SCOTTISH AIR QUALITY DATABASE

Annual Report 2022

Report for: Scottish Government

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EXECUTIVE SUMMARY

In April 2007, Ricardo Energy & Environment (Ricardo) were commissioned by the Scottish Government to undertake a three-year project to develop an Air Quality Database and Website for Scotland. This contract has been renewed in consecutive years, with the latest contract running from 2019-2024 (including extensions).

This report brings together all the Scottish Air Quality Database data for calendar year 2022 and associated work relating to project deliverables including: data management; QA/QC services; liaison with stakeholders; website development; spatial analysis of air quality data; trend analysis.

In addition, this year's report provides updated analysis on how the Covid-19 pandemic affected air quality in Scotland. This analysis follows on from the 2021 annual report Covid-19 analysis.

Legislation and Policy

Air quality management is shaped by requirements of EU, UK and Scottish legislation and policies. Following the UK's exit from the EU, under retained EU law, Scotland is required to continue to meet limit and target values for a range of air pollutants and other legal obligations covered by EU directives.

In July 2021, accompanied by a Delivery Plan, and replacing "Cleaner Air for Scotland – The Road to a Healthier Future", the Scottish Government published Scotland's second air quality strategy called "Cleaner Air for Scotland 2 – Towards a Better Place for Everyone" (CAFS2). CAFS2 is shaped around 10 general themes. These are:

1. Health – A Precautionary Approach
2. Integrated Policy
3. Placemaking
4. Data
5. Public Engagement and Behavioural Change
6. Industrial Emissions Regulation
7. Tackling Non-Transport Emission Sources
8. Transport
9. Governance, Accountability and Delivery
10. Further Progress Review

Air Quality Monitoring in Scotland

Air pollution data for 99 automatic monitoring sites throughout Scotland are available in the database for all or part of 2022. All automatic data maintained within the Scottish database are subject to the same QA/QC procedures as the UK Automatic Urban and Rural Network (AURN).

In 2022, no automatic monitoring site exceeded the annual mean or hourly AQS objective for NO_2. In 2022, Seven passive diffusion tube monitoring sites exceeded the NO_2 annual mean objective.

In 2022, no automatic monitoring sites measuring Particulate Matter (PM_{10} and $PM_{2.5}$) measured exceedances of the Scottish 24 hour or annual mean objectives for both PM_{10} and $PM_{2.5}$. One site (Edinburgh St Johns Road) exceeded the 24-hour mean objective of 50 µgm^{-3} not to exceed more than 7 times per year.

In 2022, no exceedances of AQS objectives were observed for the pollutants ozone (O_3), sulphur dioxide (SO_2), carbon monoxide (CO), benzene, 1,3-butadiene, benzo(a)pyrene, and lead (Pb).

Air Quality Mapping of Scotland

The 2021 annual mean NO_2 concentrations for Scotland were modelled for background and roadside locations for NO_2, PM_{10} and $PM_{2.5}$.

For NO_2, there were no modelled exceedances of the Scottish annual mean objective of 40 µg m^{-3} at background or roadside locations.

For PM_{10}, there were no modelled exceedances of the Scottish annual mean PM_{10} objective of 18 µg m^{-3} at background or roadside locations.

For $PM_{2.5}$, there were also no modelled exceedances of the Scottish annual mean $PM_{2.5}$ objective of 10 µg m^{-3} at both background and roadside locations.

Air Quality Trends for Scotland

NO_2

Trend analysis of nitrogen dioxide concentrations at Scotland's five long-running urban background sites shows that NO_2 concentrations are displaying highly significant decreasing trends. The more recent five years analysis shows that the decreasing trend is consistent with the long-range trends.

Analysis shows that NO_2 concentrations at Scotland's three long-running rural sites showed small decreasing trends.

Of the eight selected NO_2 urban traffic monitoring sites selected for analysis; all eight sites showed highly significant decreasing trends for both five and ten year analysis.

PM_{10}

PM_{10} trend analysis at Scotland's eight long-running urban background sites showed highly significant decreasing trends at all sites. Seven out of Scotland's eight long-running urban traffic sites also showed statistically highly significant decreasing trends at all sites. More recent years trend analysis indicates that the decreasing trend is plateauing for all the sites analysed. Trend analysis was carred out for a subsection of the traffic related sites with very similar results to background sites.

$PM_{2.5}$

By the end of 2021 there were four sites with 10 consecutive years of $PM_{2.5}$ data. The analysis shows that all sites show a slight decreasing trend over the 10-year time period at varying levels of statistical significancy. Anaysis carried out on a subsection of urban traffic sites showed all sites having a slight decreasing trend at varying statistical significance.

Ozone

Ozone has been measured at three rural sites in Scotland for 30 years. Two sites showed small but statistical highly significant increasing trends whereas the other showed no obvious trend. Ozone has been measured for the past 10 years at six rural sites. In contrast to the 30-year trends, the 10-year trends were less consistent. Four sites have increasing trends in O_3 concentrations at varying levels of statistical significance. The other two sites have slight decreasing trends

10-year trend analysis of ozone concentrations showed increasing trends (at varying statistical significance) at three Scottish urban background sites whereas the other three sites show slight decreasing trends (at varying statistical significance).

Additional Trend Analysis

Additional trend analysis was carried out at four sites located within the four major cities in Scotland. This analysis was carried out using the Openair analysis tool and compared 2022 data with data from the previous 10 years using a variety of analytical techniques.

Emissions of Pollution Species

Emissions of **nitrogen oxides** in Scotland were estimated to be 83kt in 2021, representing 12% of the UK total for nitrogen oxides. Emissions have declined by 59% (61% in 2020) since 2005, mainly due to changes in transport sources.

Emissions of **PM_{10}** in Scotland were estimated to be 12kt in 2021, declining by 41% (46% in 2020) since 2005. These emissions account for 8% of the UK total PM_{10} emissions. Unlike most other pollutants, the emissions profile of PM_{10} is diverse: transport sources, residential and industrial processes each accounted for over 15% of total PM_{10} emissions in 2021.

Emissions of **$PM_{2.5}$** in Scotland were estimated to be 7kt in 2021, declining by 47% (52% in 2020) since 2005. These emissions account for 8% of the UK total for $PM_{2.5}$ in 2021. As with PM_{10}, $PM_{2.5}$ emissions have a large number of significant sources. For $PM_{2.5}$, the residential, commercial, and public sectors accounts for 31% of

2021 emissions. The primary drivers for the decline in emissions since 2005 are the continued switch from coal to natural gas in electricity generation, and reductions in emissions from the transport sector.

Emissions of **carbon monoxide** in Scotland were estimated to be 93kt in 2021 and have declined by 60% (62% in 2020) since 2005. Emissions in Scotland accounted for 7% of the UK total for carbon monoxide in 2021. This decline in emissions stems from changes in the contribution of transport sources, particularly in the road sector where emissions have declined by 89% since 2005

Emissions of **sulphur dioxide** in Scotland were estimated to be 9kt in 2021, representing 7% of the UK total in 2021 for sulphur dioxide. Emissions have declined by 91% (92% in 2020) since 2005 because of continued changes in the power generation sector. Since 2005, SO_2 emissions from power stations have reduced by 99%.

Emissions of **ammonia** in Scotland were estimated to be 32kt in 2021. These emissions have declined by 12% (10% in 2020) since 2005 and accounted for 12% of the UK total for ammonia in 2021. Agriculture sources have dominated the inventory throughout the time series, with cattle manure management accounting for at least 34% of the emissions from this sector across the entire time series.

Emissions of **non-methane volatile organic compounds** in Scotland were estimated to be 144kt in 2021, representing 18% of the UK total for non-methane volatile organic compounds. Emissions have declined by 19% since 2005. This reduction is a result of reductions in fugitive and transport emissions.

Covid-19 lockdown and its effect on air Quality in Scotland

During 2022 there were no travel restrictions relating to the Covid-19 pandemic as was seen in 2020 and 2021. Anaysis shows that though traffic levels have returned to almost pre-covid levels in 2019, NO_2 concentrations at locations in Edinburgh and Glasgow have remain low and comparable and, in some cases, lower to 2020 and 2021. With daily trend analysis remaining similar this suggests that low NO_2 concentrations maybe related to a change in the vehicle fleet in these areas.

CONTENTS

Appendices

1 INTRODUCTION

The Scottish Government undertakes considerable monitoring of a wide range of air pollutant species as part of a joint UK programme run in conjunction with Defra, the Welsh Government and the Department of the Environment in Northern Ireland. In addition, a large number of local authorities in Scotland monitor air quality within their geographical boundaries as part of the requirements of the Local Air Quality Management system. Prior to 2006, air quality data in Scotland outside of the nationally operated sites, were collected by a wide range of organisations for many purposes and were widely dispersed. Consequently, and following experience gained across the rest of the UK, it was recognised that a comprehensive centralised resource providing air quality information for Scotland would serve to improve the quality of research and data analysis required to support Scottish air quality policy. Hence, in 2006, the Scottish Government contracted AEA, now Ricardo Energy & Environment, to undertake a pilot programme to develop an air quality database for Scotland.

The pilot study developed the initial Scottish Air Quality Database (SAQD) and Website, undertook stakeholder feedback and assessed the air quality data available across Scotland. The key recommendations that were developed from this initial study were based around the methodology for successful harmonisation of existing air quality monitoring data. It was suggested that a programme for Scotland should include the following components:

- Independent audits of every site - to include checks on both the analysers and the site calibration cylinders.
- Regular data checks; and,
- Longer term data checking and adjustment where necessary.

Following this pilot study, Ricardo Energy & Environment were commissioned to undertake the next stage which was to further develop and extend the SAQD and website incorporating all stakeholder comments and to bring selected local authority sites in line with the national Quality Assurance and Quality Control (QA/QC) requirements. Reports relating to the earlier years of the project are available on the Air Quality Scotland website (http://www.scottishairquality.scot/).

This annual report summarises the progress made during 2022 in the on-going project tasks and also highlights the new work undertaken during 2022 and into early 2023.

Section 2 of this report provides a breakdown of the legislation and policy concerning air quality within Scotland.

Section 3 provides a summary of the latest annual Air Quality in Scotland seminar.

The network of sites within the SAQD is dynamic and regularly changing to address the requirements of the local authorities to deal with air pollution issues. Section 4 describes in detail the structure of the database in terms of number and type of sites as well as pollutants measured, and how it has changed during 2022.

QA/QC is an integral part of the SAQD project. Since conception of the SAQD project, the QA/QC programme has expanded and adapted to encompass the dynamicity of the database and the changing best practice guidance and regulations. Section 5 of this report provides detailed information on the QA/QC process and how this was applied to the SAQD during 2022.

A statistical summary of all the available 2022 Scottish air quality data is provided in Section 6. This includes all pollutants covered under the Air Quality Strategy as well as other monitoring networks.

As the number of monitoring sites in Scotland has significantly increased since 2006, it has become feasible to undertake pollution climate mapping of NOx, NO_2 and PM_{10} using solely Scottish measurement data. As part of the SAQD, Ricardo Energy & Environment provide mapped concentrations of modelled background air pollutant concentrations on a 1 km x 1 km basis for the whole of Scotland. The Scottish pollution climate mapping work carried out in 2022 is described in Section 7.

Section 8 of this report provides a discussion of trends in pollutant concentrations across Scotland, based on the latest available data. The trend analysis focuses on roadside and urban background locations across Scotland and the pollutants nitrogen dioxide (NO_2), particulate matter (PM_{10} and $PM_{2.5}$) and ozone (O_3).

Section 9 provides most up to date and historical data on emissions of pollutants into the atmosphere in Scotland. The data is obtained from the UK National Atmospheric Emissions Inventory (NAEI) and the Scottish Pollution Release Inventory (SPRI).

2 LEGISLATION AND POLICY

Air quality management is shaped by requirements of EU, UK and Scottish legislation and policies. In the UK, air quality is a devolved matter, with the Scottish Government having responsibility for the development of air quality policy and legislation for Scotland. At EU level, the following air quality directives and policies are relevant:

- Directive 2008/50/EC - on ambient air quality and cleaner air for Europe (the Air Quality Directive).
- Industrial Emissions Directive 2010/75/EC – Controls emissions from industrial activities.
- National Emission Ceilings Directive 2016/2284/EU – sets emission limits for five important air pollutants.
- Clean Air Policy Package and Clean Air Programme for Europe - new air quality objectives to 2030, to improve air quality within cities.

Following the UK's exit from the EU, under retained EU law, the UK is required to continue to meet limit and target values for a range of air pollutants and other legal obligations covered by EU directives.

A substantial review of the EU's air quality policy, including the Air Quality Directive, was undertaken in 2013 with the European Commission adopting a new Clean Air Policy Package, including a new Clean Air for Europe programme with measures to ensure that existing targets are met in the short term and new air quality objectives for the period up to 2030. The Package also includes support measures to help cut air pollution, with a focus on improving air quality in cities, supporting research and innovation, and promoting international cooperation. A proposal for revision of the ambient air quality Directives was published in October 2022.

Domestic air quality legislation is largely derived from the requirements of the Environment Act 1995.

2.1 AIR QUALITY STANDARDS AND OBJECTIVES

A set of air quality standards and objectives has been developed for several pollutants of concern for human health. The objectives are derived from the standards and are a compromise between what is desirable purely on health grounds and what is practical in terms of feasibility and costs. Each objective has a date by when it must be achieved. The objectives adopted in Scotland for the purpose of Local Air Quality Management are set out in the Air Quality (Scotland) Regulations 2000, the Air Quality (Scotland) Amendment Regulations 2002 and the Air Quality (Scotland) Amendment Regulations 2016. Similar targets are set at EU level, where there are called limit or target values. These limit values are set out in the 2008 ambient air quality Directive (2008/50/EC) and transposed into Scottish legislation. It is the responsibility of EU Member States to achieve the limit and target values. A summary of the current Scottish air quality objectives is provided in Table 2-1.

Table 2-1 Summary of Scotland's Air Quality Objectives

AQ Objective-Pollutant	Concentration	Measured as	Date to be achieved by
Nitrogen Dioxide (NO_2)	200 µg m^{-3} not to be exceeded more than 18 times a year	1-hour mean	31.12.2005
	40 µg m^{-3}	Annual mean	31.12.2005
Particulate Matter (PM_{10})	50 µg m^{-3}, not to be exceeded more than 7 times a year	24-hour mean	31.12.2010
	18 µg m^{-3}	Annual mean	31.12.2010
Particulate Matter ($PM_{2.5}$)	10 µg m^{-3}	Annual mean	31.12.2020

AQ Objective-Pollutant	Concentration	Measured as	Date to be achieved by
Sulphur Dioxide (SO_2)	350 µg m^{-3}, not to be exceeded more than 24 times a year	1-hour mean	31.12.2004
	125 µg m^{-3}, not to be exceeded more than 3 times a year	24-hour mean	31.12.2004
	266 µg m^{-3}, not to be exceeded more than 35 times a year	15-minute mean	31.12.2005
Benzene	3.25 µg m^{-3}	Running annual mean	31.12.2010
1,3 Butadiene	2.25 µg m^{-3}	Running annual mean	31.12.2003
Carbon Monoxide	10.0 mg m^{-3}	Running 8-Hour mean	31.12.2003
Lead	0.25 µg m^{-3}	Annual Mean	31.12.2008
Poly Aromatic Hydrocarbons*	0.25 ng m^{-3}	Annual Mean	31.12.2010
Ozone*	100 µg m^{-3} not to be exceeded more than 10 times a year*	daily maximum 8-hour running mean	31.12.2005

* not required to be monitored or assessed by local authorities under LAQM, however is a UK requirement under retained EU law

2.2 CLEANER AIR FOR SCOTLAND STRATEGY

The first "Cleaner Air for Scotland – The Road to a Healthier Future" (CAFS) strategy was published by the Scottish Government in November 2015. The purpose of CAFS was to provide a national framework which sets out how the Scottish Government and its partner organisations propose to achieve further reductions in air pollution and fulfil their legal responsibilities to achieve the air quality objectives. It recognises that although progress has been made through Scotland, areas of poorer air quality still exist within towns and cities.

Since the Cleaner Air for Scotland strategy was published in 2015, the Scottish Government has:

- Introduced the most ambitious legislation in the world to end Scotland's contribution to climate change by 2045.
- Published an Environment Strategy which emphasises the fundamental role our natural environment plays in supporting a fairer, healthier, more inclusive society.
- Updated the National Transport Strategy.
- Established Scotland's first Low Emission Zone in Glasgow.
- Become the first country in Europe to include the World Health Organization guideline value for $PM_{2.5}$ in domestic legislation.
- Put in place a national $PM_{2.5}$ monitoring network.
- Committed to reducing motor vehicle kilometres by 20% by 2030.
- Increased our active travel funding to £500 million over five years from 2020-21; and
- Taken major steps to reform Scotland's planning system.

