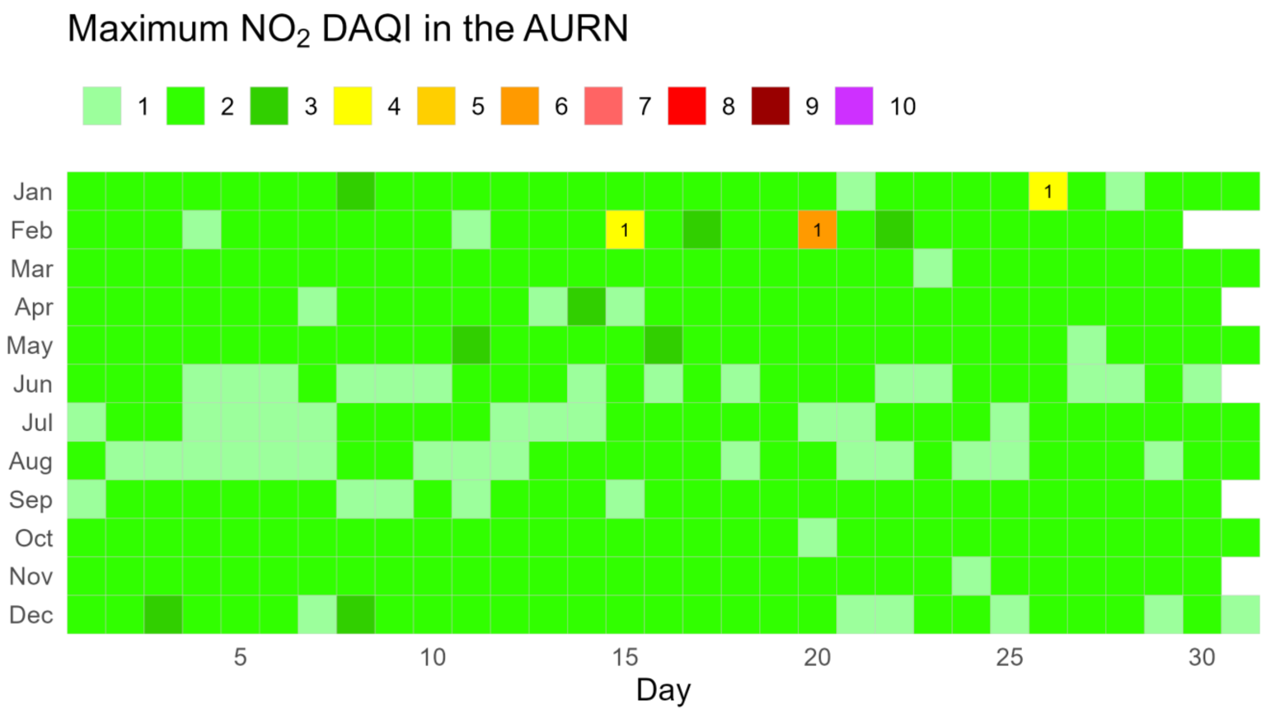


Figure 6-2 Visual summary of the daily air quality index for O_3 in the AURN in 2024. Numbers show number of monitoring sites recording a DAQI 'Moderate' level or above.

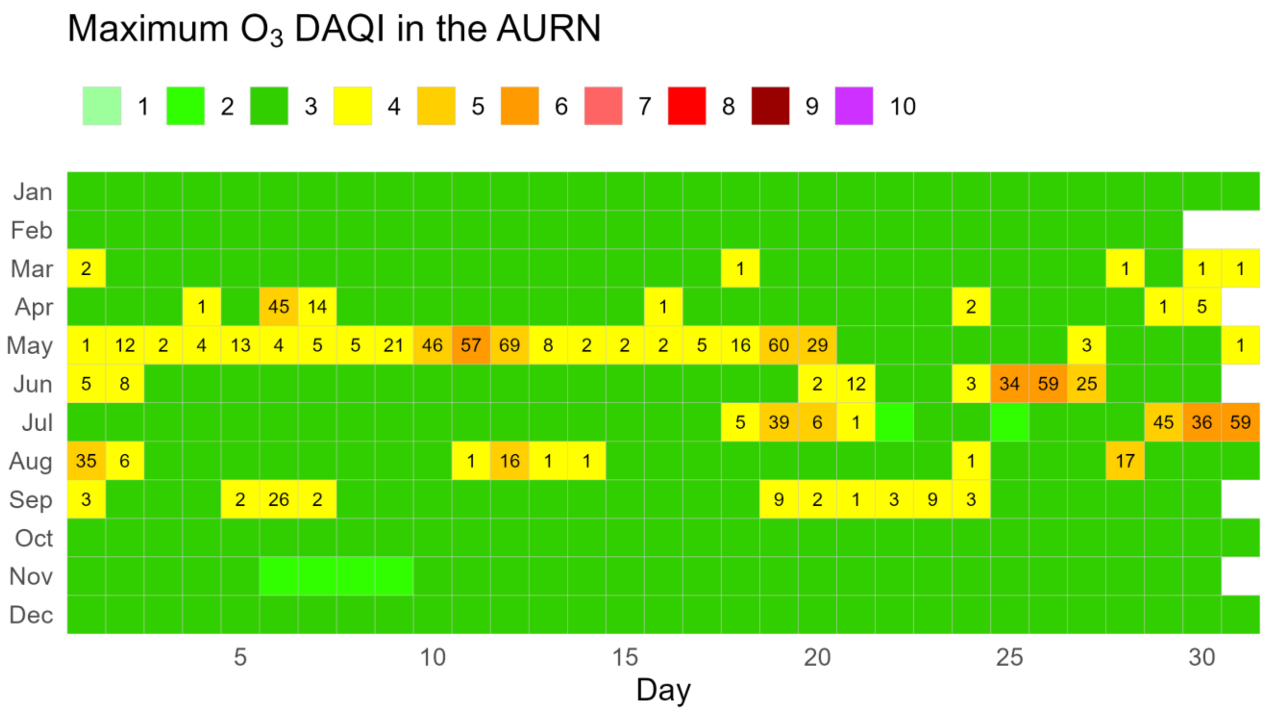


Figure 6-3 Visual summary of the daily air quality index for PM_{10} in the AURN in 2024. Numbers show number of monitoring sites recording a DAQI 'Moderate' level or above.

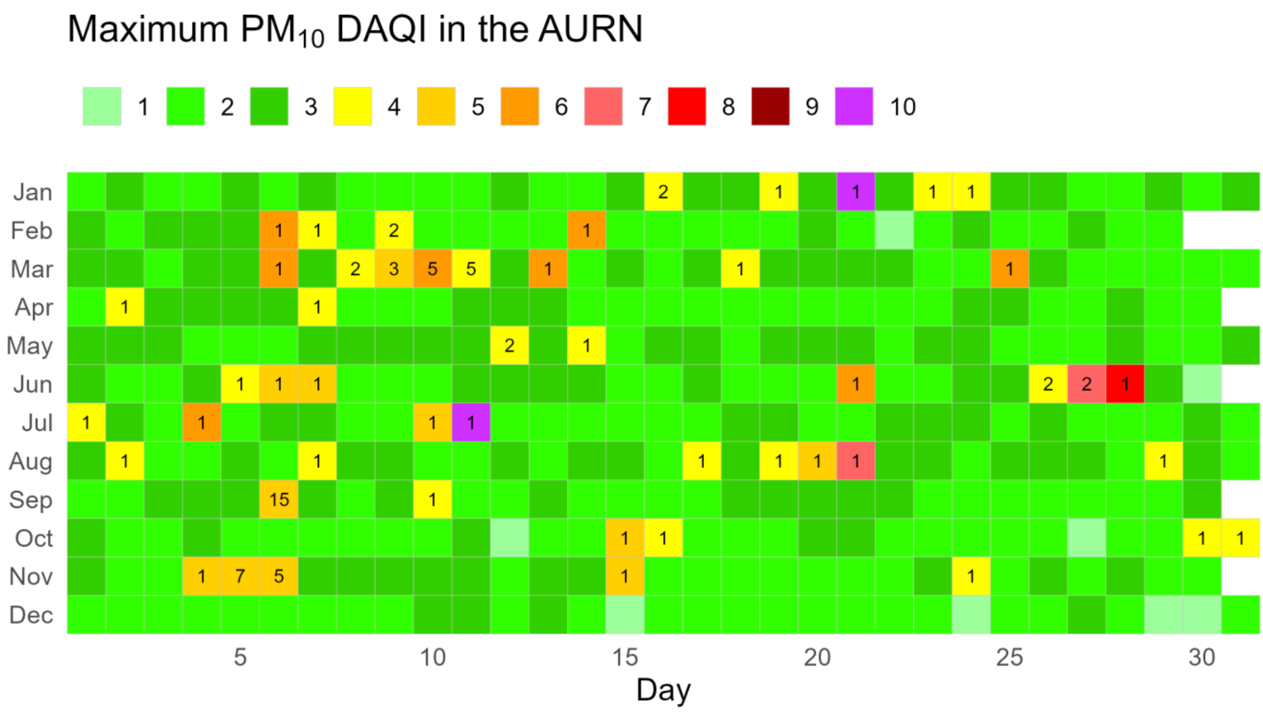


Figure 6-4 Visual summary of the daily air quality index for $PM_{2.5}$ in the AURN in 2024. Numbers show number of monitoring sites recording a DAQI 'Moderate' level or above.