In total, 36 of the 40 actions set out in CAFS were fully completed.

Starting in late 2018 the Scottish Government commissioned an in-depth independently led review of CAFS and the findings were published in July 2019. The Scottish Government used the conclusions and recommendations arising from this review to develop a draft updated air quality strategy in the first part of 2020. In October 2020 this draft was published for consultation. Following the consultation, in July 2021, accompanied by a Delivery Plan, and replacing "Cleaner Air for Scotland – The Road to a Healthier Future", the Scottish Government published Scotland's second air quality strategy "Cleaner Air for Scotland 2 – Towards a Better Place for Everyone" (CAFS2).

2.3 CLEANER AIR FOR SCOTLAND 2 (CAFS2) STRATEGY

CAFS2 sets out how the Scottish Government and its partner organisations propose to further reduce air pollution to protect human health and fulfil Scotland's legal responsibilities over the period 2021-2026. CAFS2 aims to achieve the ambitious vision for Scotland "to have the best air quality in Europe".

The CAFS2 key partner organisations are:

- Scottish Government
- Transport Scotland
- Scottish Environment Protection Agency (SEPA)
- Public Health Scotland
- Local authorities

Engagement and support from a wide range of stakeholders including representatives from the transport and planning sectors and Non-Governmental Organisations is also vital to achieving the aims of CAFS2.

Progress is supported by the CAFS2 Delivery Group, which is directly accountable to a Ministerial Group, and actions are managed by specific sub-groups and policy leads across partner organisations tasked with delivering actions across the 10 overarching policy themes set out in CAFS2.

2.4 CAFS2 – OVERVIEW

The ten general themes largely reflect the high-level recommendations arising from the Cleaner Air for Scotland (CAFS) review. These are:

1. Health – A Precautionary Approach

The current weight of evidence justifies adopting a precautionary public health approach to air pollution reduction. As a minimum, compliance is required with domestic and international air quality standards but, where practicable and feasible, there should be continued efforts to reduce preventable air pollution still further beyond these limits.

2. Integrated Policy

Strategies, policies and plans being developed and implemented by central government for placemaking, climate change mitigation and adaptation, and related polices such as noise reduction, should be closely coordinated and aligned with those for air quality in order to maximise co-benefits.

Local government, which is largely responsible for implementing the Local Air Quality Management system, besides its planning, transport delivery, public health and regulatory roles, also has a key role to play.

3. Placemaking

National Planning Framework 4 (NPF4) will transform how Scotland's planning system shapes our places and society over the years and decades to come. The Planning (Scotland) Act 2019 requires that the National Planning Framework must have regard to minister's national strategy for the improvement of air quality, so it will provide an important context within which further effort on air quality improvement in CAFS 2 will be delivered, supported by the Place Principle and the Place Standard tool.

4. Data

There are gaps in both quality and coverage of air quality, transport and human health data in Scotland. Addressing these gaps will help to improve public awareness and engagement, modelling, reporting and ultimately, policy implementation. A greater focus on collecting and presenting traffic data in a way that supports air pollutant emissions understanding will have similar benefits. Health data also require careful consideration so that Scotland-specific interpretations, plans and interventions are strengthened. Wider utilisation of low-cost sensor technology, including citizen science initiatives, has a role to play too.

5. Public Engagement and Behaviour Change

More research is needed to provide clear evidence on levels of knowledge, attitudes, and concern related to air pollution, as well as on willingness to change behaviours which contribute toward air pollution. Many of the key drivers and incentives/disincentives will be closely related to those associated with climate change, but at the same time there will be differences in focus and approach. Development of complementary and co-ordinated public engagement strategies is therefore essential to deliver the required behavioural change outcomes and to avoid confusing or conflicting messages.

6. Industrial Emissions Regulation

The Scottish Government has made clear its commitment to maintain or exceed EU standards, following the UK's departure from the European Union (EU). The Scottish Government is committed to ensuring that EU environmental principles continue to sit at the heart of environmental policy and law in Scotland. The UK Withdrawal from the European Union (Continuity) (Scotland) Act 2021 will bring the guiding European principles on the environment into force in Scots law, including the precautionary principle, polluter pays principle, prevention principle, rectification at source principle and the integration principle. In relation to current regulation, retained EU law will continue to apply, as will domestic regulations made to transpose EU Directives.

7. Tackling Non-Transport Emission Sources

Domestic (household) burning and agriculture are two sectors not addressed in detail in CAFS, but which make an important contribution to air pollution. Consideration is needed of performance and standards for domestic fires, stoves and fuels, and local authority powers to permit and control these, and a refreshed approach to good agricultural practice, which includes aiming for increased nitrogen use efficiency in farming. Together, these have the potential to deliver significant improvements in air quality beyond current regulatory and management approaches.

8. Transport

Increasing modal shift to active travel and public transport is key to further reductions in transport emissions. This will mean, amongst other objectives, providing a transport system that facilitates active travel choices, better public transport provision, embracing new technologies, and constraints upon private vehicle use, especially in urban centres where pollution and congestion are most acute. Establishment of Low Emission Zones in our four biggest cities is also important in this context.

The new National Transport Strategy (NTS2), published in February 2020, sets out an ambitious and compelling vision for Scotland's transport system for the next 20 years. The four NTS2 priorities – reducing inequalities, taking climate action, helping deliver inclusive economic growth and improving our health and wellbeing – will underpin our efforts to deliver additional air quality improvements in CAFS 2.

The Climate Change Plan update, published in December 2020, will also make a significant contribution to achieving this vision, including the commitment to reduce motor vehicle kilometres by 20% by 2030.

9. Governance, Accountability and Delivery

Simple and effective governance arrangements and a focus on practical joined up delivery are imperative for CAFS 2. We need to be clear on who is doing what, who is leading, who is supporting and who is ultimately responsible if CAFS 2 is to be delivered as a coherent, integrated and successful strategy.

10. Further Progress Review

As in the original version of CAFS, the intention is that CAFS 2 will have a five-year lifespan. A further review of progress on air quality improvements will commence during 2024 to track progress on delivering the actions in the new strategy, besides allowing Scotland to keep abreast of developments in the evidence base, technological advances and societal attitudes, so that new challenges and actions can be identified.

2.5 NATIONAL MODELLING FRAMEWORK

The National Modelling Framework (NMF) will provide a two-tiered standardised approach to modelling air quality in Scotland. Detailed models for the first four cities covering Glasgow, Edinburgh, Aberdeen and Dundee will provide evidence for taking direct actions at the city scale to reduce street-level emissions. The regional model will provide a tool for screening and assessing the potential air quality impacts associated with large-scale planned developments across local authority areas. The NMF will help with providing evidence for actions developed through the National Low Emission Framework.

2.6 NATIONAL LOW EMISSION FRAMEWORK

The National Low Emission Framework (NLEF) has been developed to assist in the appraisal of air quality improvement options related to transport. Together with the National Modelling Framework, it provides guidance on the appraisal of such measures to help facilitate consistent assessment and implementation across Scotland.

The Scottish Government published the NLEF framework in January 2019 and it is available at https://www.scottishairquality.scot/technical-reports/national-low-emissions-framework-january-2019. The framework provides a methodology for local authorities to undertake air quality assessment to inform decisions on transport related actions.

2.7 LOW EMISSION ZONES

In September 2017, the Scottish Government in their Programme for Government, committed to the introduction of Low Emission Zones (LEZs) into Scotland's four biggest cities (Glasgow, Edinburgh, Aberdeen and Dundee) by 2020 and into all other Air Quality Management Areas (AQMAs) by 2023 where the National Low Emissions Framework appraisal advocates such mitigation. On 31st December 2018, the first Scottish LEZ was introduced into Glasgow city centre and applied to buses only (phase 1). After delays resulting from the Covid-19 pandemic LEZs were also introduced across Aberdeen, Dundee, and Edinburgh on 31st May 2022, together with an expansion in scope of the Glasgow LEZ. Local grace periods now apply until enforcement begins at the dates provide

- **Glasgow (all other vehicle types) - 1st June 2023**
- **Dundee – 30th May 2024**
- **Aberdeen – 1st June 2024**
- **Edinburgh – 1st June 2024**

More information on LEZs is available here: https://www.lowemissionzones.scot/about.

2.8 LOCAL AIR QUALITY MANAGEMENT

The LAQM process places an obligation on all local authorities to regularly review and assess air quality in their areas, and to determine whether or not the air quality objectives are likely to be achieved. Where an exceedance is considered likely the local authority must:

- Declare an Air Quality Management Area (AQMA)
- Assess and identify the reasons for the problem, quantifying the sources of emissions
- Develop an Air Quality Action Plan (AQAP) to help address the problem.

The Scottish Government has produced updated Technical Guidance (2022) and Policy Guidance (2016 with further revisions in 2018 and 2023) Guidance for the LAQM regime in Scotland. One of the main changes was to the LAQM reporting process. An Annual Progress Report (APR) has replaced the previous three-year cyclical process. The latest versions of the LAQM Policy and Technical Guidance are available at http://www.scottishairquality.scot/air-quality/legislation.

3 AIR QUALITY SEMINAR

As part of the Scottish Air Quality Database project, Ricardo Energy & Environment, on behalf of the Scottish Government, organise an annual air quality seminar. The event was held online and separated into three two-hour webinars, over a three-week period. Using the Teams Events platform, the event was held on the 15th, 22nd and 29th March 2023 and attended by between 80 - 100 delegates representing the Scottish Government, local authorities, Health Protection Scotland, SEPA, consultancy, academia and students. The objective of the seminar was to discuss some of the most recent work carried out under the Scottish Air Quality Database and Website project and consider a number of other topical air quality issues that affect Scotland.

The seminar covered a number of very interesting topics in the field of air quality presented by highly respected dignitaries. These subjects included amongst others: PN measurement and the Consultation on changing the MOT testing (Ralph Wilce (WUS-AIR)), Asian Development Bank 7 cities project – Clean Air Plan (Jo Green (Ricardo)), Shifting Air Quality Policy Landscape in the UK and EU (Dr Beth Conlan (Ricardo)), Microplastics – Brake and Tyre Wear (Dr Stephanie Wright (ICL)), West Midlands – Air project (Prof Francis Pope (Uni of Birmingham)), UK Aerius pilot project (Dr Jessica Virdo (Ricardo)).

Recordings of all three webinars can be found on the Scottish air Quality website (http://www.scottishairquality.scot/). The full agendas are shown in Figure 3-1.

3.1 ANNUAL NEWSLETTER

In addition to this report, an annual newsletter (Air Pollution in Scotland) is also produced as part of this project. This sets out the legislative and policy background to air quality in Scotland and briefly reviews the latest available air quality monitoring and key results. Trends and mapping of air quality are also summarised along with recent developments and information on how to stay informed with regards to air quality matters (i.e. forecasts, health alerts and social media)

Figure 3-1 Agenda for the Scottish Air Quality Seminar 2023

SCOTTISH AIR QUALITY ANNUAL SEMINAR 2023

Wednesday 15th,22nd, and 29th March 2023 (13:00pm to 15:00pm)

Via MS Teams

Agenda

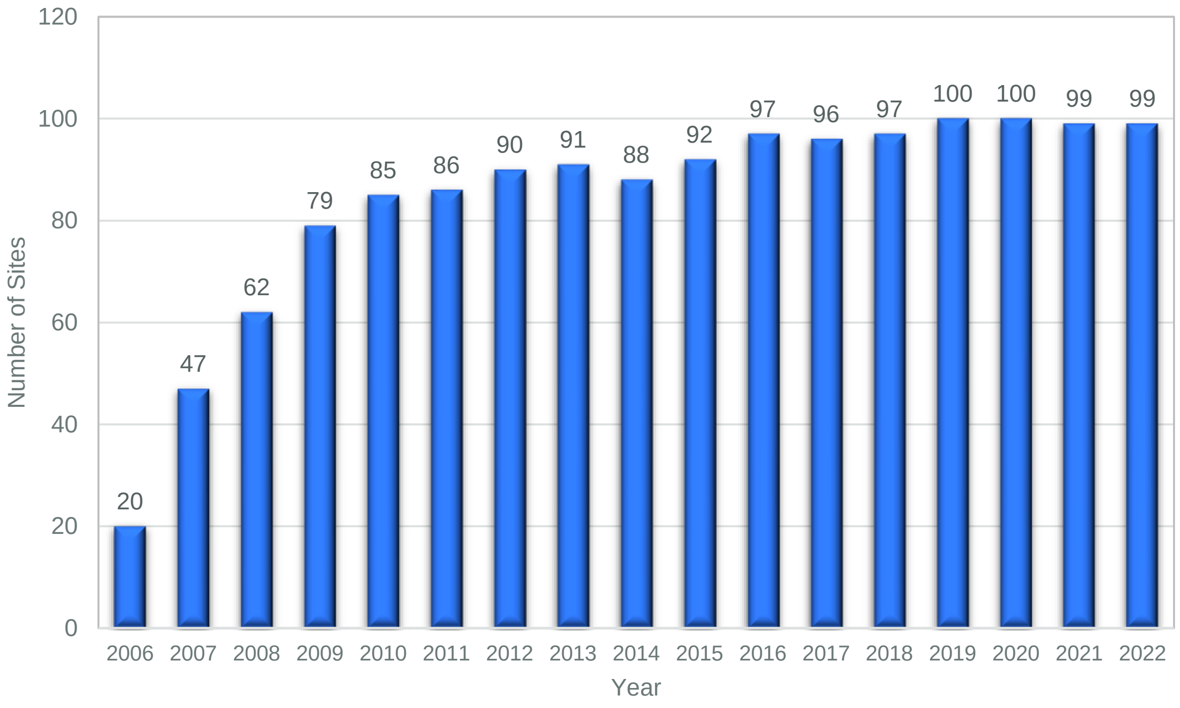
	Webinar 1: Policy	
13:00	Welcome/Introduction	Ricardo Energy and Environment
13:05	CAFS2 and Update from Scottish Government	Andrew Taylor (Scot Gov)
13:15	Implementing Glasgow City Councils LEZ	Dom Callaghan (Glasgow City Council)
13:35	PN measurement and the Consultation on changing the MOT testing	Ralph Wilce (WIJS-AIR)
13:55	Asian Development Bank 7 cities project - Clean Air Action Plans	Jo Green (Ricardo)
14:20	Shifting Air Quality Policy Landscape in the UK and EU	Beth Conlan (Ricardo)
14:50	Questions and Answer Session	
	Webinar 2: Research and Innovation	
13:00	Welcome/Introduction	Ricardo Energy and Environment
13:05	Microplastics - Brake and Tyre wear	Dr Stephanie Wright (Imperial College London)
13:30	West Midlands - Air project	Professor Francis Pope (University Of Birmingham)
13:55	Measuring AQ using Satellites	Matthieu Pommier (Ricardo)
14:20	PM intercomparison and Sensor update	Stephen Stratton (Ricardo)
14:45	Questions and Answer Session	
	Webinar 3: Health and Environmental Impact	
13:00	Welcome/Introduction	Ricardo Energy and Environment
13:05	Hospital admissions on High pollution days	Professor Jill JF Belch (University of Dundee)
13:30	UK AERIUS Pilot Project	Jessica Virdo (Ricardo)
13:55	Relationship between air pollution and Dementia	Dr Ian Mudway (imperial College London)
14:20	Scottish Governments Place Standard Air Quality Tool	Kat Hasler (Scot Gov)
14:45	Questions and Answer Session	

4 DATA AVAILABILITY 2021

4.1 HOURLY DATA FOR NITROGEN DIOXIDE, CARBON MONOXIDE, SULPHUR DIOXIDE, OZONE, PM_{10} AND $PM_{2.5}$

At the end of 2022 the Scottish Air Quality Database contained data for 99 automatic monitoring sites. One new monitoring site was added to the network: North Lanarkshire Ravenscraig Plantation Rd and one site was decommissioned and removed from the network during 2022: North Lanarkshire Coatbridge Whifflet. Figure 4.1 shows the growth of the SAQD from 20 sites in 2006 pilot study to 99 sites during 2022.

Figure 4-1 Number of Monitoring Sites within the Scottish Air Quality Database Network 2006 – 2022



For the 22 National Network AURN monitoring stations in the Scottish Database, the data are available from the commencement of these stations, which in some cases is as long ago as 1986. However, for local authority monitoring stations, data are only available from when the station joined the database project. In many cases the stations commenced monitoring much earlier and these earlier data may be available from the relevant local authority.

Data availability for 2022, in terms of site, pollutants and months available, is summarised in Table 4.1. The full 12-figure OS grid reference and the site location classification ("Type") are also provided for each site and the monitoring network the site is affiliated to; either the Scottish Air Quality Database Network (SAQD) or the Automatic Urban and Rural Network (AURN).Table 4.1 also provides the start date for each site. However, not all pollutants are measured over the same period at all sites – measurements of some pollutants may commence or cease during the lifetime of monitoring at a particular site. The dates of availability of data for each pollutant measured at each site can be found by selecting the site of interest on the 'Latest Data' page of the air Quality in Scotland website (http://www.scottishairquality.scot/latest/) and then selecting the "site details" tab.

In addition, some sites may join a network or change network during their lifetime and hence, earlier data from a site may be available elsewhere. At a small number of sites, different pollutants are in different networks. This is due to the differing requirements of specific networks. The data from closed sites are also available (https://www.scottishairquality.scot/latest/closed-sites) in the database for their period of operation.

Table 4-1 Scottish Air Quality Database Data Availability in 2022

Site Name	Type	East	North	Pollutants	Network	Start Year[#]	Data in 2022
Aberdeen Anderson Dr	RS	392506	804186	NO_2 PM_{10} $PM_{2.5}$	SAQD	2004	Jan – Dec
Aberdeen Errol Park	UB	394366	807396	NO_2 O_3 PM_{10} $PM_{2.5}$	AURN	2021	Jan - Dec
Aberdeen King Street	RS	394333	808770	NO_2 PM_{10} $PM_{2.5}$	SAQD	2008	Jan – Dec
Aberdeen Market Street 2	RS	394535	805687	NO_2 PM_{10} $PM_{2.5}$	SAQD	2009	Jan – Dec
Aberdeen Union St[~]	RS	393655	805984	NO_2 PM_{10} $PM_{2.5}$	AURN / SAQD	2005	Jan – Dec
Aberdeen Wellington Road	RS	394395	804779	NO_2 PM_{10} $PM_{2.5}$	SAQD	2008	Jan – Dec
Alloa A907	RS	288689	693068	NO_2 PM_{10} $PM_{2.5}$	SAQD	2016	Jan – Dec
Angus Forfar Glamis Road	RS	345248	750385	PM_{10}	SAQD	2016	Jan – Dec
Auchencorth Moss	R	322167	656123	13BD BENZ O_3 PM_{10} $PM_{2.5}$ TOL XYL	AURN	2006	Jan – Dec
Bush Estate	R	324626	663880	NO_2 O_3	AURN	1986	Jan – Dec
Dumfries	RS	297012	576278	NO_2	AURN	2001	Jan – Dec
Dundee Broughty Ferry Road	RS	341970	730997	PM_{10} SO_2	SAQD	2006	Jan – Dec
Dundee Lochee Road	KS	330773	738861	NO_2 PM_{10} $PM_{2.5}$	SAQD	2006	Jan – Dec
Dundee Mains Loan	UB	340972	731893	NO_2 PM_{10} $PM_{2.5}$	SAQD / AURN	2006	Jan – Dec
Dundee Meadowside	RS	340241	730654	NO_2 PM_{10} $PM_{2.5}$	SAQD	2011	Jan – Dec
Dundee Seagate	KS	340487	730446	NO_2 PM_{10} $PM_{2.5}$	SAQD	2006	Jan – Dec
Dundee Whitehall Street	KS	330155	740279	NO_2 PM_{10} $PM_{2.5}$	SAQD	2006	Jan – Dec
East Ayrshire Kilmarnock St Marnock St	RS	242742	637705	NO_2 PM_{10} $PM_{2.5}$	SAQD	2012	Jan – Dec
East Dunbartonshire Bearsden	RS	254269	672067	NO_2 PM_{10} $PM_{2.5}$	SAQD	2005	Jan – Dec
East Dunbartonshire Bishopbriggs	RS	260995	670130	NO_2 PM_{10} $PM_{2.5}$	SAQD	2003	Jan – Dec
East Dunbartonshire Kirkintilloch	RS	265700	673500	NO_2 PM_{10} $PM_{2.5}$	SAQD	2007	Jan – Dec
East Dunbartonshire Milngavie	RS	255325	674115	NO_2 PM_{10} $PM_{2.5}$	SAQD	2011	Jan – Dec
East Lothian Musselburgh N High St	RS	333941	672836	NO_2 PM_{10} $PM_{2.5}$	SAQD	2008	Jan – Dec
Edinburgh Currie	UB	317575	667874	NO_2 PM_{10} $PM_{2.5}$	SAQD	2013	Jan – Dec
Edinburgh Glasgow Road	RS	313101	672651	NO_2 PM_{10} $PM_{2.5}$	SAQD	2012	Jan – Dec
Edinburgh Gorgie Road	RS	323121	672314	NO2	SAQD	2005	Jan – Dec
Edinburgh Nicolson Street	RS	326145	673038	NO_2 PM_{10} $PM_{2.5}$	SAQD / AURN	2017	Jan – Dec

Site Name	Type	East	North	Pollutants	Network	Start Year#	Data in 2022
Edinburgh Queensferry Road	RS	318734	674931	NO_2 PM_{10} $PM_{2.5}$	SAQD	2011	Jan – Dec
Edinburgh Salamander St	RS	327621	676342	NO_2 PM_{10} $PM_{2.5}$	SAQD	2009	Jan – Dec
Edinburgh St John's Road	KS	320100	672890	NO_2 PM_{10} $PM_{2.5}$	SAQD	2007	Jan – Dec
Edinburgh St Leonards	UB	326250	673132	CO NO_2 O_3 PM_{10} $PM_{2.5}$ SO_2	AURN	2003	Jan – Dec
Edinburgh Tower Street	RS	327460	676531	PM_{10} $PM_{2.5}$	SAQD	2018	Jan- Dec
Eskdalemuir	R	323552	603018	NO_2 O_3	AURN	1986	Jan – Dec
Falkirk Bo'ness	UI	299827	681462	SO_2	SAQD	2016	Jan – Dec
Falkirk Grangemouth MC	UB	292816	682009	NO_2 PM_{10} $PM_{2.5}$ SO_2	SAQD	2003	Jan – Dec
Falkirk Grangemouth Zetland Park	UI	292969	681106	NO_2 PM_{10} $PM_{2.5}$	SAQD	2016	Jan – Dec
Falkirk Haggs	RS	278977	679271	NO_2 PM_{10} $PM_{2.5}$	SAQD	2009	Jan – Dec
Falkirk Hope St	RS	288688	680218	NO_2 PM_{10} $PM_{2.5}$ SO_2	SAQD	2007	Jan – Dec
Falkirk Main St Bainsford	RS	288569	681519	NO_2 PM_{10} $PM_{2.5}$	SAQD	2015	Jan – Dec
Falkirk West Bridge Street	RS	288457	680064	NO_2 PM_{10} $PM_{2.5}$	SAQD	2007	Jan – Dec
Fife Cupar	RS	337401	714572	NO_2 PM_{10} $PM_{2.5}$	SAQD	2005	Jan – Dec
Fife Dunfermline	RS	309912	687738	NO_2 PM_{10} $PM_{2.5}$	SAQD	2007	Jan – Dec
Fife Kirkcaldy	RS	329143	692986	NO_2 PM_{10} $PM_{2.5}$	SAQD	2011	Jan – Dec
Fife Rosyth	RS	311752	683515	NO_2 PM_{10} $PM_{2.5}$	SAQD	2008	Jan – Dec
Fort William	S	210849	774421	NO_2 O_3	AURN	2006	Jan – Dec
Glasgow Anderston	UB	257925	665487	NO_2 PM_{10} $PM_{2.5}$	SAQD	2005	Jan – Dec
Glasgow Broomhill	RS	255030	667195	PM10 PM2.5	SAQD	2007	Jan – Dec
Glasgow Byres Road	RS	256553	665487	NO_2 PM_{10} $PM_{2.5}$	SAQD	2005	Jan – Dec
Glasgow Dumbarton Road	RS	255030	666608	NO_2 PM_{10} $PM_{2.5}$	SAQD	2012	Jan – Dec
Glasgow Kerbside	KS	258708	665200	NO_2 PM_{10} $PM_{2.5}$	SAQD / AURN	1997	Jan – Dec
Glasgow Great Western Road	RS	258007	666650	NO_2	AURN	2016	Jan – Dec
Glasgow High Street	RS	260014	665348	NO_2 PM_{10} $PM_{2.5}$	AURN	2016	Jan – Dec
Glasgow Nithsdale Road	RS	257883	662673	NO_2 PM_{10} $PM_{2.5}$	SAQD	2007	Jan – Dec
Glasgow Townhead	UB	259692	665899	NO_2 O_3 PM_{10} $PM_{2.5}$	AURN	2013	Jan – Dec
Glasgow Waulkmillglen Reservoir	R	252520	658095	NO_2 O_3 PM_{10} $PM_{2.5}$	SAQD	2005	Jan – Dec
Grangemouth	UI	293837	681035	NO_2 PM_{10} $PM_{2.5}$ SO_2	AURN	2001	Jan – Dec
Grangemouth Moray~	UB	293469	681321	NO_2	AURN	2009	Jan – Dec
Grangemouth Moray Scot Gov~	UB	293469	681321	SO_2	SAQD	2007	Jan – Dec
Inverclyde Greenock A8	RS	229335	675710	NO_2 PM_{10} $PM_{2.5}$	SAQD	2016	Jan – Dec
Inverness	RS	265720	845680	NO_2 PM_{10} $PM_{2.5}$	AURN	2001	Jan – Dec

Site Name	Type	East	North	Pollutants	Network	Start Year#	Data in 2022
Inverness Academy Street	RS	266644	845440	NO_2	SAQD	2016	Jan – Dec
Inverness Academy Street 1st Floor	RS	266644	845440	NO_2	SAQD	2019	Jan – Dec
Lerwick	R	445337	1139683	O_3	AURN	2005	Jan – Dec
N Lanarkshire Airdrie Kenilworth Dr	RS	277385	665831	NO_2 PM_{10}	SAQD	2019	Jan – Dec
N Lanarkshire Chapelhall	RS	278174	663124	NO_2 PM_{10} $PM_{2.5}$	SAQD	2005	Jan – Dec
N Lanarkshire Coatbridge Whifflet	RS	273668	663938	NO_2 PM_{10} $PM_{2.5}$	SAQD	2007	Jan - Feb
N Lanarkshire Coatbridge Whifflet A725	RS	273646.2	663867	NO_2 PM_{10} $PM_{2.5}$	SAQD	2022	Jan-Dec
N Lanarkshire Croy	RS	272775	675738	NO_2 PM_{10} $PM_{2.5}$	SAQD	2006	Jan – Dec
N Lanarkshire Kirkshaws	RS	272522	663029	NO_2 PM_{10} $PM_{2.5}$	SAQD	2016	Jan – Dec
N Lanarkshire Motherwell	RS	275460	656785	PM_{10} $PM_{2.}$	SAQD	2007	Jan – Dec
N Lanarkshire Motherwell Adele Street	RS	275642	656147	NO_2 PM_{10} $PM_{2.5}$	SAQD	2020	Jan – Dec
N Lanarkshire Ravenscraig Plantation Rd	UB	277307.4	657612	NO_2 PM_{10} $PM_{2.5}$	SAQD	2022	Jan – Dec
N Lanarkshire Shawhead Coatbridge	RS	273411	662997	NO_2 PM_{10} $PM_{2.5}$	SAQD	2009	Jan – Dec
N Lanarkshire Uddingston New Edinburgh Rd	RS	269145	661499	NO_2 PM_{10} $PM_{2.5}$	SAQD	2019	Jan – Dec
North Ayrshire Irvine High Street	KS	232142	638892	NO_2 PM_{10} $PM_{2.5}$	SAQD	2009	Jan – Dec
Peebles	S	324812	641083	NO2 O3	AURN	2009	Jan – Dec
Perth Atholl Street	RS	311582	723931	NO_2 PM_{10} $PM_{2.5}$	SAQD	2004	Jan – Dec
Perth Bridgend	RS	312254	724159	NO_2 PM_{10} $PM_{2.5}$	SAQD	2021	Mar – Dec
Perth Crieff	RS	286363	721614	NO_2 PM_{10} $PM_{2.5}$	SAQD	2010	Jan – Dec
Perth Muirton	UB	311688	723625	PM_{10} $PM_{2.}$	SAQD	2012	Jan – Dec
Renfrew Cockels Loan	RS	250467	665943	NO_2	SAQD	2013	Jan – Dec
Renfrew Inchinnan Road	RS	250567	667558	NO_2	SAQD	2019	Jan – Dec
Renfrewshire Johnston	RS	243002	663183	PM_{10} $PM_{2.5}$	SAQD	2017	Jan – Dec
Shetland Lerwick	R	445337	1139683	NO_2 SO_2	SAQD	2012	Jan – Dec
South Ayrshire Ayr Harbour	RS	233617	622749	NO_2 PM_{10} $PM_{2.5}$	SAQD	2012	Jan – Dec
South Ayrshire Ayr High St	RS	233725	622120	NO_2 PM_{10} $PM_{2.5}$	SAQD	2007	Jan – Dec
South Lanarkshire Blantyre	RS	250567	667558	NO_2 PM_{10} $PM_{2.5}$	SAQD	2019	Jan – Dec
South Lanarkshire Cambuslang	KS	264340	660496	NO_2 PM_{10} $PM_{2.5}$	SAQD	2015	Jan – Dec
South Lanarkshire East Kilbride	RS	264390	655658	NO_2 PM_{10} $PM_{2.5}$	SAQD	2008	Jan – Dec

Site Name	Type	East	North	Pollutants	Network	Start Year#	Data in 2022
South Lanarkshire Hamilton	RS	272298	655289	NO_2 PM_{10} $PM_{2.5}$	SAQD	2013	Jan – Dec
South Lanarkshire Lanark	RS	288427	643701	NO_2 PM_{10} $PM_{2.5}$	SAQD	2012	Jan – Dec
South Lanarkshire Raith Interchange 2	RS	271065	658087	NO_2 PM_{10} $PM_{2.5}$	SAQD	2016	Jan – Dec
South Lanarkshire Rutherglen	RS	261113	661690	NO_2 PM_{10} $PM_{2.5}$	SAQD	2012	Jan – Dec
South Lanarkshire Uddingston	RS	269657	660305	NO_2 PM_{10} $PM_{2.5}$	SAQD	2013	Jan – Dec
Stirling Craig's Roundabout	RS	279955	693012	NO_2 PM_{10} $PM_{2.5}$	SAQD	2009	Jan – Dec
Strath Vaich	RS	234829	874785	O_3	AURN	1987	Jan – Dec
West Dunbartonshire Clydebank	RS	249724	672042	NO_2 PM_{10} $PM_{2.5}$	SAQD	2007	Jan – Dec
West Dunbartonshire Glasgow Road	RS	240234	675193	NO_2	AURN	2010	Jan – Dec
West Lothian Broxburn	RS	308364	672248	NO_2 PM_{10} $PM_{2.5}$	SAQD	2008	Jan – Dec
West Lothian Linlithgow High St 2	RS	300419	677120	NO_2 PM_{10} $PM_{2.5}$	SAQD	2013	Jan – Dec
West Lothian Newton	RS	309258	677728	NO_2 PM_{10} $PM_{2.5}$	SAQD	2012	Jan – Dec

+ Sites added to database in 2022
* Sites changed monitoring
^Changes in number of measured pollutants or monitoring method during 2021
This is the date of the site joining the network. Data for some pollutants may not be available from this date. Also, data for some pollutants may be available from earlier dates from the Local Authority other networks. The period of availability for data for each pollutant measured at each site can be seen on www.scottishairquality.scot by selecting the site and the "site details" tab.

KS – Kerbside
R – Rural
RS – Roadside
S – Suburban
UB – Urban Background
UI – Urban Industrial

4.2 SUMMARY OF CHANGES TO MONITORING SITES WITHIN THE DATABASE DURING 2022

Details of changes to monitoring sites included within the SAQD are summarised below:

Sites opened during 2022:

- North Lanarkshire Ravenscraig Plantation Rd NO_2 PM_{10} $PM_{2.5}$ on 27/01/2022

Sites closed during 2022:

- North Lanarkshire Coatbridge Whifflet NO_2 O_3 PM_{10} $PM_{2.5}$ on 08/02/2022

4.3 NO_2 AND PM_{10} DATA CAPTURE RATES

Figures 4-2 and 4-3 show the average data capture rates achieved between 2008 and 2022 for NO_2 and PM_{10} sites, respectively. Note that 2006 and 2007 data capture rates have not been included due to the rapid change in site numbers.

Data capture rates can be used as an indication on how well the network is performing in terms of data quality. With the introduction of a harmonised QA/QC regime, the data capture rates for NO_2 and PM_{10} monitoring improved year on year.