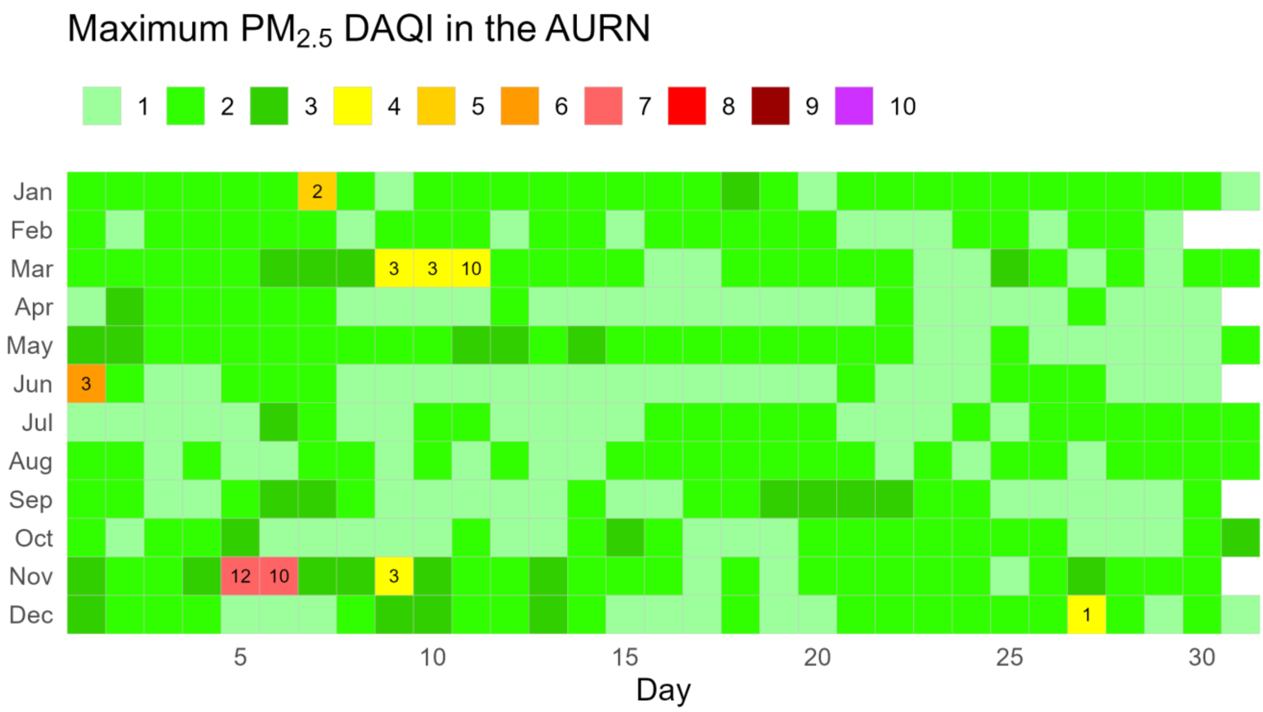
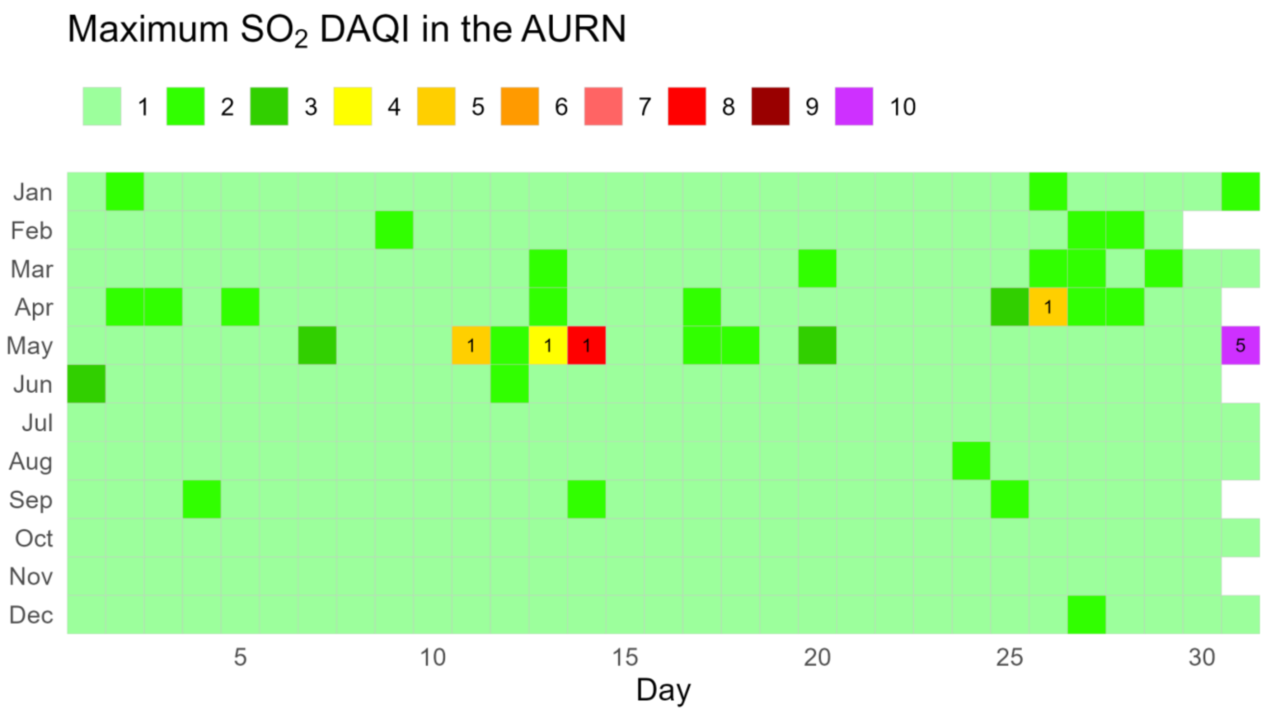


Figure 6-5 Visual summary of the daily air quality index for SO_2 in the AURN in 2024. Numbers show number of monitoring sites recording a DAQI 'Moderate' level or above.



6.2 SO_2 from Volcanic Activity

SO_2 episodes are now very rare in the UK. The National Atmospheric Emissions Inventory (NAEI) estimates that, since 1990, UK SO_2 emissions have dropped by 97% due a decline in the use of coal and fuel oil and the adoption of flue-gas desulphurisation (FGD) systems at coal-fired power stations.[8] This means that the UK has very few significant domestic sources of atmospheric SO_2 to cause SO_2 episodes.

However, volcanic eruptions can be a significant source of SO_2. Throughout 2024, the Sundhnúkur volcanic system in Iceland's Reykjanes Peninsula experienced a series of eruptions, beginning on 14 January 2024. Six eruptions of varying magnitudes occurred in 2024. A press release from the Centre for Ecology and Hydrology provides more information. These eruptions released significant quantities of SO_2 into the atmosphere, leading to transboundary pollution concerns in the United Kingdom owing to the proximity of the two countries. The six eruptions were:

- January Eruption: 14 January to 16 January 2024
- February Eruption: 8 February to 9 February 2024
- March-May Eruption: 16 March to 9 May 2024
- May-June Eruption: 29 May to 22 June 2024
- August-September Eruption: 22 August to 6 September 2024
- November-December Eruption: 20 November to 8 December 2024

There are relatively few AURN monitoring sites measuring SO_2 compared to the four other DAQI pollutants. There were 29 sites measuring SO_2 in 2024: 17 Urban Background, 16 Rural Background, four Urban Industrial and two Urban Traffic.

Figure 6-6 shows how the DAQI changed across 2024, highlighting that the biggest impact on the UK came from the Icelandic volcanic activity in May. Each 'bubble' represents a different day and index, with the size of the bubble representing the number of sites at that index on that day. The vertical grey bands show the periods when the volcanic eruptions took place. Days with a DAQI of 1 are not included in the figure.

[8] Sulphur Dioxide | National Atmospheric Emissions Inventory: https://naei.energysecurity.gov.uk/node/54

Figure 6-6 The distribution of daily SO_2 pollution indices during 2024. Each bubble is a different day and index, with the size of the bubble representing the number of sites at that index on that day. Colours show the DAQI. The vertical shaded grey bands show the durations of the volcanic eruptions.