The exception to this is 2021 where a significant drop in NO_2 data capture was recorded. Investigations found that it was due to the the following factors:

- Delays between sites closing and new sites opening.
- An increase in poor NO_2 analyser performance and a delay in replacement parts/analysers (partially due to supply change issues relating to the Covid-19 pandemic).
- Poor site performance (mainly air conditioning failures during summer) causing monitoring to be stopped periodically.

2022 recorded an increase in NO_2 data capture back to 2020 levels. Some temporary site closures due to construction, a site closure in February and poor site performance are issues that affected 2022 data capture result.

The sudden increase in PM_{10} data capture in 2017 and 2019 has been attributed to the change in analyser type measuring Particulate Matter (PM) at a significant number of local authority sites. Likewise, a number of new PM sites were introduced, and analysers decommissioned partially through 2018 resulting in a decrease in the average data capture rate. The drop in PM_{10} data capture in 2020 and 2021 has been attributed to the issues mentioned above relating to NO_2 data capture .

Figure 4-2 Network data capture rate for NO_2 monitoring, 2008 – 2022

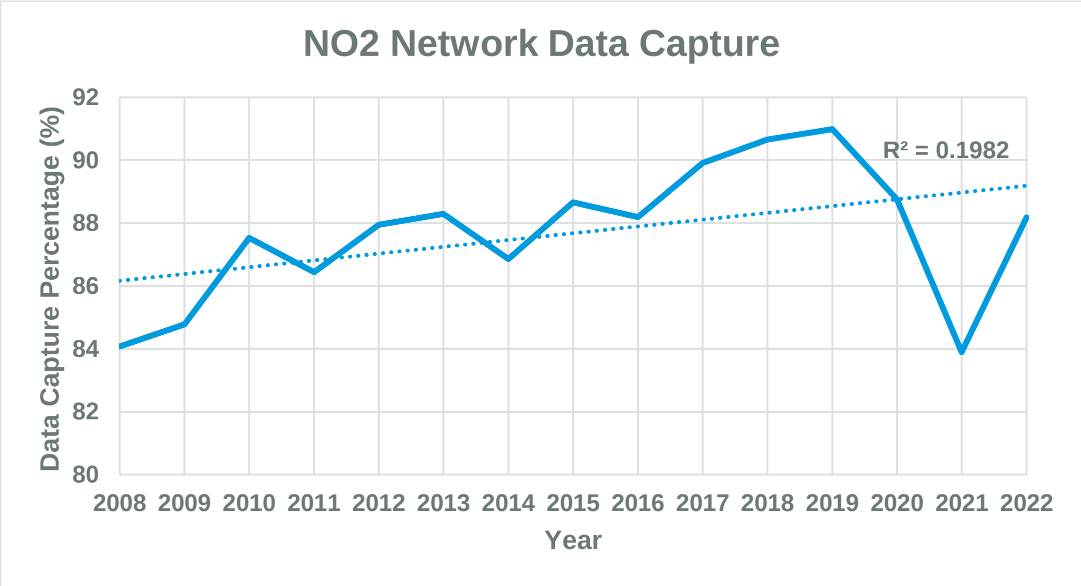
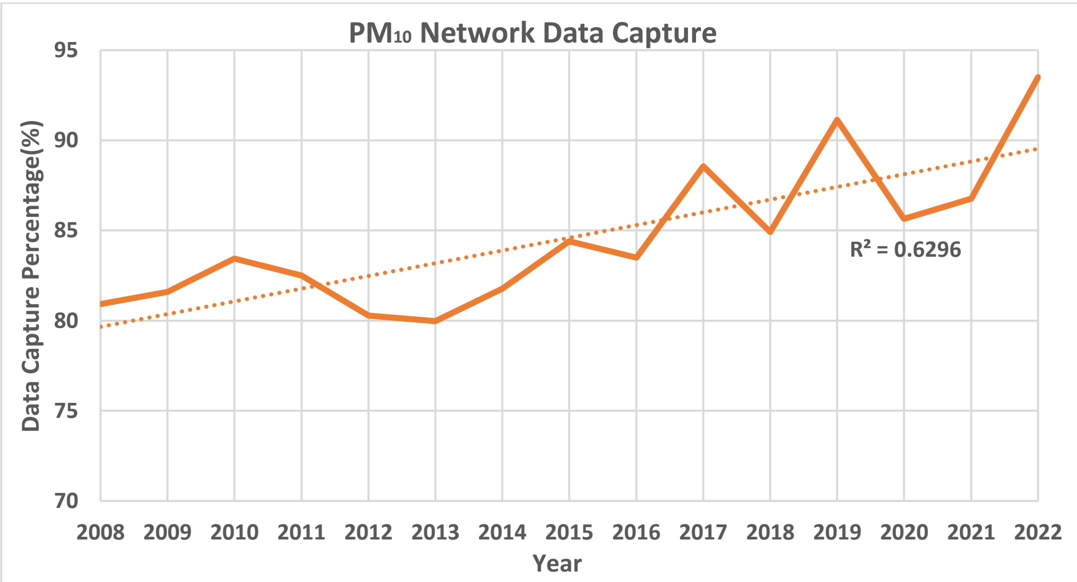


Figure 4-3 Network data capture rate for PM_{10} monitoring, 2008 – 2022



5 QA/QC OF THE SCOTTISH DATABASE

In order that all data within the Scottish Air Quality Database are harmonised to the same quality standard, the QA/QC procedures adopted within the UK Automatic and Rural Network (AURN) are provided for all Local Authority sites within the database.

The main elements of the QA/QC programme are sites six-monthly audits (which incudes on-site analyser testing and calibration gas inter-calibrations), daily automatic data collection and validation and data ratification in three-monthly blocks.

5.1 ON-SITE ANALYSER AND CALIBRATION GAS AUDITS

The automatic air quality monitoring stations located throughout Scotland employ a wide variety of different analyser types and site infrastructure. Intercalibration of the stations provides essential input to the data management process, to ensure that data across Scotland are harmonised, consistent in quality and traceable to a recognised gas calibration standard.

Monitoring station audits evaluate analysers to obtain an assessment of their performance level on the date of test. This information, in conjunction with the full analyser data set and additional calibration and service records, helps ensure data quality specifications have been met during the preceding data period.

During the audit, the site sampling and calibration systems are assessed and tested to ensure there integrity.

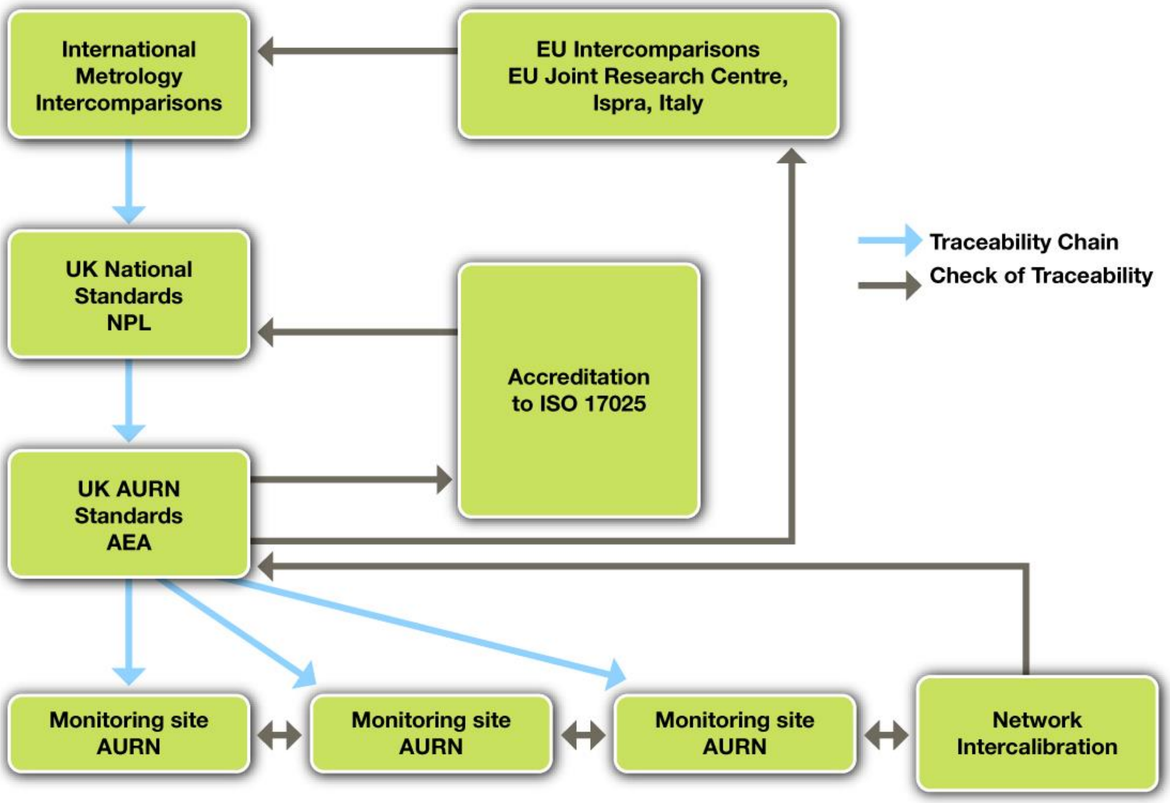
The assessment of the on-site calibration cylinder concentrations against accredited and traceable Ricardo Energy & Environment (Ricardo) gas standard cylinders provides the essential final link in the measurement traceability chain (Figure 5-1). This process ensures that all monitoring stations in Scotland are traceable to reference gas standards held at Ricardo. These in turn are traceable to UK national reference standard gases held by the National Physical Laboratory who, in turn regularly inter-compare these standards internationally. Ricardo also participates in EU level inter-comparisons at the EU Joint Research Centre. Hence, there is an unbroken traceability chain from each monitoring site in Scotland to internationally agreed gas calibration standards. This check also enables the identification of any unstable or erroneous gas cylinders which may need to be recertified or discarded.

The aims and objectives of the audit and intercalibration exercise can be summarised as follows:

- Ensure the correct operation of analysers and sampling systems at each monitoring station.
- Ensure harmonisation of data throughout the network (i.e., that a NO_X analyser at one station measuring 40 $\mu g\ m^{-3}$ of NO_2 would also measure 40 $\mu g\ m^{-3}$ of NO_2 at any other site).
- Ensure traceability of all stations in the network to national and international standards.
- Provide information on any necessary adjustments to data into the ratification process.
- Report any faults found to the site operator.

Detailed audit procedures are provided in Appendix 2.

Figure 5-1 Traceability chain for the SAQD monitoring stations



5.2 DATA MANAGEMENT

The following sections describe the data management package applied to the data from the Scottish local authority monitoring stations. This is the same data management package, using the same data ratification procedures, that is applied to the AURN network stations across the UK.

The process includes the following tasks:

- Data acquisition
- Data validation
- Ratification

The data acquisition and management system consist of a central computer and telemetry facility that has been developed by Ricardo specifically for the UK's air quality monitoring programmes. The database used in this system is backed-up on a 24-hour basis to independent network servers to ensure data security.

A wide range of data management activities are routinely performed, and these are integrated into the streamlined automatic data management system. Data are retrieved automatically from the Scottish air quality monitoring stations (*data acquisition*). The data are then rapidly processed by applying the latest available calibration factors (*data scaling*) and carefully screened using specifically developed computer algorithms to identify suspect data or equipment faults (*data validation*). These validated data are then appended to the site database and uploaded to the Scottish Database and Website. These operations are carried out automatically by computer systems, with all outputs manually checked by data management experts.

The validated data are then updated to the Scottish Air Quality Database – and accessible via the air quality in Scotland website (https://www.scottishairquality.scot/latest) - as provisional data. These data are therefore available to all users on a day-to-day basis. This gives the local authority the opportunity to easily view both their own data and data from other stations throughout Scotland on a near real time basis. This will assist in dealing with day-to-day requests for information on specific data or the overall pollution situation either locally or throughout Scotland. In addition the automatic data summary bulletin, available by email from the website, plotting package incorporated into this, the AQ Scotland App, and data analysis facilities, are useful to authorities to rapidly evaluate their data against that from other stations and idientify data errors.

5.3 DATA RATIFICATION

The validated data, which have been screened and scaled, are fit for day-to-day use and provide a good indication of pollution levels. However, the final stage of data management is a comprehensive and detailed critical review of the data and is generally termed 'ratification'. Note that ratification necessarily includes the results from the site audits and inter-calibrations – ratified data must be shown to be traceable to national gas standards.

The aim of data ratification is to make use of all of the available information to identify and remove any faulty data, ensuring that remaining measurement data meet the accuracy and precision specifications of the Scottish Government for local authority review and assessment (LAQM.TG(22)).

The policy on data rejection opted by Ricardo is that all data are assumed to be correct unless there is good evidence to suggest otherwise. This prevents the ratification process from erroneously removing any important air pollution episode data. The ratification process is comprehensive and is outlined step-by-step in Appendix 2.

Data ratification of the Scottish local authority station data is undertaken on a three-monthly basis, based on calendar year timetables (January through to December). The process of ratification can take up to six weeks - we therefore aim to have the finalised datasets from all network sites ready by 31st March of the following year. This fits in with the timetable for local authority reporting under the LAQM review and assessment process.

The ratified data are uploaded to the Scottish Database and overwrite the provisional data. Summary statistics (i.e. https://www.scottishairquality.scot/latest/site-info/PET2) and annual statistic reports (https://www.scottishairquality.scot/laqm/statistics) of these ratified data are available from the website to assist local authorities complete their LAQM review and assessment reports. The data selector function on the website (https://www.scottishairquality.scot/data/data-selector) also provides all the relevant datasets and statistics required.

5.4 QA/QC DURING 2022

As discussed above, site inter-calibrations and audit visits are undertaken at 6-monthly intervals. However, where a site joins the database part way through a year then it is possible that only one audit will be conducted during the year. Appendix 2 shows the full list of inter-calibrations and audits undertaken on air quality sites in the Scottish Database during 2022.

The majority of analysers and sites were found to be operating satisfactorily during the audits. However, inevitably some problems were identified at some sites, these are summarised in Table 5.1.

Table 5-1 Monitoring site faults identified during the 2022 audits

Site Faults Identified 2022	Number of Monitoring Sites Winter 2021/22	Number of Monitoring Sites Summer 2022
Particulate Analyser* flow out by >10%	10	8
NO_x analyser converter <97% efficiency	7	11
NO cylinder out by >10%	5	4
SO_2 cylinder out by >10%	2	0
CO cylinder out by >10%	0	0
O3 Analyser out by >5%	0	0

* These include TEOM, FDMS, FIDAS and Beta Attenuation Monitors (BAM)

These are all typical faults that are found during audit and intercalibration exercises and as can be seen from the 2022 figures.

In many cases, the results from the audit and intercalibration visits provide the information necessary to correct for these issues at the data ratification stage so that the data can be corrected and retained, rather than being deleted as erroneous data. Appendix 2 summarises the site inter-calibrations and audits undertaken during 2022, where the period Winter 2021/22 corresponds to Dec-2021 to Mar-2022 and Summer 2022 corresponds to Jun-2022 to Aug-2022.

5.4.1 Data Ratification

Data ratification is carried out in three-monthly intervals in line with the AURN schedule. Hence, as with the inter-calibrations and site audits, if the site joins the database part way through a year, then data can only be ratified from the date of the site joining the database.

All ratified data for 2022 has been uploaded to the Scottish Air Quality website. A summary of all the data ratification undertaken during 2022 is provided in Appendix 2.

6 AIR POLLUTION IN SCOTLAND IN 2022

In this section we present a statistical summary of the available air quality data for Scotland as follows:

- Section 6.1 - Automatic monitoring of the pollutants NO_2, PM_{10}, $PM_{2.5}$ CO, SO_2 and O_3 summary data for 2022.
- Section 6.2 - Other pollutants covered by the Air Quality Strategy – PAH (benzo[a]pyrene), Benzene, 1,3-butadiene and lead and summary statistics for 2022.
- Section 6.3 - Other pollutants and/or other methods of monitoring:
  1. NO_2 Diffusion Tube Samplers
  2. Non-methane Volatile Organic Compounds (NMVOC)
  3. Poly-aromatic Hydrocarbons (PAH)
  4. Toxic Organic Micropollutants (TOMPS)
  5. Metals (Urban network)
  6. Metals (Rural and deposition network)
  7. United Kingdom Eutrophying & Acidifying Pollutants Network:
     i. The Precipitation Network
     ii. NO_2 Rural Diffusion Tube Network
     iii. Acid Gases and Aerosol Network (AGANET)
     iv. National Ammonia Monitoring Network

6.1 AUTOMATIC MONITORING OF POLLUTANTS NO_2, PM_{10}, $PM_{2.5}$, CO, SO_2 AND O_3

Table 6-1 to Table 6-7 show the 2022 annual average data statistics for NO_2, PM_{10}, $PM_{2.5}$, CO, SO_2 and O_3 for the ratified automatic data from monitoring sites included in the SAQD. These are shown along with the corresponding data capture for the year.

These data will have been used by local authorities to assess air quality within their area as part of the review and assessment process. Where any of the air quality objectives for Scotland have been exceeded, at locations where there is relevant exposure of the general public, then the authority will need to carry out a more detailed assessment as an addendum to their Annual Progress Report to confirm the exceedance and estimate its extent. Where the exceedance is confirmed then the authority will declare an Air Quality Management Area (AQMA). At the time of writing, 14 local authorities in Scotland have declared a total of 34 AQMAs (see https://www.scottishairquality.scot/laqm/aqma). Based on the data in the database, a summary of the air quality situation throughout Scotland is provided in the following sections for each separate pollutant.

6.1.1 Nitrogen Dioxide

Table 6-1 shows nitrogen dioxide data for 89 sites utilising automatic monitoring during 2022. Although, data for 16 of these are only available for part of the year with the overall data capture less than 75%. These include sites which opened or closed during the year and sites which were closed for part of the year due to instrument problems.

Of the remaining 73 sites with 75% data capture or more, none of the sites exceeded the annual mean objective for NO_2 (40 µg m^{-3}). The objective of not more than 18 exceedances of 200 µg m^{-3} for the hourly mean was also not exceeded at any site.

The highest annual average concentrations were measured at Glasgow Kerbside (Hope Street), with a measured concentration of 39.1 µg m^{-3}. There were no exceedances of the hourly mean objective at any site.

Table 6-1 Ratified data annual average concentration and data capture for NO_2 in 2022 for monitoring sites in the SAQD

Site Name	Type	Annual Average NO_2 2022 ($\mu g\ m^{-3}$)	No. hours >200 $\mu g\ m^{-3}$	Data capture NO_2 2022 (%)
Aberdeen Anderson Dr	RS	11.6	0	95.5
Aberdeen Erroll Park	UB	16.5	0	99.5
Aberdeen King Street	RS	15.5	0	95.9
Aberdeen Market Street 2	RS	23.4	0	99.7
Aberdeen Union Street Roadside	RS	26.6	0	99.4
Aberdeen Wellington Road	RS	24.5	0	99.7
Alloa A907	RS	15.8	0	99.0
Bush Estate	RB	3.8	0	99.6
Dumfries	RS	21.2	0	95.5
Dundee Broughty Ferry Road	RS	11.2	0	99.7
Dundee Lochee Road	RS	29.0	0	99.8
Dundee Mains Loan	UB	9.1	0	52.8
Dundee Meadowside	RS	26.1	0	99.5
Dundee Seagate	RS	26.5	0	90.3
Dundee Whitehall Street	RS	20.1	0	99.8
E Ayrshire Kilmarnock St Marnock St	RS	19.2	0	99.8
East Dunbartonshire Bearsden	RS	21.9	0	94.4
East Dunbartonshire Bishopbriggs	RS	16.2	0	72.9
East Dunbartonshire Kirkintilloch	RS	18.2	0	99.0
East Dunbartonshire Milngavie	RS	14.3	0	74.2
East Lothian Musselburgh N High St	RS	14.4	0	96.4
Edinburgh Currie	UB	4.8	0	98.9
Edinburgh Glasgow Road	RS	15.1	0	68.3
Edinburgh Gorgie Road	RS	17.4	0	83.5
Edinburgh Nicolson Street	RS	23.8	0	99.7
Edinburgh Queensferry Road	RS	25.9	0	98.1
Edinburgh Salamander St	RS	17.8	0	95.5
Edinburgh St John's Road	RS	29.2	0	99.7
Edinburgh St Leonards	UB	13.0	0	97.8
Falkirk Grangemouth MC	UB	14.0	0	85.9
Falkirk Haggs	RS	18.5	0	86.7
Falkirk Hope St	RS	14.3	0	95.1
Falkirk Main St Bainsford	RS	19.4	0	88.6
Falkirk West Bridge Street	RS	27.0	0	99.7
Fife Cupar	RS	17.7	0	98.0
Fife Dunfermline	RS	14.7	0	98.4
Fife Kirkcaldy	RS	12.5	0	99.9

Site Name	Type	Annual Average NO_2 2022 ($\mu g\ m^{-3}$)	No. hours >200 $\mu g\ m^{-3}$	Data capture NO_2 2022 (%)
Fife Rosyth	RS	17.9	0	94.8
Fort William	S	7.0	0	98.2
Glasgow Anderston	UB	21.6	0	99.0
Glasgow Byres Road	RS	25.3	0	99.7
Glasgow Dumbarton Road	RS	24.4	0	81.9
Glasgow Great Western Road	RS	19.8	0	95.5
Glasgow High Street	RS	20.9	0	94.6
Glasgow Kerbside	RS	39.1	0	99.3
Glasgow Nithsdale Road	RS	22.1	0	99.7
Glasgow Townhead	UB	16.8	0	99.1
Glasgow Waulkmillglen Reservoir	RB	10.8	0	28.5
Grangemouth	UI	14.9	0	62.1
Grangemouth Moray	UB	12.3	0	99.2
Inverclyde Greenock A8	RS	21.3	0	79.1
Inverness	RS	13.4	0	95.0
Inverness Academy Street	RS	28.9	0	56.9
Inverness Academy Street 1st Floor	RS	24.3	0	39.6
Lerwick	RB	2.3	0	84.5
N Lanarkshire Airdrie Kenilworth Dr	RS	12.2	0	99.9
N Lanarkshire Chapelhall	RS	13.8	0	99.6
N Lanarkshire Coatbridge Whifflet	UB	14.5	0	2.8
N Lanarkshire Coatbridge Whifflet A725	RS	17.2	0	83.2
N Lanarkshire Croy	RS	9.6	0	99.5
N Lanarkshire Kirkshaws	RS	13.0	0	99.9
N Lanarkshire Motherwell	RS	10.3	0	88.9
N Lanarkshire Motherwell Adele St.	RS	13.2	0	44.0
N Lanarkshire Shawhead Coatbridge	RS	5.9	0	73.6
N Lanarkshire Uddingston New Edinburgh Rd	RS	13.5	0	99.6
North Ayrshire Irvine High St	RS	15.1	0	99.6
Paisley Gordon Street	RS	10.5	0	95.9
Peebles	S	4.8	0	99.3
Perth Atholl Street	RS	29.9	0	99.7
Perth Bridgend	RS	18.2	0	99.3
Perth Crieff	RS	12.3	0	97.3
Renfrew Cockels Loan	RS	22.4	0	99.7
Renfrew Inchinnan Road	RS	19.7	0	98.2
South Ayrshire Ayr Harbour	RS	8.6	0	34.5
South Ayrshire Ayr High St	RS	10.3	0	58.6

Site Name	Type	Annual Average NO_2 2022 (µg m^{-3})	No. hours >200 µg m^{-3}	Data capture NO_2 2022 (%)
South Lanarkshire Blantyre	RS	18.7	0	99.7
South Lanarkshire Cambuslang	RS	25.6	0	39.6
South Lanarkshire East Kilbride	RS	22.0	0	82.4
South Lanarkshire Hamilton	RS	23.2	0	73.4
South Lanarkshire Lanark	RS	14.5	0	99.5
South Lanarkshire Raith Interchange 2	RS	14.0	0	98.4
South Lanarkshire Rutherglen	RS	22.5	0	98.3
South Lanarkshire Uddingston	RS	17.7	0	94.4
Stirling Craig's Roundabout	RS	15.1	0	90.0
West Dunbartonshire Clydebank	RS	17.6	0	98.5
West Dunbartonshire Glasgow Road	RS	12.1	0	99.7
West Lothian Broxburn	RS	21.4	0	94.4
West Lothian Linlithgow High Street 2	RS	17.3	0	95.7
West Lothian Newton	RS	12.2	0	48.0

Shaded sites indicate data only available for part year and/or <75% data capture

Highlighted figures (in yellow) indicate exceedances of Scottish Air Quality Objectives

6.1.1.1 NO_2 Diffusion Tube data 2022

The NO_2 diffusion tube database and map were released on the Air Quality in Scotland website in June 2019. The map provides bias corrected annual mean data previously published in local authority annual progress reports. The database and map bring together local authority diffusion tube monitoring for each year, enabling the user to easily identify where monitoring has been carried out, what the concentrations are for the current year and compare it against historical data, and identify which sites have exceeded the annual mean objective of 40 µg m^{-3}.

In 2022, seven diffusion tube sites exceeded the annual mean objective for NO_2, three more than in 2021. Table 6-2 provides a list of the exceeding sites along with local authority they are located within. Figure 6-1 provides data on the number exceeding NO_2 diffusion tube sites compared to the number of monitoring locations going back to 2013. As you can see the number of exceeding sites have dropped significantly since 2019.

It should be noted that it is the responsibility of the local authority to provide the Scottish Government with the data to be included in the map. Therefore, it could be the case that diffusion tube monitoring taken place during 2022 or any other year is not represented in the database. To identify if this is the case, please refer to the local authority's annual progress report for the year in question.

For more information on the 2021 data and historical diffusion tube data, go the Diffusion Tube site map on the Air Quality in Scotland website (http://www.scottishairquality.scot/latest/diffusion-sites). The diffusion tube data can also now be downloaded via the data selector tool (http://www.scottishairquality.scot/data/data-selector).

Figure 6-1 Number of NO_2 diffusion tube sites exceeding the Annual Mean Objective since 2013

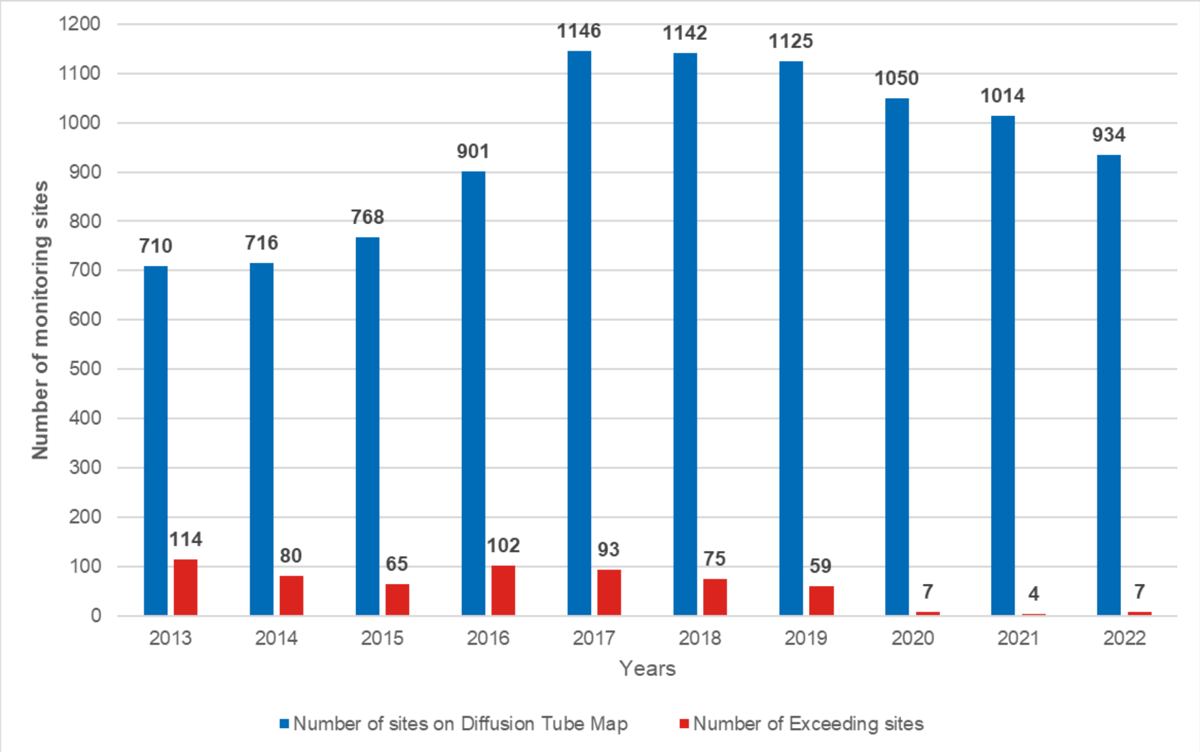


Table 6-2 NO_2 diffusion tube sites exceeding the Annual Mean Objective in 2022

Site Name	Annual Mean Concentration ($\mu g\ m^{-3}$)	Local Authority Name
6 Bridge Street	48	Aberdeen City
19 Bridge Street	48	Aberdeen City
Queensferry Road 550	41	City of Edinburgh
Hope Street 1	45	Glasgow City
Hope Street 3	40	Glasgow City
Gordon Street	50	Glasgow City
Heilanman Umbrella 39	42	Glasgow City

(Data sourced from http://www.scottishairquality.scot/latest)

6.1.2 Particulate Matter – PM_{10}

Table 6-3 shows the 2022 PM_{10} data and gravimetric equivalent from 83 sites utilising automatic monitoring. Of these sites, seven have less than 75% data capture. Also provided in Table 6-3 is the SAQD specific FIDAS corrected data which is used for LAQM reporting in Scotland. This data has a correction factor (divided by 0.909) applied as recommended in a guidance note issed by the Scottish Government[1].

Of the 76 sites with 75% or greater data capture, no sites exceeded the annual average PM_{10} objective of 18 $\mu g\ m^{-3}$. The maximum PM_{10} annual mean concentration was measured at Perth Atholl St with a measured annual mean concentration of 15.9 $\mu g\ m^{-3}$. The daily mean objective of 50 $\mu g\ m^{-3}$ not to be

[1] https://www.scottishairquality.scot/technical-reports/local-authority-guidance-note-laqm-reporting-scottish-pm-data

exceeded more than seven times in a year was exceeded at one site, Edinburgh St John's Road. The exceedances occurred during August and September. Preliminary investigations carried out during the data ratification process found that the exceedances were due to road resurfacing works being carried out near to the site.

Table 6-3 Ratified data annual average concentration and data capture for PM_{10} in 2022 for monitoring sites in the Scottish Air Quality Database

Site Name	Type	PM_{10} Analyser Type*	Annual Average 2022 (µg m^{-3})	FIDAS annual mean corrected. 2022 (µg m^{-3})	No. Days > 50 µg m^{-3}	Data Capture (%)
Aberdeen Anderson Dr	RS	Fidas	10.1	11.1	1	92.6
Aberdeen Erroll Park	UB	Fidas	11.3	12.4	2	100.0
Aberdeen King Street	RS	Fidas	13.0	14.3	3	96.8
Aberdeen Market Street 2	RS	Fidas	12.7	14	4	99.5
Aberdeen Union Street Roadside	RS	Fidas	13.0	14.3	3	99.8
Aberdeen Wellington Road	RS	Fidas	10.6	11.6	0	56.7
Alloa A907	RS	Fidas	10.4	11.4	2	89.3
Angus Forfar Glamis Rd	RS	Fidas	9.8	10.7	2	98.4
Auchencorth Moss	RB	Fidas	6.2	6.9	0	99.7
Dundee Broughty Ferry Road	RS	Fidas	11.8	13	5	94.7
Dundee Lochee Road	RS	Fidas	12.5	13.7	4	99.7
Dundee Mains Loan	UB	Fidas	8.9	9.8	2	99.1
Dundee Meadowside	RS	Fidas	12.0	13.2	5	99.2
Dundee Seagate	RS	Fidas	13.6	14.9	4	99.7
Dundee Whitehall Street	RS	Fidas	10.2	11.2	2	99.7
E Ayrshire Kilmarnock St Marnock St	RS	Fidas	10.4	11.4	0	98.4
East Dunbartonshire Bearsden	RS	Fidas	10.0	11	2	99.7
East Dunbartonshire Bishopbriggs	RS	Fidas	11.4	12.6	3	94.6
East Dunbartonshire Kirkintilloch	RS	Fidas	10.6	11.6	4	99.1
East Dunbartonshire Milngavie	RS	Fidas	9.0	9	0	89.7
East Lothian Musselburgh N High St	RS	BAM	12.7		1	78.6
Edinburgh Currie	RS	Fidas	8.6	9.4	2	99.9
Edinburgh Glasgow Road	RS	Fidas	11.8	13	2	99.9