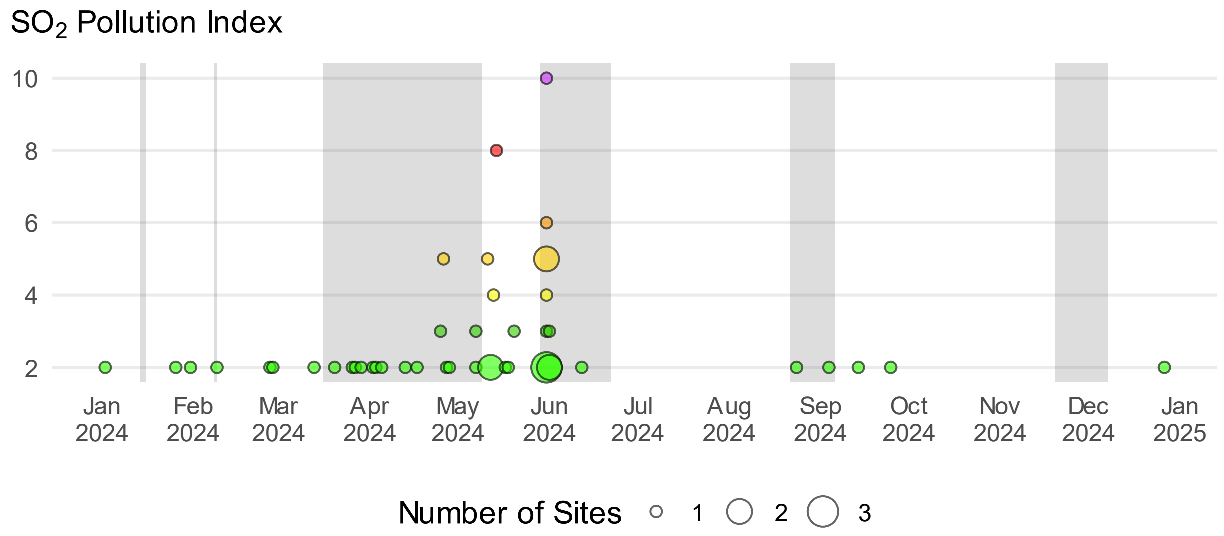


Figure 6-7 shows the highest SO_2 DAQI at each AURN monitoring site in 2024. For sites that recorded a DAQI greater than 3 (i.e. Moderate band or higher), the date at which the index was highest is labelled alongside the site name. Only the most northern AURN sites reached Moderate and higher DAQI bands, as these were most affected by the gases from the volcano.

However, the three SO_2 monitoring stations in Northern Ireland remained in the Low band despite being further north geographically than some of the Moderate sites in England. This can be attributed to the differing origins of air masses arriving at different parts of the UK. Back trajectories showing the origins of the air masses were calculated using the HYSPLIT Trajectory Model from NOAA Air Resources Laboratory (ARL) and Global NOAA-NCEP/NCAR reanalysis data archives (Stein, et al., 2015), and plotted using the Openair package for R (R Core Team, 2019), (Carslaw & Ropkins, 2012). **Figure 6-8** shows the paths air masses took arriving into the UK at midday on 31 May 2024, and shows that air masses arriving in Northern Ireland on that day originated from over the Atlantic Ocean rather than passing over Iceland.

Volcanic activity is a natural process, so there is little that can be done to mitigate its air quality effects. Events such as this are a reminder that local air quality can be influenced by natural or human-made emissions long distances away.

Figure 6-7 The highest SO_2 DAQI measured at each AURN SO_2 station in 2024. For Moderate and higher indices, the date at which they occurred is labelled alongside the site name.

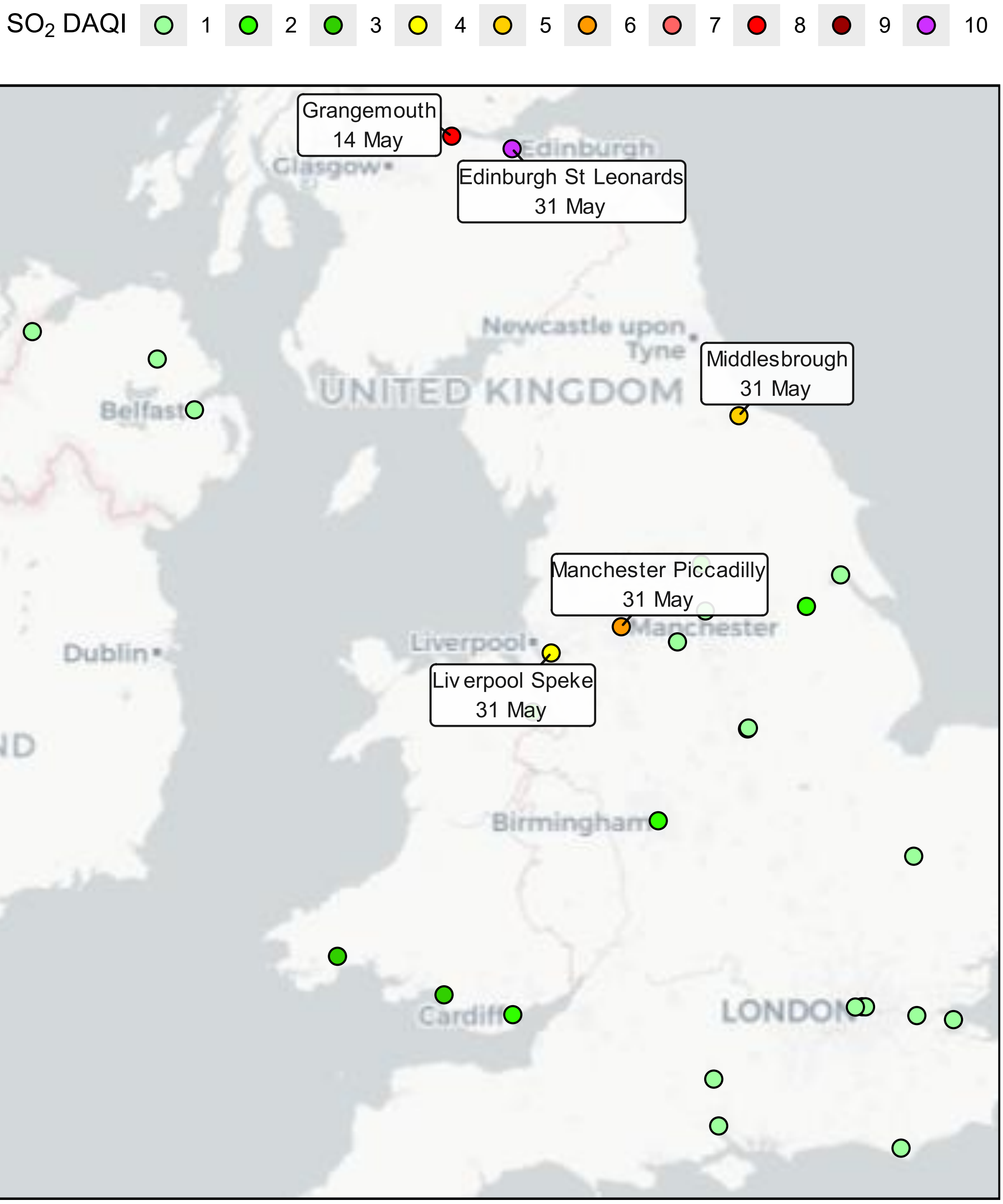
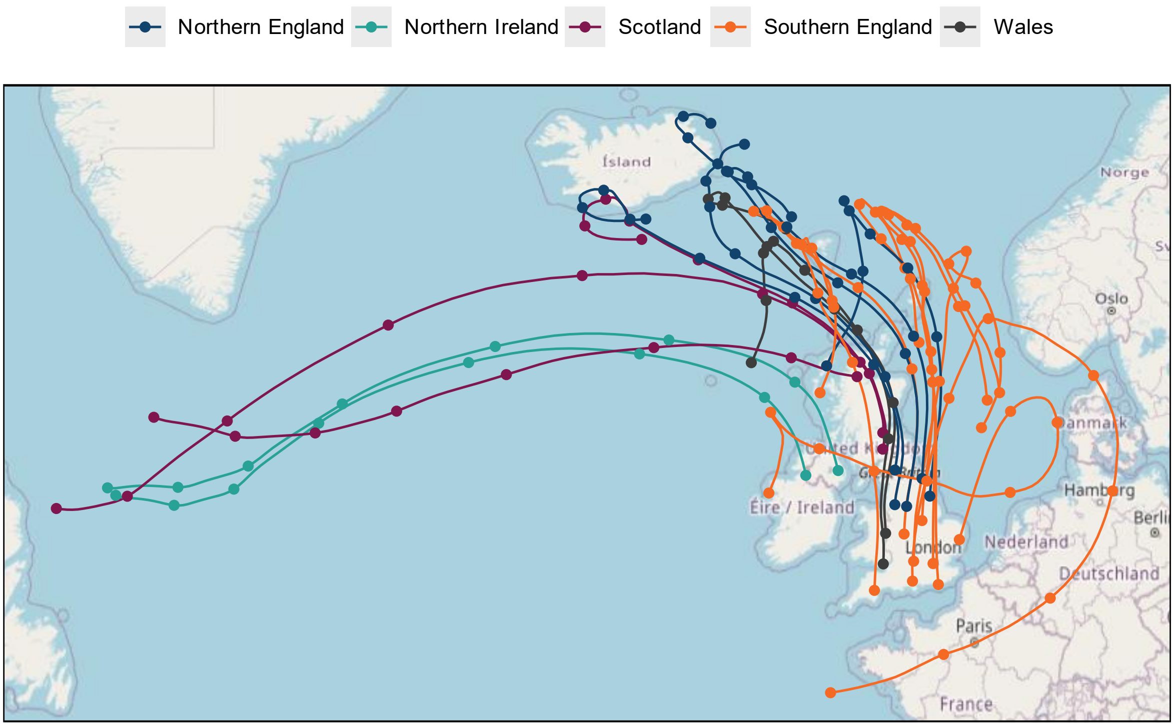


Figure 6-8 Air mass trajectories arriving 31 May 2024. Trajectory paths are coloured by region of the UK. 'Northern England' refers to sites in Sheffield and further north: 'Southern England' refers to sites to the south of Sheffield.



6.3 Elevated Summer O_3

Ozone is a secondary pollutant that forms when nitrogen oxides (NO_x) react with volatile organic compounds (VOCs) in the presence of sunlight. Concentrations tend to be higher during spring and summer due to longer daylight hours, increased sunlight intensity, and stable atmospheric conditions that allow ozone to accumulate. Additionally, warmer temperatures can accelerate the chemical reactions that produce ozone.

Ozone concentrations remained relatively low in 2024: they did not reach the 'High' band at any time during the year, and there were no exceedances of the Population Information Threshold. However, there were periods of 'Moderate' ozone pollution. As shown in **Figure 6-9**, these occurred throughout the summer, from March through to September but highest in May through to July.

Figure 6-9 Maximum O_3 DAQI for AURN sites, March - September 2024, overlaying average air temperature modelled at each of the AURN monitoring sites.

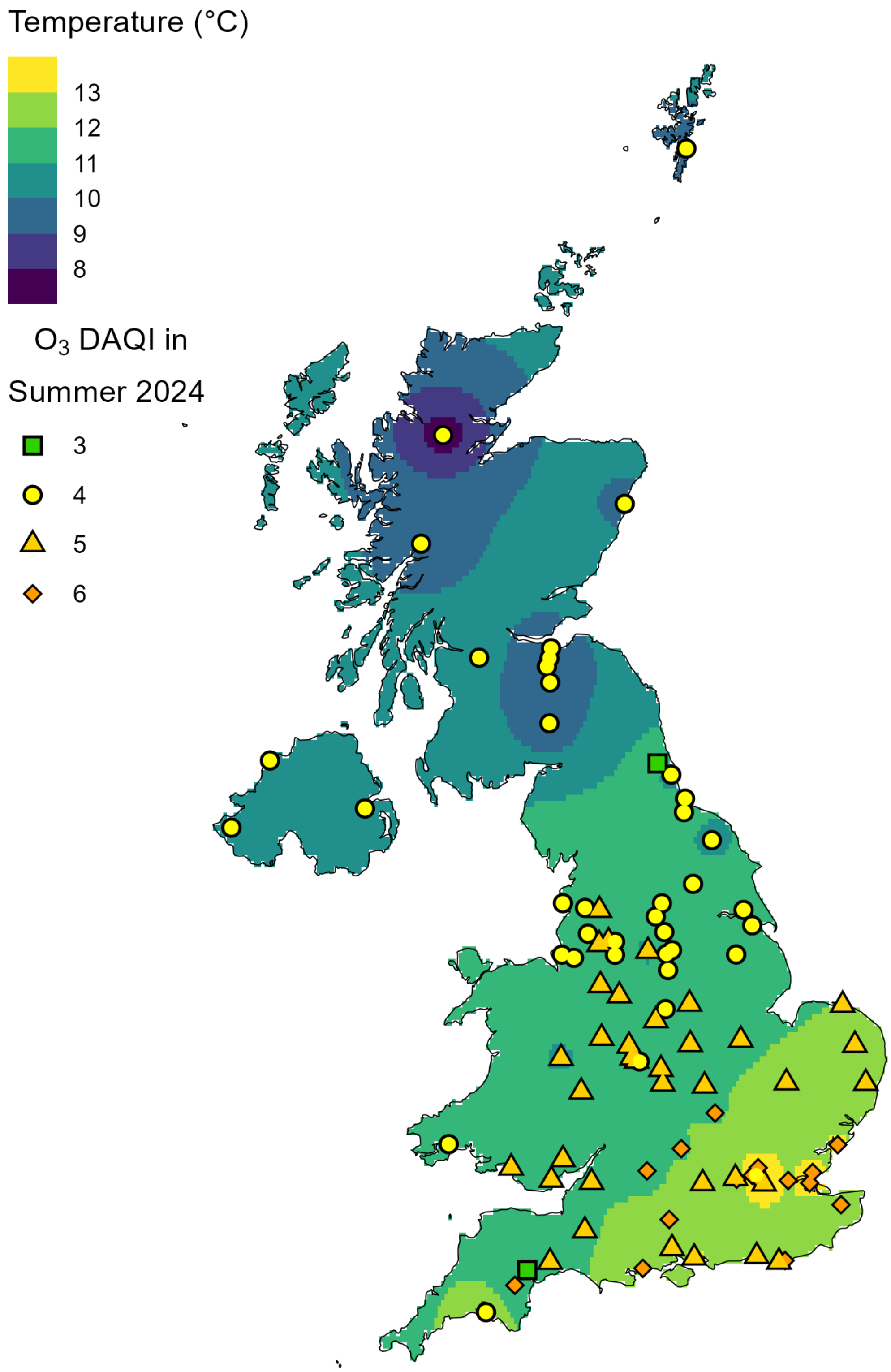


Figure 6-9 shows that the higher indices (5 and 6) were mostly concentrated in the South of England, with Scotland, Northern Ireland and the North of England broadly only reaching an index of 4 at a maximum. This can be attributed to the warmer, likely sunnier weather in the south; **Figure 6-9** also shows average hourly air temperature from March

to September 2024, using temperature data modelled at each AURN site using the Weather Research and Forecasting (WRF) model.[9]

6.4 Transboundary and Local PM

There were two periods in 2024 that could be described as particulate matter episodes – a PM_{10} episode on 6 September in which fifteen AURN sites reached the 'Moderate' DAQI band, and a two-day PM_{10} and $PM_{2.5}$ episode centred around Bonfire Night (5 November).

6.4.1 September 2024

The 6 September event was associated with a few sites in central and eastern England, as illustrated in **Figure 6-10.** This is likely to have been caused by long-range transport of air pollution from mainland Europe: **Figure 6-11** shows the paths of air masses arriving at 22 different locations in the UK on 6 September. This map shows that air arrived from over mainland Europe, stretching well into Eastern Europe. This air will be 'dirtier' than air originating from over the Atlantic, for example, which may have contributed to this short episode.

[9] Weather Research & Forecasting Model (WRF) | Mesoscale & Microscale Meteorology: https://www.mmm.ucar.edu/models/wrf

Figure 6-10 A map showing the DAQI for PM_{10} on 6 September 2024. All sites at 'Moderate' are contained within the black outline.

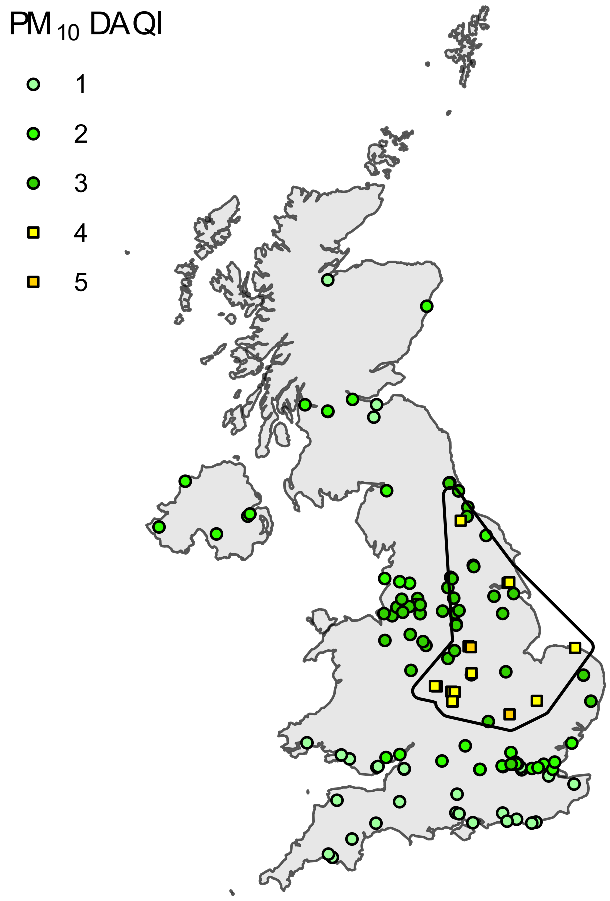


Figure 6-11 22 trajectories taken by the air arriving at the UK on 6 September 2024.