Site Name	Type	PM_{10} Analyser Type*	Annual Average 2022 (µg m^{-3})	FIDAS annual mean corrected. 2022 (µg m^{-3})	No. Days > 50 µg m^{-3}	Data Capture (%)
Edinburgh Nicolson Street	RS	Fidas	12.1	13.3	2	97.8
Edinburgh Queensferry Road	RS	Fidas	13.1	14.4	3	88.4
Edinburgh Salamander St	UB	Fidas	14.3	15.7	5	98.9
Edinburgh St John's Road	UB	Fidas	14.3	15.7	**12**	99.9
Edinburgh St Leonards	RS	Fidas	9.2	10.1	1	99.3
Edinburgh Tower Street	RS	Fidas	10.0	11	1	100.0
Falkirk Grangemouth MC	UB	Fidas	9.8	10.8	2	100.0
Falkirk Grangemouth Zetland Park	UI	Fidas	9.1	10	2	96.6
Falkirk Haggs	RS	Fidas	11.0	12.1	3	97.2
Falkirk Hope St	RS	Fidas	9.3	10.2	1	97.5
Falkirk Main St Bainsford	RS	Fidas	11.2	12.3	3	92.4
Falkirk West Bridge Street	RS	Fidas	9.6	10.6	1	99.0
Fife Cupar	RS	Fidas	14.3	15.7	4	99.6
Fife Dunfermline	RS	Fidas	11.5	12.7	2	99.7
Fife Kirkcaldy	RS	Fidas	10.7	11.8	2	99.8
Fife Rosyth	RS	Fidas	10.6	11.7	4	99.7
Glasgow Anderston	UB	Fidas	12.0	13.2	2	98.1
Glasgow Broomhill	RS	Fidas	10.6	11.7	1	99.9
Glasgow Byres Road	RS	Fidas	11.4	12.5	2	79.6
Glasgow Dumbarton Road	RS	Fidas	12.9	14.1	2	70.8
Glasgow High Street	RS	Fidas	10.9	12	1	99.7
Glasgow Kerbside	RS	Fidas	12.5	13.8	2	99.8
Glasgow Nithsdale Road	RS	Fidas	10.9	12	0	99.7
Glasgow Townhead	UB	Fidas	10.3	11.3	2	99.4
Glasgow Waulkmillglen Reservoir	RB	Fidas	8.2	9	0	96.1
Grangemouth	UI	BAM (heated)	10.3		1	96.4
Inverclyde Greenock A8	RS	Fidas	11.7	12.9	4	94.4
Inverness	RS	Fidas	8.6	9.4	0	98.6
N Lanarkshire Airdrie Kenilworth Dr	RS	BAM	10.9		0	65.3
N Lanarkshire Chapelhall	RS	Fidas	9.9	10.9	0	99.9

Site Name	Type	PM_{10} Analyser Type*	Annual Average 2022 (µg m^{-3})	FIDAS annual mean corrected. 2022 (µg m^{-3})	No. Days > 50 µg m^{-3}	Data Capture (%)
N Lanarkshire Coatbridge Whifflet	RS	Fidas	9.4	10.4	0	10.4
N Lanarkshire Coatbridge Whifflet A725	RS	Fidas	10.2	11.3	0	99.6
N Lanarkshire Croy	RS	Fidas	10.6	11.7	2	99.9
N Lanarkshire Kirkshaws	RS	Fidas	9.8	10.7	0	99.9
N Lanarkshire Motherwell	RS	Fidas	10.0	11	0	86.9
N Lanarkshire Motherwell Adele St.	RS	Fidas	7.7	8.5	0	81.6
N Lanarkshire Ravenscraig Plantation Road	RS	Fidas	8.3	9.1	0	89.4
N Lanarkshire Shawhead Coatbridge	RS	Fidas	9.4	10.4	0	99.9
N Lanarkshire Uddingston New Edinburgh Rd	RS	Fidas	10.7	11.8	0	99.0
North Ayrshire Irvine High St	RS	Fidas	12.5	13.8	1	98.1
Perth Atholl Street	RS	Fidas	15.9	17.5	7	96.9
Perth Bridgend	RS	Fidas	9.7	10.7	1	98.8
Perth Crieff	RS	Fidas	9.7	10.6	0	95.3
Perth Muirton	RS	Fidas	9.6	10.5	1	100.0
Renfrewshire Johnstone	RS	Fidas	12.9	14.2	4	82.3
South Ayrshire Ayr Harbour	RS	Fidas	12.5	13.8	1	79.3
South Ayrshire Ayr High St	RS	Fidas	15.2	16.7	7	89.8
South Lanarkshire Blantyre	RS	Fidas	10.7	11.7	0	99.7
South Lanarkshire Cambuslang	RS	Fidas	11.4	12.5	2	99.8
South Lanarkshire East Kilbride	RS	Fidas	10.1	11.1	0	99.3
South Lanarkshire Hamilton	RS	Fidas	10.4	11.4	0	85.4
South Lanarkshire Lanark	RS	Fidas	10.1	11.1	1	99.9
South Lanarkshire Raith Interchange 2	RS	Fidas	9.5	10.4	0	98.4
South Lanarkshire Rutherglen	RS	Fidas	11.8	12.9	2	98.6
South Lanarkshire Uddingston	RS	Fidas	9.5	10.5	0	60.7
Stirling Craig's Roundabout	RS	Fidas	9.7	10.7	1	85.7
West Dunbartonshire Clydebank	RS	Fidas	10.3	11.3	1	99.8

Site Name	Type	PM_{10} Analyser Type*	Annual Average 2022 (µg m^{-3})	FIDAS annual mean corrected. 2022 (µg m^{-3})	No. Days > 50 µg m^{-3}	Data Capture (%)
West Lothian Broxburn	RS	Fidas	11.9	13.1	1	91.1
West Lothian Linlithgow High Street 2	RS	Fidas	11.9	12.6	0	43.0
West Lothian Newton	RS	Fidas	8.5	9.3	0	39.9

Shaded sites indicate data only available for part year and/or <75% data capture
Highlighted figures (in yellow) indicate exceedance of a Scottish Air Quality Objectives

6.1.3 Particulate Matter – $PM_{2.5}$

Table 6-4 shows the 2022 $PM_{2.5}$ data and gravimetric equivalent from 82 sites utilising automatic monitoring. Data capture rates of less than 75% were measured at seven sites. Also provided in Table 6-4 is the SAQD specific FIDAS corrected data which is used for LAQM reporting in Scotland. This data has a correction factor (multiplied by 1.06) applied as recommended in a guidance note issed by Scottish Government[2].

Of the 75 sites with with more than 75% data capture none exceeded the annual mean objective of 10 µg m^{-3}. The highest concentrations (7.8µg m^{-3}) measured during 2022 were at Grangemouth and Fife Cupar (taking into consideration the FIDAS correction factor).

Figure 6-2 illustrated the 2022 annual mean $PM_{2.5}$ and PM_{10} concentrations for all SAQD monitoring sites compared against their respective annual mean objectives.

Table 6-4 Ratified data annual average concentration and data capture for $PM_{2.5}$ in 2022 for monitoring sites in the Scottish Air Quality Database

Site Name	Type	$PM_{2.5}$ Analyser Type	Annual Average $PM_{2.5}$ 2022 (µg m^{-3})	FIDAS annual mean corrected. 2022 (µg m^{-3})	Data Capture (%)
Aberdeen Anderson Dr	RS	Fidas	5.6	6	92.6
Aberdeen Erroll Park	UB	Fidas	6.0	6.3	100.0
Aberdeen King Street	RS	Fidas	6.5	6.9	96.8
Aberdeen Market Street 2	RS	Fidas	6.4	6.8	99.5
Aberdeen Union Street Roadside	RS	Fidas	7.1	7.5	99.8
Aberdeen Wellington Road	RS	Fidas	5.2	5.5	56.7
Alloa A907	RS	Fidas	5.8	6.1	89.3
Angus Forfar Glamis Rd	RS	Fidas	5.4	5.8	98.4
Auchencorth Moss	RB	Fidas	3.8	4.1	99.7
Dundee Broughty Ferry Road	RS	Fidas	6.0	6.4	94.7
Dundee Lochee Road	RS	Fidas	6.5	6.9	99.7
Dundee Mains Loan	UB	Fidas	5.2	5.5	99.1
Dundee Meadowside	RS	Fidas	5.8	6.2	99.2
Dundee Seagate	RS	Fidas	6.7	7.1	99.7
Dundee Whitehall Street	RS	Fidas	5.7	6.1	99.7

[2] https://www.scottishairquality.scot/technical-reports/local-authority-guidance-note-laqm-reporting-scottish-pm-data

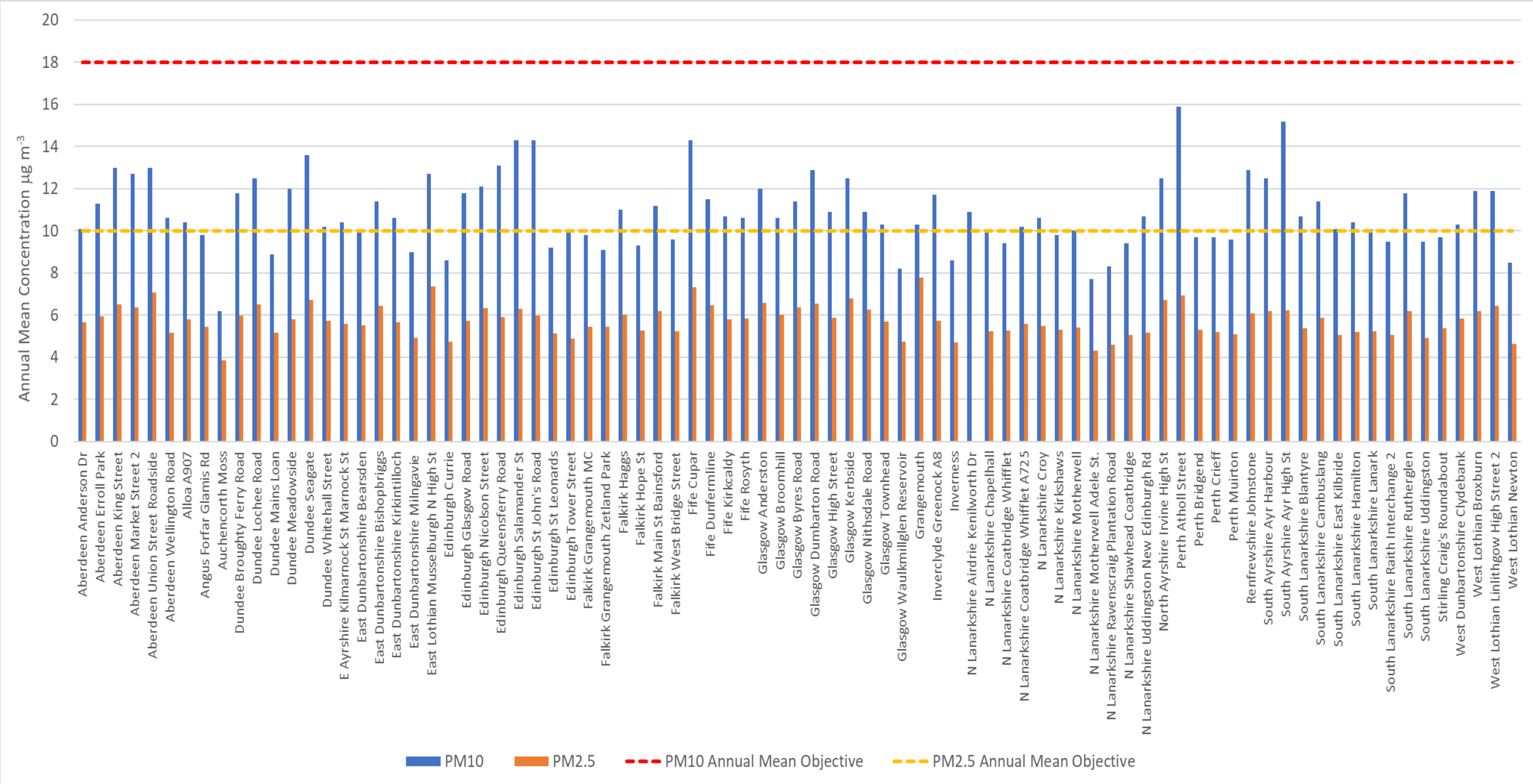
Site Name	Type	$PM_{2.5}$ Analyser Type	Annual Average $PM_{2.5}$ 2022 ($\mu g\ m^{-3}$)	FIDAS annual mean corrected. 2022 ($\mu g\ m^{-3}$)	Data Capture (%)
E Ayrshire Kilmarnock St Marnock St	RS	Fidas	5.6	5.9	98.4
East Dunbartonshire Bearsden	RS	Fidas	5.5	5.8	99.7
East Dunbartonshire Bishopbriggs	RS	Fidas	6.4	6.8	94.6
East Dunbartonshire Kirkintilloch	RS	Fidas	5.7	6	99.1
East Dunbartonshire Milngavie	RS	Fidas	4.9	4.9	89.7
East Lothian Musselburgh N High St	RS	BAM	7.3		60.3
Edinburgh Currie	UB	Fidas	4.7	5	99.9
Edinburgh Glasgow Road	RS	Fidas	5.7	6.1	99.9
Edinburgh Nicolson Street	RS	Fidas	6.3	6.7	97.8
Edinburgh Queensferry Road	RS	Fidas	5.9	6.3	88.4
Edinburgh Salamander St	UB	Fidas	6.3	6.7	98.9
Edinburgh St John's Road	UB	Fidas	6.0	6.3	99.9
Edinburgh St Leonards	RS	Fidas	5.1	5.4	99.3
Edinburgh Tower Street	RS	Fidas	4.9	5.2	100.0
Falkirk Grangemouth MC	UB	Fidas	5.4	5.8	100.0
Falkirk Grangemouth Zetland Park	UI	Fidas	5.5	5.8	96.6
Falkirk Haggs	RS	Fidas	6.0	6.4	97.2
Falkirk Hope St	RS	Fidas	5.3	5.6	97.5
Falkirk Main St Bainsford	RS	Fidas	6.2	6.5	92.4
Falkirk West Bridge Street	RS	Fidas	5.2	5.5	99.0
Fife Cupar	RS	Fidas	7.3	7.8	99.6
Fife Dunfermline	RS	Fidas	6.5	6.9	99.7
Fife Kirkcaldy	RS	Fidas	5.8	6.1	99.8
Fife Rosyth	RS	Fidas	5.9	6.2	99.7
Glasgow Anderston	UB	Fidas	6.6	7	98.1
Glasgow Broomhill	RS	Fidas	6.0	6.4	99.9
Glasgow Byres Road	RS	Fidas	6.4	6.8	79.6
Glasgow Dumbarton Road	RS	Fidas	6.5	6.9	70.9
Glasgow High Street	RS	Fidas	5.9	6.2	99.7
Glasgow Kerbside	RS	Fidas	6.8	7.2	99.8
Glasgow Nithsdale Road	RS	Fidas	6.3	6.6	99.7
Glasgow Townhead	UB	Fidas	5.7	6.1	99.4
Glasgow Waulkmillglen Reservoir	RB	Fidas	4.8	5	96.1
Grangemouth	UI	BAM (heated)	7.8		83.1
Inverclyde Greenock A8	RS	Fidas	5.7	6.1	94.4
Inverness	RS	Fidas	4.7	5	98.6
N Lanarkshire Chapelhall	RS	Fidas	5.2	5.6	99.9

Site Name	Type	$PM_{2.5}$ Analyser Type	Annual Average $PM_{2.5}$ 2022 ($\mu g\ m^{-3}$)	FIDAS annual mean corrected. 2022 ($\mu g\ m^{-3}$)	Data Capture (%)
N Lanarkshire Coatbridge Whifflet	RS	Fidas	5.3	5.6	10.4
N Lanarkshire Coatbridge Whifflet A725	RS	Fidas	5.6	5.9	99.6
N Lanarkshire Croy	RS	Fidas	5.5	5.8	99.9
N Lanarkshire Kirkshaws	RS	Fidas	5.3	5.6	99.9
N Lanarkshire Motherwell	RS	Fidas	5.4	5.7	86.9
N Lanarkshire Motherwell Adele St.	RS	Fidas	4.3	4.6	81.5
N Lanarkshire Ravenscraig Plantation Road	RS	Fidas	4.6	4.9	89.4
N Lanarkshire Shawhead Coatbridge	RS	Fidas	5.1	5.4	99.9
N Lanarkshire Uddingston New Edinburgh Rd	RS	Fidas	5.2	5.5	99.0
North Ayrshire Irvine High St	RS	Fidas	6.7	7.1	98.1
Perth Atholl Street	RS	Fidas	6.9	7.4	96.9
Perth Bridgend	RS	Fidas	5.3	5.6	98.8
Perth Crieff	RS	Fidas	5.2	5.5	95.3
Perth Muirton	RS	Fidas	5.1	5.4	100.0
Renfrewshire Johnstone	RS	Fidas	6.1	6.5	82.3
South Ayrshire Ayr Harbour	RS	Fidas	6.2	6.6	79.3
South Ayrshire Ayr High St	RS	Fidas	6.2	6.6	89.8
South Lanarkshire Blantyre	RS	Fidas	5.4	5.7	99.7
South Lanarkshire Cambuslang	RS	Fidas	5.9	6.2	99.8
South Lanarkshire East Kilbride	RS	Fidas	5.1	5.4	99.3
South Lanarkshire Hamilton	RS	Fidas	5.2	5.5	85.4
South Lanarkshire Lanark	RS	Fidas	5.2	5.6	99.9
South Lanarkshire Raith Interchange 2	RS	Fidas	5.1	5.4	98.4
South Lanarkshire Rutherglen	RS	Fidas	6.2	6.6	98.6
South Lanarkshire Uddingston	RS	Fidas	4.9	5.2	60.3
Stirling Craig's Roundabout	RS	Fidas	5.4	5.7	85.7
West Dunbartonshire Clydebank	RS	Fidas	5.8	6.2	99.8
West Lothian Broxburn	RS	Fidas	6.2	6.6	91.1
West Lothian Linlithgow High Street 2	RS	Fidas	6.5	6.8	27.5
West Lothian Newton	RS	Fidas	4.6	4.9	39.9

Shaded sites indicate data only available for part year and/or <75% data capture

BAM data are equivalent to gravimetric and hence are not adjusted

Figure 6-2 Annual Average PM_{10} and $PM_{2.5}$ concentrations (µg m^{-3}) for all SAQD sites in 2022



6.1.4 Carbon monoxide

Table 6-5 shows carbon monoxide was monitored using automatic techniques at one SAQD site during 2022. Edinburgh St Leonard's did not exceed the Running 8-hour mean of 10 mg m^{-3} and had a data caprure of 94.7%.