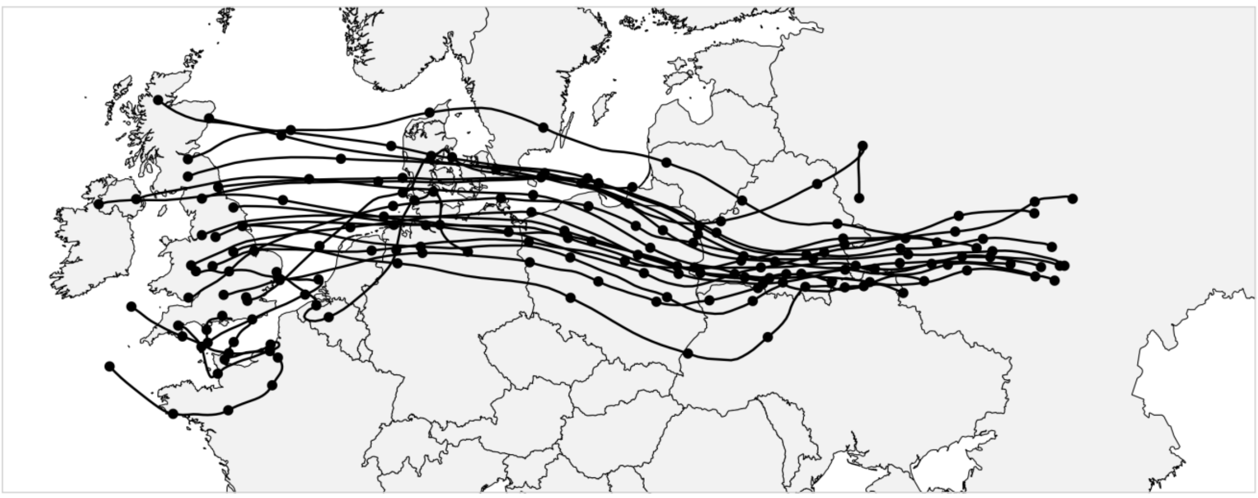
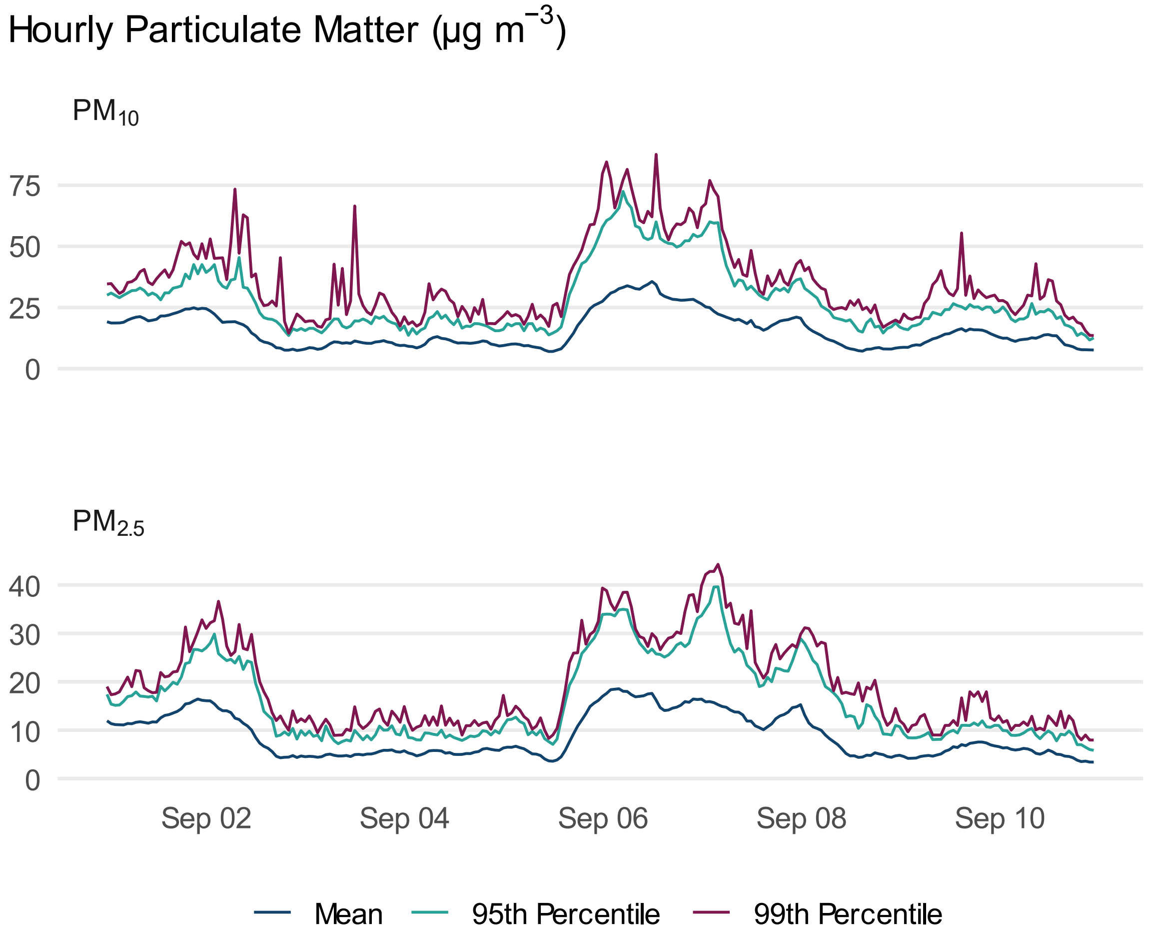


Figure 6-12 shows a time series chart of PM_{10} concentration as measured by the AURN over the period 2 September to 10 September 2024. This clearly shows that there was a peak in hourly mean measured PM_{10} across the whole of the AURN in a period centred on the 6 and 7 September 2024. So while not all AURN sites in central and eastern England went into the 'Moderate' band, it is likely that transboundary PM_{10} affected the UK generally on these dates, with more local geography and meteorology influencing the extent to which it impacted individual AURN sites.

Figure 6-12 Hourly mean particulate matter across the AURN in September 2024. The three lines show the mean, 95th percentile (top 5%) and 99th percentile (top 1%) of measurements at each hour.

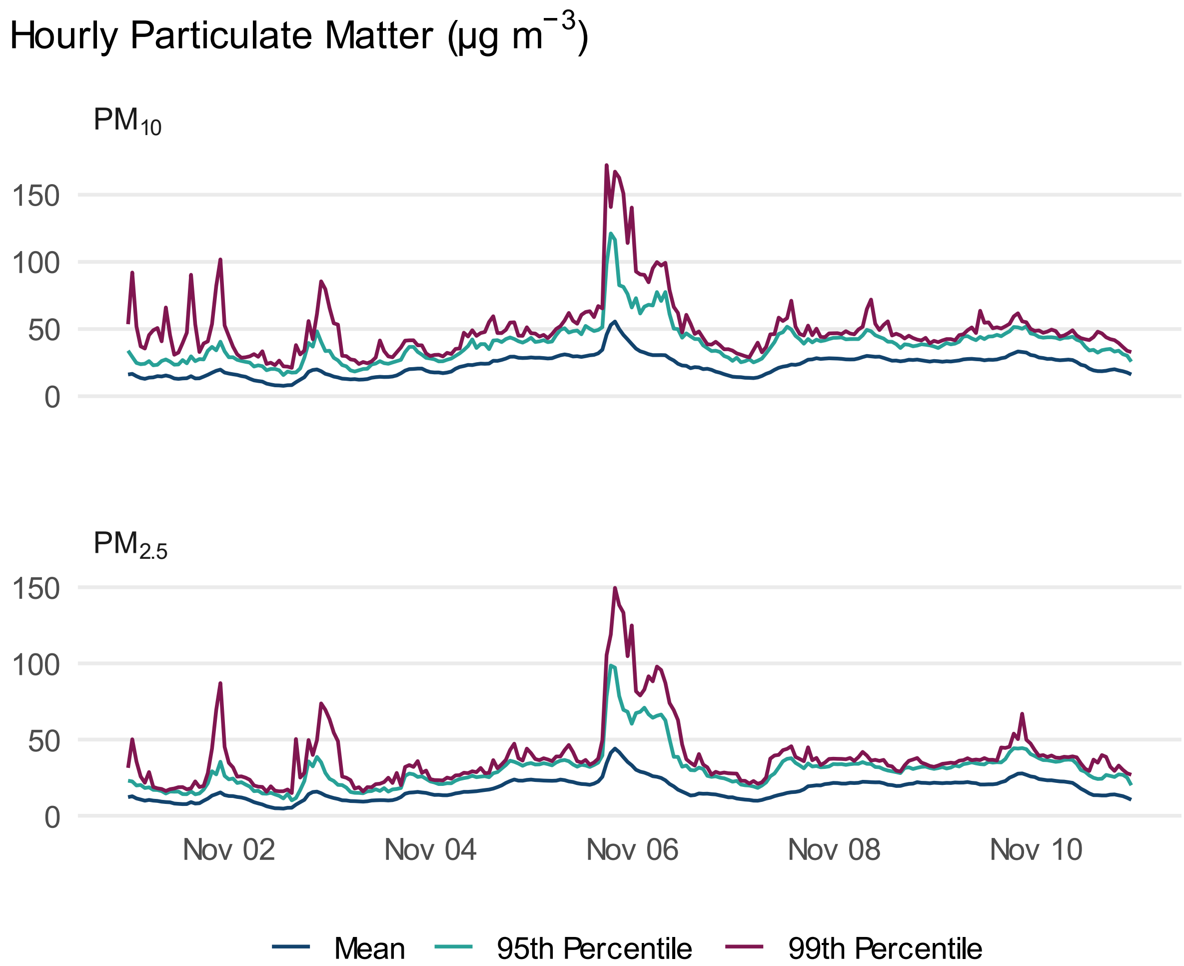


6.4.2 Bonfire Night

Activities around Bonfire Night (5 November) also caused a short episode of elevated PM_{10} and $PM_{2.5}$ concentrations lasting from 5 to 6 November. This was measured at 13 monitoring sites in the North East and Yorkshire, with Leeds Headingley Kerbside and Stockton-on-Tees Eaglescliffe recording concentrations in the High band. Elsewhere, Liverpool Speke and five sites in the South East of England also reached at least the Moderate band during this period. This is illustrated as a time series chart in **Figure 6-13**.

The nature of Bonfire Night makes it challenging to analyse closely; each bonfire event is organised locally, and their individual air quality impacts will vary depending on their length, the kinds of activities occurring (fireworks, bonfires, etc.), local meteorology, and even the distance between the event and its nearest AURN site. The DAQI may itself be too coarse a metric to fully capture the health impacts of Bonfire Night as they are local and potentially short-lived. People attending bonfire events are likely to be exposed (in the short term) to higher concentrations of airborne PM than monitoring evidence from the AURN suggests, as they are closer to the source – particularly in stable weather conditions which prevent smoke from dispersing.

Figure 6-13 Hourly mean particulate matter across the AURN around Bonfire Night (5 November) 2024. The three lines show the mean, 95th percentile (top 5%) and 99th percentile (top 1%) of measurements at each hour.



7 Where to Find Out More

Defra has published a Guide to Air Pollution Information Resources, detailing the types of information that are made available.

Information on the UK's air quality, now and in the past, is available on UK-AIR, the Defra online air quality resource, and the national repository for historic air quality data. Tools available on UK-AIR include the UK Ambient Air Quality Interactive Map that allows you to look at outputs for the national modelling conducted for this compliance assessment, based on pollutant, background or roadside and geographical location.

UK-AIR also provides a daily air quality forecast, which is further disseminated via e-mail, RSS feeds and X (formerly Twitter) (see https://x.com/DefraUKAir). Latest forecasts are issued daily, at the UK-AIR website's forecasting page. Defra also provides a free telephone information service, with current air pollution levels and forecasts updated every hour. To use this service, call 0800 556677 and follow the instructions.

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

- Air Quality in Wales at https://airquality.gov.wales/
- Air Quality in Scotland at https://www.scottishairquality.scot/
- Air Quality in Northern Ireland 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 parts of the UK. These reports are available from the above websites.

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

- The Scottish Government Air Quality web page
- The Welsh Government Environment and Climate Change web page
- The Northern Ireland Department of Agriculture, Environment and Rural Affairs (DAERA) web page

Detailed pollutant emission data for the UK are available from the National Atmospheric Emissions Inventory (NAEI).

The 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 the Global Action Plan.

8 References

Air Quality Expert Group, 2013. *Mitigation of United Kingdom PM2.5 Concentrations.* [Online]
Available at: https://uk-air.defra.gov.uk/assets/documents/reports/cat11/1508060903_DEF-PB14161_Mitigation_of_UK_PM25.pdf
[Accessed 30 July 2025].

BS EN, 2023. *BS EN 12341:2023: Ambient air quality - Standard gravimetric measurement method for the determination of the PM10 or PM2.5 mass fraction of suspended particulate matter.* s.l.:CEN.

Carslaw, D. C. & Ropkins, K., 2012. Openair – an R package for air quality data analysis. *Environmental Modelling & Software,* Volume 27, pp. 52-61.

CEN, 2005. *EN 14902:2005 Reference method for determination of Pb/Cd/As/Ni in ambient air,* s.l.: BSI.

CEN, 2023. *EN 14662-1:2023 Ambient air quality - Standard method for measurement of benzene concentrations - Part 1: Pumped sampling followed by thermal desorption and gas chromatography,* s.l.: BSI.

CEN, 2024a. *EN 14625:2024 Ambient air quality – standard method for the measurement of the concentration of ozone by ultraviolet photometry,* s.l.: BSI.

CEN, 2024b. *EN 14211:2024 Ambient air quality - Standard method for the measurement of the concentration of nitrogen dioxide and nitrogen monoxide by Chemiluminescence,* s.l.: BSI.

CEN, 2024c. *EN 14212:2024 Ambient air quality – Standard method for the measurement of the concentration of sulphur dioxide by UV fluorescence,* s.l.: BSI.

CEN, 2024d. *EN 14626:2024 Ambient air quality - Standard method for the measurement of the concentration of carbon monoxide by non-dispersive infrared spectroscopy,* s.l.: BSI.

COMEAP, 2006. *Cardiovascular Disease and Air Pollution.* [Online]
Available at:
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/304668/COMEAP_cardiovascular_disease_and_air_pollution.pdf
[Accessed 30 July 2025].

COMEAP, 2009. *Long-Term Exposure to Air Pollution: Effect on Mortality.* [Online]
Available at:
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/304667/COMEAP_long_term_exposure_to_air_pollution.pdf
[Accessed 30 July 2025].

COMEAP, 2010. *The Mortality Effects of Long-Term Exposure to Particulate Air Pollution in the United Kingdom.* [Online]
Available at:
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/304641/COMEAP_mortality_effects_of_long_term_exposure.pdf
[Accessed 30 July 2025].

COMEAP, 2011. *The Review of the UK Air Quality Index.* [Online]
Available at:
https://webarchive.nationalarchives.gov.uk/20140505104700/http://comeap.org.uk/images/stories/Documents/Reports/comeap%20review%20of%20the%20uk%20air%20quality%20index.pdf
[Accessed 30 July 2025].

COMEAP, 2015. *Statement on the Evidence for the Effects of Nitrogen Dioxide on Health.* [Online]
Available at: https://www.gov.uk/government/publications/nitrogen-dioxide-health-effects-of-exposure
[Accessed 12 July 2025].

COMEAP, 2018a. *The Effects of Long-Term Exposure to Ambient Air Pollution on Cardiovascular Morbidity: Mechanistic Evidence.* [Online]
Available at:
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/749657/COMEAP_CV_Mechanisms_Report.pdf
[Accessed 30 July 2025].

COMEAP, 2018. *Nitrogen Dioxide: Effects on Mortality.* [Online]
Available at: https://www.gov.uk/government/publications/nitrogen-dioxide-effects-on-mortality
[Accessed 5 August 2025].

COMEAP, 2022. *Cognitive Decline, Dementia and Air Pollution.* [Online]
Available at:
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1090376/COMEAP-dementia-report-2022.pdf
[Accessed 30 July 2025].

DAERA, 2017. *The Air Quality Standards (Amendment) Regulations (Northern Ireland) 2017.* [Online]
Available at: https://www.legislation.gov.uk/nisr/2017/2/contents/made
[Accessed 30 July 2025].