Table 6-5 Ratified data and data capture statistics for CO in 2022 for monitoring sites in the Scottish Air Quality Database

Site Name	Type	Annual Average CO 2023 (mg m^{-3})	Max. Running 8hr Mean CO 2022 (mg m^{-3})	Data Capture (%)
Edinburgh St Leonards	UB	0.09	0.81	94.7

6.1.5 Sulphur dioxide

Table 6-6 shows sulphur dioxide data from the eight sites utilising automatic monitoring for 2022 of which one (Lerwick) did not achieve a data capture rate of greater than 75%. Of the remaining seven sites, all met the requirements of the Air Quality Strategy as there were no exceedances for the 15-minute (266 µg not to be exceeded more than 35 times per year), 1-hour (350 µg m^{-3} not to be exceeded more than 24 times per year) and 24-hour mean (125 µg m^{-3} not to be exceeded more than three times per year) SO_2 objectives in 2022.

Table 6-6 Ratified data and data capture Statistics for SO_2 in 2022 for monitoring sites in the Scottish Air Quality Database

Site Name	Type	Annual Average SO_2 2022 (µg m^{-3})	No. 15 min SO_2 > 266µg m^{-3} 2022	No. 1 hr SO_2 > 350µg m^{-3} 2022	No. 24 hr SO_2 > 125µg m^{-3} 2022	Data Capture (%)
Edinburgh St Leonards	UB	0.7	0	0	0	94.1
Falkirk Bo'ness	UI	1.2	0	0	0	99.1
Falkirk Hope St	UB	0.9	0	0	0	96.1
Falkirk Grangemouth Zetland Park	UI	0.5	0	0	0	90.8
Falkirk Grangemouth MC	RS	0.9	0	0	0	96.8
Grangemouth Moray	UI	1.3	0	0	0	86.2
Grangemouth	UB	2.2	5	0	0	89.7
Lerwick	RB	1.0	0	0	0	18.2

Shaded sites indicate data only available for part year and/or <75% data capture

6.1.6 Ozone

Table 6-7 shows ozone data from 11 sites utilising automatic monitoring for 2022, of which two did not achieve a data capture rate of greater than 75%. Ozone (O_3) is a secondary pollutant formed by reactions involving other pollutant gases in the presence of sunlight and over several hours; it may persist for several days and be transported over long distances. This means that individual local authorities have little control over ozone levels in their area. In 2022, the Air Quality Strategy objective of 100 µg m^{-3} not to be exceeded more than 10 time at a 8-hour running mean, was not exceeded at any nine sites with more than 75% data capture.

Table 6-7 Ratified data and data capture statistics for O_3 in 2022 for monitoring sites in the Scottish Air Quality Database

Site Name	Type	Annual Average O_3 2022 ($\mu g\ m^{-3}$)	No of days with Maximum running 8-hr mean >100 ug m^{-3}	Data capture O_3 2022 (%)
Auchencorth Moss	RB	61.6	5	93.9
Bush Estate	RB	59.4	6	86.7
Edinburgh St Leonards	UB	49.2	0	46.1
Eskdalemuir	RB	0.0	0	0.0
Fort William	S	53.9	2	99.7
Glasgow Townhead	UB	48.4	4	99.5
Glasgow Waulkmillglen Reservoir	RB	57.0	5	96.2
Lerwick	RB	71.2	4	85.4
Peebles	S	56.1	4	99.1
Strath Vaich	RB	68.9	8	99.1

Shaded sites indicate data only available for part year and/or <75% data capture

6.2 OTHER POLLUTANTS COVERED BY THE AIR QUALITY STRATEGY – PAH (BENZO[A]PYRENE), BENZENE, 1,3-BUTADIENE AND LEAD

In this section, we present a summary of data from a range of national monitoring networks. Summaries are provided for pollutants covered by the Air Quality Strategy. As some of these networks are based on sampler measurement techniques and subsequent chemical analysis there is often a considerable delay in the availability of data. Where other pollutants are also monitored in these networks, these pollutants are listed, but the data are not provided in this report. Data, statistics and site information on these networks sites can be accessed via the Air Quality In Scotland Website “other Networks” interactive map (https://www.scottishairquality.scot/latest) and also the data selector function (https://www.scottishairquality.scot/data/data-selector).

6.2.1 PAH Monitoring Network[3]

The UK Monitoring and Analysis Network monitor some 39 Polycyclic Aromatic Hydrocarbon (PAH) species at 33 sites (see Table A.3 3, Appendix 3). Monitoring of the PAH benzo[a]pyrene is undertaken to provide data in compliance with retained EU law. An air quality objective for this PAH is also set in the Air Quality Strategy. A wide range of other PAH species are also monitored in the particulate phase and in the gaseous phase at some sites, for research purposes.

The airborne PAH monitoring is undertaken using Digitel DHA-80 Air Sampling System with PM_{10} inlet. Particulate collection is undertaken on a filter and at some sites, vapour-phase collection is also undertaken using polyurethane foam in addition to filter. At two sites, deposition samplers are also used to determine deposited PAH material.

The PAH monitoring sites in Scotland are shown in Table 6-8. The sites at Edinburgh and Glasgow are co-located with the Edinburgh St Leonards and Glasgow Townhead AURN sites respectively. The site at Kinlochleven is located close to the closed aluminium works and the site at Auchencorth Moss is a rural EMEP site as discussed in the automatic hydrocarbon section.

[3] Conolly C. et al Final Contract Report for the UK PAH Monitoring and Analysis Network (2004-2010) [online] Available at http://uk-air.defra.gov.uk/reports/cat05/1103040911_AEA_PAH_Network_Report_2010_Final_v3.1.pdf [Accessed no 30/05/2012]

Table 6-8 PAH monitoring sites in Scotland

Site	Address	Grid Reference
Auchencorth Moss	Rural site in Scotland, south of Edinburgh	322167,656123
Edinburgh	145 Pleasance, Edinburgh, EH8 9RU	326265, 673136
Glasgow Townhead	Not available	259692, 665899
Kinlochleven	Electrical Substation, Kinlochleven	219305,761905

Annual average concentrations for Benzo(a)pyrene (B(a)P) for 2020 to 2022 are shown in Table 6-9. As can be seen, the Air Quality objective for B(a)P of 0.25 ng m^{-3} as an annual average or the EU Directive target value of 1 ng m^{-3} was not exceeded at any site in 2021.

Table 6-9 Annual Mean Benzo(a)Pyrene concentrations for 2020 - 2022 at four sites in Scotland

Site	2020 Annual Mean B(a)P Concentration (ng m^{-3})	2021 Annual Mean B(a)P Concentration (ng m^{-3})	2022 Annual Mean B(a)P Concentration (ng m^{-3})
Auchencorth Moss	0.010	0.029	0.015
Edinburgh St Leonards	0.0368	0.049	0.061
Glasgow Townhead	0.0577	0.075	0.078
Kinlochleven	0.240	0.220	0.140

6.2.2 Benzene

6.2.2.1 Non-automatic hydrocarbon monitoring

Monitoring of benzene is undertaken on a two-weekly basis with pumped tube samplers at 36 sites throughout the UK – The UK Non-automatic Hydrocarbon Network. Two of these sites are located in Grangemouth and Glasgow Kerbside and are co-located with the Grangemouth and Glasgow Kerbside AURN sites. The non-automatic monitoring network provides benzene data for compliance with retained EU law and Scottish objective of 16.25 μg m^{-3} as an running annual mean.

The benzene monitoring method used in this network involves pumping ambient air at a rate of 10 ml min^{-1} through nominally duplicate tubes containing the sorbent Carbopack X, with subsequent laboratory analysis of the benzene content of the tubes. Results for this site for 2020 to 2022 are provided in Table 6-10.

Table 6-10 Annual Mean Benzene concentrations for 2020 - 2022 at two sites in Scotland in the UK Non-Automatic Hydrocarbon Network

Site Name	Annual Mean benzene for 2020 (μg m^{-3})	Annual Mean benzene for 2021 (μg m^{-3})	Annual Mean benzene for 2022 (μg m^{-3})
Glasgow Kerbside	0.52	0.50	0.44
Grangemouth	0.58	0.68	0.66

6.2.2.2 Automatic Hydrocarbon Monitoring

Table 6-11 gives the site details for the one automatic hydrocarbon monitoring station in Scotland - Auchencorth Moss: a rural site south of Edinburgh. The data from this site are used both to provide data for ozone precursor hydrocarbon species, in compliance with retained EU law. In addition, this site is one of the two European Monitoring and Evaluation Programme (EMEP) level II sites (EMEP "supersites") in the UK. The other EMEP supersite is located at Chilbolton in Hampshire. A much wider range of hydrocarbon species is monitored at Auchencorth Moss. However, the rural nature of this site means that often the concentrations are below the detection limit and hence, the data capture is low. Data for the full range of hydrocarbon species monitored at Auchencorth Moss can be downloaded from https://www.scottishairquality.scot/.

Table 6-11 Location of Automatic Hydrocarbon Monitoring Sites in Scotland

Site Name	Site Type	Species Measured
Auchencorth Moss	RURAL	Benzene and 1,3-butadiene and 24 other ozone precursor hydrocarbon species*

*EU requirement and part of the EMEP long-range transboundary air pollution monitoring programme.

Table 6-12 indicates that it is unlikely that the EU limit value for benzene of 5 μg m^{-3} and the Scottish Objective of 3.25 μg m^{-3} for the annual running mean concentration have been exceeded at Auchencorth Moss during 2022.

Table 6-12 Annual Mean & Max. Running Annual Mean Benzene Concentration at Auchencorth Moss in the UK Automatic Hydrocarbon Network, for 2022

Site	Benzene Annual mean concentration for 2022 (μg m^{-3})	Benzene Maximum running annual concentration for 2022 (μg m^{-3})
Auchencorth Moss	0.161	0.905

6.2.3 1,3-Butadiene

The species 1,3-butadiene is also measured as part of the UK Automatic Hydrocarbon Network at the same sites as for Benzene. Table 6-13 shows that 1,3-butadiene concentrations less than the Scottish Air Quality objective of 2.25 μg m^{-3} were measured during 2022. There is no EU Directive target for 1,3-butadiene.

Table 6-13 Annual Average & Max. Running Annual Mean 1,3-butadiene Concentration at Auchencorth Moss in the UK Automatic Hydrocarbon Network, for 2022

Site	1,3-butadiene Annual mean concentration for 2022 (μg m^{-3})	1,3-butadiene maximum running annual concentration for 2022 (μg m^{-3})
Auchencorth Moss	0.015	0.141

6.2.4 Heavy Metals

Lead and a wide range of other metals are monitored in two UK networks – the UK Heavy Metals Monitoring Network (mainly urban sites) and the National Monitoring Network for Heavy Metals (mostly rural sites). The urban network determines airborne particulate concentrations of 15 metals, including the metals lead, nickel, arsenic, cadmium and mercury which are covered by the EU Directive (Directives 2008/50/EC for lead and Directive 2004/107/EC for other metals). The rural network determines the concentration of more than 20 metals both as airborne particulate matter and as deposited material in rainwater samples. Results for all metals monitored in the UK Heavy Metals Monitoring Network and for a selection of metals monitored in the National Monitoring Network for Heavy Metals are available from the data selector on the Air Quality in Scotland website https://www.scottishairquality.scot/data/data-selector.

6.2.4.1 Rural Heavy Metals

In the National Monitoring Network for Heavy Metals, particles are collected using either single sample or multiple-sample FH95 samplers which draw air through a PM_{10} head at a flow rate of 1 m^3 h^{-1}. Particulate metals are collected on a filter paper for subsequent analysis. The sampling period is normally one week. Rainwater collectors are used to collect samples for rainwater analysis of metals to determine metal deposition. Details of the two rural sites in Scotland are provided in Table 6-14 and data for the measurement of lead, nickel, arsenic and cadmium in 2022 are provided in Table 6-15.

The results from these networks show that the EU limit value for lead (0.5µg m^{-3}as an annual mean), and the target values for nickel (20ng m^{-3}), arsenic (6 ng m^{-3}) and cadmium (5ng m^{-3}) were not exceeded at any site in Scotland. The air quality objectives for lead (500 ng m^{-3} for 2004 and 250 ng m^{-3} for 2008) were also not exceeded at any site in Scotland.

Table 6-14 Rural Network metals monitoring sites in Scotland

Site	Address	Grid Reference
Auchencorth Moss	Rural site, SE Scotland	322167,656123
Eskdalemuir	The Met Office Eskdalemuir Observatory, Langholm, Dumfries & Galloway, DG13 0QW	323552,603018

Table 6-15 Annual mean metal concentrations 2022 (Rural Network)

Site	Annual Mean Arsenic Concentration (ng m^{-3})	Annual Mean Cadmium Concentration (ng m^{-3})	Annual Mean Nickel Concentration (ng m^{-3})	Annual Mean Lead Concentration (ng m^{-3})
Auchencorth Moss	0.19	0.025	0.21	0.81
Eskdalemuir	0.15	0.022	0.33	0.67

6.3 DISCUSSION OF ADDITIONAL POLLUTANTS MONITORED AND/OR OTHER METHODS OF MONITORING

This section discusses other air pollution measurements made in Scotland. Detailed results are not provided but are available in the annual reports of the various networks. The following additional pollutants or additional monitoring methods are discussed:

1. NO_2 diffusion tube samplers
2. Non- methane Volatile Organic Compounds (NMVOC)
3. Poly aromatic hydrocarbons (PAH)
4. Toxic Organic Micropollutants (TOMPS)
5. Metals (Urban network)
6. Metals (Rural and deposition network)
7. United Kingdom Eutrophying & Acidifying Pollutants Network:
    i. The Precipitation Network
    ii. NO_2 rural diffusion tube Network
    iii. Acid Gases and Aerosol Network (AGANET)
    iv. National Ammonia Monitoring Network

6.3.1 NO_2 Diffusion Tube

See section 6.1.1.1.

6.3.2 Non-Methane Volatile Organic Compounds (NMVOC)

At Auchencorth Moss a much wider range of NMVOCs are monitored to provide ozone precursor pollutant concentrations in compliance with retained EU law. The following compounds are monitored:

- Ethane
- Ethene
- Propane
- Propene
- Ethyne
- 2-Methylpropane
- n-Butane
- trans-2-Butene
- 1-Butene
- cis-2-Butene
- 2-Methylbutane
- n-Pentane
- 1,3-Butadiene
- trans-2-Pentene
- 1-Pentene
- 2-Methylpentane
- n-Hexane
- Isoprene
- Benzene
- 2,2,4-trimethylpentane
- n-Heptane
- n-Octane
- Toluene
- Ethylbenzene
- (m+p)-Xylene
- o-Xylene
- 1,3,5-Trimethylbenzene
- 1,2,4-Trimethylbenzene
- 1,2,3-Trimethylbenzene

Hourly data for all these species are available on the Scottish Air Quality Database website.