Defra, 2007. *The Air Quality Strategy for England, Scotland, Wales and Northern Ireland (Volume 1).* [Online]
Available at: https://www.gov.uk/government/publications/the-air-quality-strategy-for-

england-scotland-wales-and-northern-ireland-volume-1
[Accessed 30 July 2025].

Defra, 2016. *Quality Assurance and Quality Control (QA/QC) Procedures for UK Air Quality Monitoring under 2008/50/EC and 2004/107/EC.* [Online]
Available at: https://uk-air.defra.gov.uk/assets/documents/reports/cat09/1902040953_All_Networks_QAQC_Document_2012__Issue2.pdf
[Accessed 30 July 2025].

Defra, 2017. *UK plan for tackling roadside nitrogen dioxide concentrations.* [Online]
Available at: https://www.gov.uk/government/publications/air-quality-plan-for-nitrogen-dioxide-no2-in-uk-2017
[Accessed 31 July 2025].

Defra, 2022. *Part IV of the Environment Act 1995 as amended by the Environment Act 2021: Local Air Quality Management Policy Guidance (PG22).* [Online]
Available at: https://laqm.defra.gov.uk/wp-content/uploads/2022/08/LAQM-Policy-Guidance-2022.pdf
[Accessed 30 July 2025].

Defra, 2023a. *UK Report on measures for 2021 exceedance of the Target Value for Nickel.* [Online]
Available at: https://uk-air.defra.gov.uk/assets/documents/reports/bap-nickel-measures/ni_overview_reportonmeasures_2021.pdf
[Accessed 30 July 2025].

Defra, 2023. *Environmental Improvement Plan 2023.* [Online]
Available at: https://www.gov.uk/government/publications/environmental-improvement-plan
[Accessed 30 July 2025].

Defra, 2025a. *Emissions of air pollutants in the UK - Summary.* [Online]
Available at: https://www.gov.uk/government/statistical-data-sets/env01-emissions-of-air-pollutants
[Accessed 25 July 2025].

Defra, 2025b. *National statistics - Concentrations of Nitrogen Dioxide.* [Online]
Available at: https://www.gov.uk/government/statistics/air-quality-statistics/ntrogen-dioxide
[Accessed 25 July 2025].

Defra, 2025c. *National Statistics - Concentrations of particulate matter (PM10 and PM2.5).* [Online]
Available at: https://www.gov.uk/government/statistics/air-quality-statistics/concentrations-of-particulate-matter-pm10-and-pm25
[Accessed 25 July 2025].

Defra, 2025d. *National Statistics - Concentrations of Ozone.* [Online]
Available at: https://www.gov.uk/government/statistics/air-quality-statistics/concentrations-of-ozone
[Accessed 28 July 2025].

Defra, 2025. *UK-AIR Website.* [Online]
Available at: https://uk-air.defra.gov.uk/
[Accessed 31 July 2025].

Department of Environment Northern Ireland, 2010. *The Air Quality Standards Regulations (Northern Ireland) (2010).* [Online]
Available at: https://www.legislation.gov.uk/nisr/2010/188/contents/made
[Accessed 30 July 2025].

Department of Environment Northern Ireland, 2013. *The Pollution Prevention and Control (Industrial Emissions) Regulations (Northern Ireland) (2013) as amended.* [Online]
Available at: https://www.legislation.gov.uk/nisr/2013/160
[Accessed 30 July 2025].

Department of Health and Social Care, 2016. *Improving outcomes and supporting transparency Part 2: Summary technical specifications of public health indicators, updated August 2016.* [Online]
Available at: https://www.gov.uk/government/publications/public-health-outcomes-framework-2016-to-2019
[Accessed 31 July 2025].

EPAQS, 2009. *Defra and the Devolved Administrations' Expert Panel on Air Quality Standards: Metals and Metalloids.* [Online]
Available at:
https://webarchive.nationalarchives.gov.uk/20130402151656/http://archive.defra.gov.uk/environment/quality/air/airquality/panels/aqs/documents/metals-and-metalloids.pdf
[Accessed 30 July 2025].

European Parliament and Council of the European Commission, 2011. *2011/850/EU: Commission Implementing Decision of 12 December 2011 laying down rules for Directives 2004/107/EC and 2008/50/EC as regards the reciprocal exchange of information and reporting on ambient air quality.* [Online]
Available at: https://eur-lex.europa.eu/eli/dec_impl/2011/850/oj/eng#anx_II
[Accessed 4 September 2025].

European Parliament and Council of the European Union, 2008. *Council Directive on ambient air quality and cleaner air for Europe (2008/50/EC).* [Online]
Available at: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32008L0050:EN:NOT
[Accessed 30 July 2025].

European Parliament and Council of the European Union, 2016. *Directive (EU) 2016/2284 of the European Parliament and of the Council of 14 December 2016 on the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC.* [Online]
Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2016.344.01.0001.01.ENG&toc=OJ:L:2016:344:TOC
[Accessed 30 July 2025].

European Parliament and Council of the European, 2004. *Directive 2004/107/EC of the European Parliament and of the Council of 15 December 2004 relating to arsenic, cadmium, mercury, nickel and polycylic aromatic hydrocarbons in ambient air.* [Online]
Available at: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32004L0107:EN:NOT
[Accessed 30 July 2025].

HM Government of Gibraltar, 2016. *Environment (Air Quality Standards) (Amendment) Regulations 2016 (Legal Notice No. 2016/242).* [Online]
Available at: https://www.gibraltarlaws.gov.gi/legislations/environment-air-quality-standards-amendment-regulations-2016-2922
[Accessed 30 July 2025].

Imperial College London, 2022. *Analysis of abatement options to reduce PM2.5.* [Online]
Available at: https://uk-air.defra.gov.uk/assets/documents/reports/cat09/2302091626_Analysis_of_abatement_options_to_reduce_PM2.5.pdf
[Accessed 30 July 2025].

Mayor of London, 2019. *The London Local Air Quality Management Framework.* [Online]
Available at: https://www.london.gov.uk/what-we-do/environment/pollution-and-air-quality/working-london-boroughs
[Accessed 30 July 2025].

National Atmospheric Emissions Inventory, 2025. *Overview of air pollutants.* [Online]
Available at: https://naei.energysecurity.gov.uk/air-pollutants
[Accessed 30 July 2025].

Northern Ireland Government, 2002. *The Environment (Northern Ireland) Order 2002 (SI No. 3153 (N.I. 7).* [Online]
Available at: https://www.legislation.gov.uk/nisi/2002/3153/contents
[Accessed 30 July 2025].

Northern Ireland Government, 2003. *The Air Quality Regulations (Northern Ireland) 2003 (SI No. 342).* [Online]
Available at: https://www.legislation.gov.uk/nisr/2003/342/contents/made
[Accessed 30 July 2025].

NPL, 2020. *Annual Report for 2019 on the UK Heavy Metals Network (NPL Report ENV30).* [Online]
Available at: https://uk-air.defra.gov.uk/assets/documents/reports/cat09/2109211243_Metals_Network_Annual_Report_2019.pdf
[Accessed 30 July 2025].

Orellano, P. et al., 2020. Short-term exposure to particulate matter (PM10 and PM2.5), nitrogen dioxide (NO2), and ozone (O3) and all-cause and cause-specific mortality: Systematic review and meta-analysis. *Environ. Int.,* 142:105876(https://doi.org/10.1016/j.envint.2020.105876).

Pugsley, K. L. et al., 2025. *Technical report on UK supplementary modelling assessment under the Air Quality Standards Regulations 2010 for 2023.* [Online]
Available at: https://uk-air.defra.gov.uk/assets/documents/reports/cat05/2503131612_2023_PCM_technical_report.pdf#:~:text=This%20report%20provides%20a%20summary%20of%20key%20attainment,against%20limit%20values%20are%20summarised%20in%20Table%20E0.1.
[Accessed 30 July 2025].

R Core Team, 2019. *A language and environment for statistical computing. R.* [Online]
Available at: https://www.r-project.org/

Resongles, E. et al., 2021. Strong evidence for the continued contribution of lead deposited during the 20th century to the atmospheric environment in London of today. *Proceedings of the National Academy of Sciences of the United States of America*, 29 June, 118(26).

Sarantiridis, D., 2014. *Annual Report for 2012 on the UK PAH Monitoring and Analysis Network.* [Online]
Available at: https://uk-air.defra.gov.uk/assets/documents/reports/cat05/1402041506_Defra_PAH_Network_2012_annual_report_FINAL_v2.pdf
[Accessed 31 July 2025].

Scottish Government, 2000. *The Air Quality (Scotland) Regulations 2000. (SSI 2000 No. 97).* [Online]
Available at: https://www.legislation.gov.uk/ssi/2000/97/contents/made
[Accessed 30 July 2025].

Scottish Government, 2002. *The Air Quality (Scotland) Amendment Regulations 2002. (SSI No. 297).* [Online]
Available at: https://www.legislation.gov.uk/ssi/2002/297/contents/made
[Accessed 30 July 2025].

Scottish Government, 2010. *The Air Quality Standards (Scotland) Regulations.* [Online]
Available at: https://www.legislation.gov.uk/ssi/2010/204/made
[Accessed 30 July 2025].

Scottish Government, 2016. *The Air Quality Standards (Scotland) Amendment Regulations 2016.* [Online]
Available at: https://www.legislation.gov.uk/ssi/2016/376/contents/made
[Accessed 30 July 2025].

Scottish Government, 2018. *Environmental Authorisations (Scotland) Regulations 2018.* [Online]
Available at: https://www.legislation.gov.uk/ssi/2018/219/regulation/1/made
[Accessed 30 July 2025].

Scottish Government, 2023. *Local Air Quality Management for Scotland: Policy Guidance.* [Online]
Available at: https://www.gov.scot/publications/local-air-quality-management-policy-guidance/
[Accessed 30 July 2025].

Stein, A. F. et al., 2015. NOAA's HYSPLIT Atmospheric Transport and Dispersion Modeling System. *Bulletin of the American Meteorological Society,* Volume 96, p. 2059–2077.

UK Government, 1995. *Environment Act 1995.* [Online]
Available at: https://www.legislation.gov.uk/ukpga/1995/25/contents
[Accessed 30 July 2025].

UK Government, 1999. *The Motor Fuel (Composition and Content) Regulations 1999 (UK Statutory Instruments 1999 No. 3107).* [Online]
Available at: https://www.legislation.gov.uk/uksi/1999/3107/contents/made
[Accessed 16 September 2025].

UK Government, 2000. *The Air Quality (England) Regulations 2000. (SI 2000 No.928).* [Online]
Available at: https://www.legislation.gov.uk/uksi/2000/928/introduction/made
[Accessed 30 July 2025].

UK Government, 2002. *The Air Quality (England) (Amendment) Regulations 2002 (SI No. 3043).* [Online]
Available at: https://www.legislation.gov.uk/uksi/2002/3043/contents/made
[Accessed 30 July 2025].

UK Government, 2010. *UK Air Quality Standards Regulations 2010.* [Online]
Available at: https://www.legislation.gov.uk/uksi/2010/1001/contents/made
[Accessed 30 July 2025].

UK Government, 2016. *The Air Quality Standards (Amendment) Regulations 2016.* [Online]
Available at: https://www.legislation.gov.uk/uksi/2016/1184/contents/made
[Accessed 30 July 2025].

UK Government, 2018a. *The National Emission Ceilings Regulations 2018.* [Online]
Available at: https://www.legislation.gov.uk/uksi/2018/129/made
[Accessed 30 July 2025].

UK Government, 2018. *The Air Quality (Miscellaneous Amendment and Revocation of Retained Direct EU Legislation) (EU Exit) Regulations 2018.* [Online]
Available at: https://www.gov.uk/eu-withdrawal-act-2018-statutory-instruments/the-air-quality-miscellaneous-amendment-and-revocation-of-retained-direct-eu-legislation-eu-exit-regulations-2018
[Accessed 30 July 2025].

UK Government, 2019. *The Air Quality (Amendment of Domestic Regulations) (EU Exit) Regulations 2019.* [Online]
Available at: https://www.legislation.gov.uk/uksi/2019/74/made
[Accessed 30 July 2025].

UK Government, 2021. *Environment Act 2021.* [Online]
Available at: https://www.legislation.gov.uk/ukpga/2021/30/contents/enacted
[Accessed 30 July 2025].

UK Government, 2022. *Air Quality Provisional Common Framework.* [Online]
Available at: https://www.gov.uk/government/publications/air-quality-provisional-common-framework
[Accessed 30 July 2025].

UK Government, 2023. *The Environmental Targets (Fine Particulate Matter) (England) Regulations 2023.* [Online]
Available at: https://www.legislation.gov.uk/uksi/2023/96/contents/made
[Accessed 30 July 2025].

UK Government, 2025. *Open Government Licence.* [Online]
Available at: https://www.nationalarchives.gov.uk/doc/open-government-licence/version/2/
[Accessed 30 July 2025].

UK Health Security Agency, 2014. *Nickel: health effects, incident management and toxicology.* [Online]
Available at: https://www.gov.uk/government/publications/nickel-properties-incident-management-and-toxicology
[Accessed 30 July 2025].

UK Health Security Agency, 2016. *Lead: General Information.* [Online]
Available at:
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_

data/file/562435/lead_general_information.pdf
[Accessed 30 July 2025].

UK Health Security Agency, 2018. *Polycyclic aromatic hydrocarbons (Benzo[a]pyrene): general information.* [Online]
Available at: https://www.gov.uk/government/publications/benzoapyrene-properties-incident-management-and-toxicology/polycyclic-aromatic-hydrocarbons-benzoapyrene-general-information
[Accessed 30 July 2025].

UK Health Security Agency, 2019a. *Benzene: General Information.* [Online]
Available at: https://www.gov.uk/government/publications/benzene-general-information-incident-management-and-toxicology/benzene-general-information
[Accessed 30 July 2025].

UK Health Security Agency, 2019b. *Arsenic: General Information.* [Online]
Available at: https://www.gov.uk/government/publications/arsenic-properties-incident-management-and-toxicology/arsenic-general-information
[Accessed 30 July 2025].

UK Health Security Agency, 2022a. *Chemical Hazards and Poisons Report Issue 28 – June 2022.* [Online]
Available at:
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1083447/CHaPR_AQ_Special_Edition_2206116.pdf
[Accessed 30 July 2025].

UK Health Security Agency, 2022b. *Mercury: health effects, incident management and toxicology.* [Online]
Available at: https://www.gov.uk/government/publications/mercury-properties-incident-management-and-toxicology
[Accessed 30 July 2025].

UK Health Security Agency, 2022. *Carbon Monoxide: Toxicological Overview.* [Online]
Available at: https://www.gov.uk/government/publications/carbon-monoxide-properties-incident-management-and-toxicology/carbon-monoxide-toxicological-overview
[Accessed 5 August 2025].

United Nations Economic Commission for Europe (UNECE), 1999. *Gothenburg Protocol.* [Online]
Available at: https://unece.org/environment-policy/air/protocol-abate-acidification-eutrophication-and-ground-level-ozone
[Accessed 30 July 2025].

Vinzargan, R., 2004. A review of surface ozone background levels and trends. *Atmospheric Environment,* Volume 38, pp. 3431-3442 .

Welsh Government, 2000. *The Air Quality (Wales) Regulations 2000. (SI No. 1940 W. 138).* [Online]
Available at: https://www.legislation.gov.uk/wsi/2000/1940/contents/made
[Accessed 30 July 2025].

Welsh Government, 2002. *The Air Quality (Amendment) (Wales) Regulations 2002 (SI No. 3182 W. 298).* [Online]
Available at: https://www.legislation.gov.uk/wsi/2002/3182/contents/made
[Accessed 30 July 2025].

Welsh Government, 2010. *The Air Quality Standards (Wales) Regulations.* [Online]
Available at: https://www.legislation.gov.uk/wsi/2010/1433/contents/made
[Accessed 30 July 2025].

Welsh Government, 2017. *Local air quality management in Wales.* [Online]
Available at: https://gov.wales/sites/default/files/publications/2019-04/local-air-quality-management-in-wales.pdf
[Accessed 30 July 2025].

Welsh Government, 2020. *The Clean Air Plan for Wales - Healthy Air, Healthy Wales.* [Online]
Available at: https://www.gov.wales/clean-air-plan-wales-healthy-air-healthy-wales
[Accessed 30 July 2025].

Welsh Government, 2023. *Clean Air Plan for Wales: Healthy Air, Healthy Wales (Update Report on Progress Against Actions).* [Online]
Available at: https://www.gov.wales/clean-air-plan-wales-healthy-air-healthy-wales
[Accessed 30 July 2025].

Welsh Government, 2025. *The Environment (Air Quality and Soundscapes) (Wales) Act 2025.* [Online]
Available at: https://www.gov.wales/sites/default/files/publications/2025-07/local-air-quality-management-in-wales-2025.pdf
[Accessed 12 September 2025].

WHO, 2013. *Review of Evidence on Health Aspects of Air Pollution – REVIHAAP Project.* [Online]
Available at: https://www.who.int/europe/publications/i/item/WHO-EURO-2013-4101-43860-61757
[Accessed 30 July 2025].

WHO, 2019. *Exposure to cadmium: a major public health concern.* [Online]
Available at: https://www.who.int/publications/i/item/WHO-CED-PHE-EPE-19-4-3
[Accessed 30 July 2025].

WHO, 2021. *WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide.* [Online]

Available at: https://apps.who.int/iris/handle/10665/345329
[Accessed 30 July 2025].