6.3.3 Polycyclic Aromatic Hydrocarbons (PAH)

As discussed in Section 6.2.1, a wide range of particulate and gaseous PAH compounds are monitored within the UK PAH network. The following PAH species are sampled on a daily basis (but bulked into monthly results after analysis) at the four PAH sites in Scotland:

- Benzo(c)phenanthrene
- Benzo(a)anthracene
- Chrysene
- Cyclopenta(c,d)pyrene
- Benzo(b)naph(2,1-d)thiophene
- 5-Methyl Chrysene
- Benzo(b+j)fluoranthene
- Benzo(k)fluoranthene
- Benzo(e)pyrene
- Benzo(a)pyrene
- Perylene
- Indeno(1,2,3-cd)pyrene
- Dibenzo(ah.ac)anthracene
- Benzo(ghi)perylene
- Dibenzo(al)pyrene
- Dibenzo (ae)pyrene
- Dibenzo(ai)pyrene
- Dibenzo(ah)pyrene
- Coronene
- Cholanthrene
- Dibenzo(al)pyrene

6.3.4 Toxic Organic Micropollutants

Toxic Organic Micropollutants (TOMPs) include Polychlorinated Dibenzo-p-Dioxins, Polychlorinated Dibenzofurans (PCDD/Fs), PAHs, and Polychlorinated Biphenyls (PCBs). PCDD/Fs and PAHs are formed as unwanted by-products during various industrial, chemical and combustion processes. PCBs were formerly manufactured for use in a wide range of electrical and other products until 1986. These highly toxic and persistent species are ubiquitous in the environment, but are normally present at extremely low concentrations, the atmosphere being the principal route for their redistribution in the environment. The TOMPs network provides data on concentrations of these species in the air throughout the UK. There were six sites in the TOMPs network during 2022: one in Scotland at Auchencorth Moss.

The TOMPs network samples are analysed for PCDD/Fs and PCBs. Portions from the extracts of samples are also analysed for PAHs as part of the PAH network. The sampling method is based around the use of a modified Andersen GPS-1 sampler with subsequent chemical analysis requiring the use of a range of sophisticated chemical analysis techniques. These include gas chromatography coupled with high-resolution mass spectrometry for the PCDD/Fs and for those PCBs with dioxin-like effects and low-resolution mass spectrometry for the other PCBs.

6.3.5 Heavy Metals Network

As discussed in Section 6.2.5 a wide range of metals are monitored in both air and rainwater within the National Monitoring Network for Heavy Metals. At the two sites in Scotland, Auchencorth Moss and Eskdalemuir, the following metals are monitored:

Arsenic (As), Cadmium (Cd), Cobalt (Co), Chromium (Cr), Copper (Cu), Iron (Fe), Lead (Pb), Manganese (Mn), Nickel (Ni), Selenium (Se), Vanadium (V) and Zinc (Zn).

6.3.6 United Kingdom Eutrophying & Acidifying Pollutant Network (UKEAP)

This network focuses on the measurement of Eutrophying & Acidifying Pollutants in rural areas. The number of sites in Scotland is different for the various species measured.

The UKEAP has four component networks:

- The Precipitation Network (PrecipNet),
- Rural NO_2 network (NO_2-Net),
- Acid Gas and Aerosol Network (AGANET),
- National Ammonia Monitoring Network (NAMN),
- Automatic Mercury Network.

Each network functions on a national scale, however with differing spatial and temporal resolution which reflects the spatial and temporal heterogeneity of the atmospheric pollutant concerned.

6.3.7 The Precipitation Network (Precip-Net)

There are 41 sites in PrecipNet at which the chemical composition of precipitation (i.e., rainwater) is measured. Six of the sites, Lochnagar, Llyn Llagi, Scoat Tarn, Loch Chon/Tinker, River Etherow, Beaghs Burn and Crai Reservoir (Head of the Valleys) were specifically located within sensitive ecosystems. The network allows estimates of wet deposition of sulphur and nitrogen chemicals.

Fortnightly precipitation samples are collected at 41 sites throughout the UK, of which 10 are in Scotland (see Table A.3 7, Appendix 3). Sampling is undertaken with using a bulk rainwater collector. The collected rainwater samples are analysed for sulphate, nitrate, chloride, phosphate, sodium, magnesium, calcium, potassium, pH and conductivity.

6.3.8 Rural NO_2 Network (NO_2-Net)

The nitrogen dioxide measurements are made at 24 of the Precip-Net composition sites. Diffusion tubes are used to measure nitrogen dioxide. The tubes are mounted on the upright of the rain collector stand and exposed for four or five-week periods throughout each year.

Triplicate nitrogen dioxide diffusion tube measurements are run at three AURN sites with co-located automatic instruments (Yarner Wood, Harwell and Eskdalemuir). The annual average NO_2 concentration measured at the Eskdalemuir automatic monitoring site was 1.7 µg m^{-3} in 2022 with a data capture rate of 100%. Nitrogen dioxide is measured with diffusion tube samplers at nine sites in Scotland. The annual average concentrations measured in 2022 are provided in Table 6-16.

Table 6-16 NO_2 annual average concentrations 2022 at rural monitoring sites

Site	Annual Mean NO_2 for 2022 (ug m^{-3})	Data Capture for 2022 (%)
Allt a'Mharcaidh	0.653	100
Balquhidder 2	1.392	84.7
Eskdalemuir	1.647	100
Forsinard RSPB	0.979	88.2
Glensaugh	2.411	100
Loch Dee	1.67	100
Polloch	0.523	100
Strathvaich	0.419	100
Whiteadder	2.104	100

6.3.9 Acid Gas and Aerosol Network (AGANET)

The UK Acid Gases and Aerosols Monitoring Network has been in operation since September 1999, providing monthly measurement data of acid gases and aerosols.

An extension of the CEH Denuder for Long Term Atmospheric sampling (DELTA) system at the network sites is used to additionally sample gaseous HNO_3, SO_2, HCl and particulate NO_3^-, SO_4^{2-}, Cl^-, Na^+, Ca^{2+}, Mg^{2+}. The new expanded network includes measurements of gaseous SO_2 and particulate SO_4^{2-} .

The nine sites in this network located in Scotland are listed in Table A.3 8 in Appendix 3.

6.3.10 National Ammonia Monitoring Network (NAMN)

Established in 1996, the objectives of the network are to quantify temporal and spatial changes in air concentrations and deposition in NH_3 and NH_4^+ (included since 1999) on a long-term basis. 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 17 sites in this network located in Scotland are listed in Table A.3 8 in Appendix 3.

7 AIR QUALITY MAPPING FOR SCOTLAND

As part of the Scottish Air Quality Database project, Ricardo Energy & Environment provides mapped concentrations of modelled background air pollutant concentrations on a 1 km x 1 km basis for the whole of Scotland. Modelled roadside air pollutant concentrations are provided for urban major road links in Scotland. The air pollution maps are derived from a combination of measurements from Scotland's network of air quality monitoring stations, and spatially disaggregated emissions information from the UK National Atmospheric Emissions Inventory (NAEI). They provide estimated pollutant concentrations for the whole of Scotland. The methodology for producing the Scottish maps is based on the UK Pollution Climate Mapping (PCM) approach, used for producing air pollution maps for the whole of the UK for the purposes of annual compliance reporting under the Air Quality Standards Regulations 2010.

The PCM methodology has been applied to provide pollution maps of Scotland for the Scottish Government for 2021 using measurements exclusively from Scottish air quality monitoring sites. The maps provide spatial representation of the annual mean concentrations of:

- PM_{10} (gravimetric equivalent)
- $PM_{2.5}$ (gravimetric equivalent)
- NO_X and NO_2.

The air pollution measurements used to prepare the maps presented here consists of PM_{10} and $PM_{2.5}$ monitoring data (FIDAS and Beta Attenuated Monitors (BAM)) and automatic monitoring measurements for NO_X and NO_2 from the model year. The model also uses meteorology data from the Weather Research and Forecasting (WRF) model to create the Scotland-specific maps.

In 2009 Ricardo Energy & Environment undertook a short study[4] on behalf of the Scottish Government which demonstrated the use of Scotland-specific air quality maps for Local Air Quality Management Review and Assessment (LAQM) purposes. This study recommended the use of air pollutant source apportionment data and forward-projected concentrations of air pollutants using Scotland-specific data. Updates to these Scotland-specific air pollutant source apportionment data and forward-projected concentrations have been made and are available for LAQM from a base year of 2018 at: https://www.scottishairquality.scot/data/mapping/data. Please note the available projections from a base year of 2018 are based on assumptions that were applicable prior to the Covid-19 pandemic, and as such, do not reflect short- or long-term impacts of the pandemic and associated lockdowns on emissions in 2020 and beyond.

7.1 AIR QUALITY MAPS FOR SCOTLAND 2021

The details of the methodology and full results of the mapping study are provided in a separate report[5]. In this report, we summarise the main findings of this work.

[4] Stevenson, K., Kent, A.J., and Stedman, J. (2010). Investigation of the possible effect of the use of Scottish specific air quality maps in the LAQM process in four selected Local Authorities. AEA Report AEAT/ENV/R/2948. https://www.scottishairquality.scot/sites/default/files/orig/publications/reports2/258100203_la_mapping_report_issue_1_final.pdf

[5] Wareham, J., Pepler, A. Stedman, J., Morris, R. and Hector, D. (2023). Scottish Air Quality Maps. Annual mean NO_X, NO_2, PM_{10} and $PM_{2.5}$ modelling for 2021. https://www.scottishairquality.scot/sites/default/files/publications/2023-10/Scottish_mapping_report_2021.html

7.1.1 NO_2 maps for 2021

The 2021 annual mean NO_2 concentrations for Scotland were modelled for background and roadside locations. Figure 7-1 and Figure 7-2 show modelled annual mean NO_2 concentrations in Scotland, for background and roadside locations respectively.

Figure 7-1 Background NO_2 map for 2021, µg m^{-3} (Scotland-specific model)

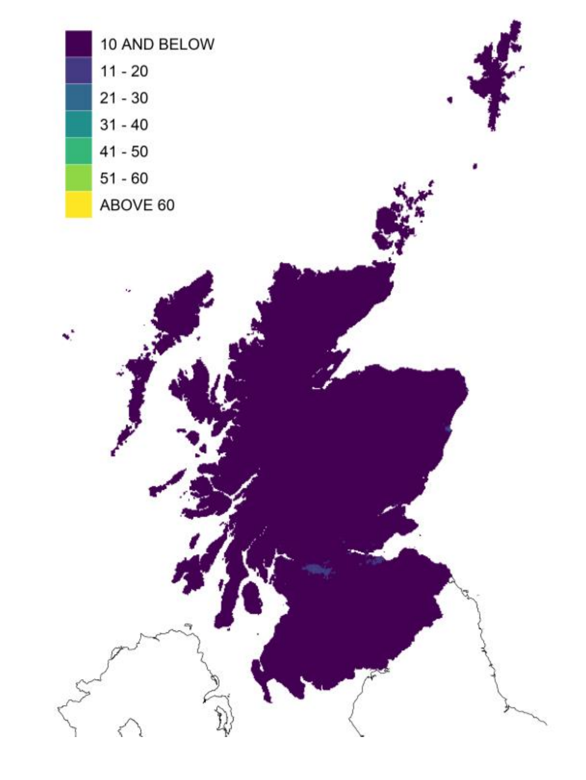


Figure 7-2 Roadside NO_2 map for 2021, µg m^{-3} (Scotland-specific model)

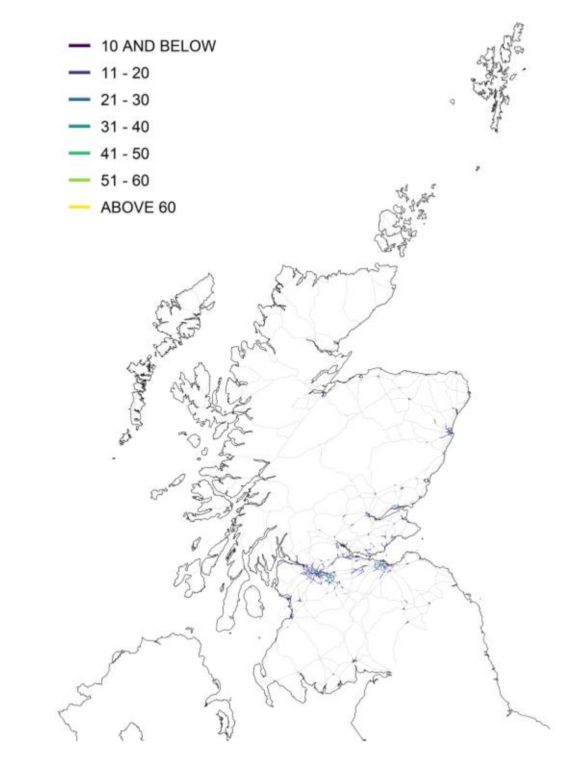


Table 7-1 shows that there were no modelled exceedances of the Scottish annual mean NO_2 objective of 40 µg m^{-3} at background locations. Table 7-2 shows that there were no modelled exceedances of the Scottish annual mean NO_2 objective of 40 µg m^{-3} at roadside locations. Interactive versions of the maps showing the background and roadside annual mean NO_2 concentrations can be found in the Scottish Air Quality Mapping report for 2021.

Table 7-1 Annual mean exceedance statistics for background NO_2 in Scotland based on the Scotland-specific model, 2021.[1]

Zone or agglomeration	Total		>40 µg m^{-3}	
	Area (km^2)	Population	Area (km^2)	Population
Glasgow Urban Area	367	1,080,395	0	0
Edinburgh Urban Area	134	441,849	0	0
Central Scotland	10,064	1,869,293	0	0
North East Scotland	19,057	1,049,238	0	0
Highland	44,116	368,884	0	0
Scottish Borders	11,403	254,166	0	0
Total	**85,141**	**5,063,824**	**0**	**0**

[1] Note: Totals may differ from sum of individual sub-totals due to rounding.

Table 7-2 Annual mean exceedance statistics for roadside NO_2 in Scotland based on the Scotland-specific model, 2021.[2]

	Road links	Length (km)	Road links	Length (km)
Glasgow Urban Area	303	430.6	0	0
Edinburgh Urban Area	71	119.3	0	0
Central Scotland	315	508.8	0	0
North East Scotland	178	260.5	0	0
Highland	45	67.5	0	0
Scottish Borders	51	53.8	0	0
Total	**963**	**1,440.4**	**0**	**0**

[2] Note: Totals may differ from sum of individual sub-totals due to rounding.

7.1.2 PM_{10} maps for 2021

2021 annual mean PM_{10} concentrations for Scotland were modelled for background and roadside locations. The modelling methodology used to calculate the annual mean PM_{10} concentration was similar to that used in previous years and used a mixture of PM_{10} monitoring (FIDAS and Beta Attenuated Monitors (BAM)) data. Many of the chemical components of the PM_{10} model are not affected by the Scotland-specific changes to the UK PCM model. This includes the contribution to the total PM_{10} mass from the following components:

- secondary inorganic aerosols (SIA, e.g., sulphate, nitrate, ammonium-based particles)
- secondary organic aerosols (SOA)
- primary particles from long-range transport
- sea salt aerosol, and
- iron and calcium-rich dusts.

Maps of the modelled 2021 annual mean PM_{10} concentrations for Scotland's background and roadside locations are shown in Figures 7-3 and 7-4, respectively.

Figure 7-3 Background PM_{10} map for 2021, µg m^{-3} (Scotland-specific model)

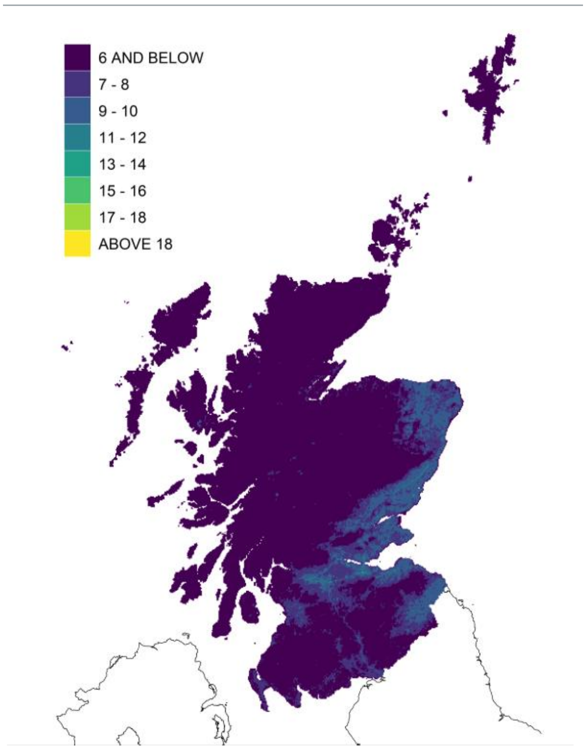


Figure 7-4 Roadside PM_{10} map for 2021, µg m^{-3} (Scotland-specific model)

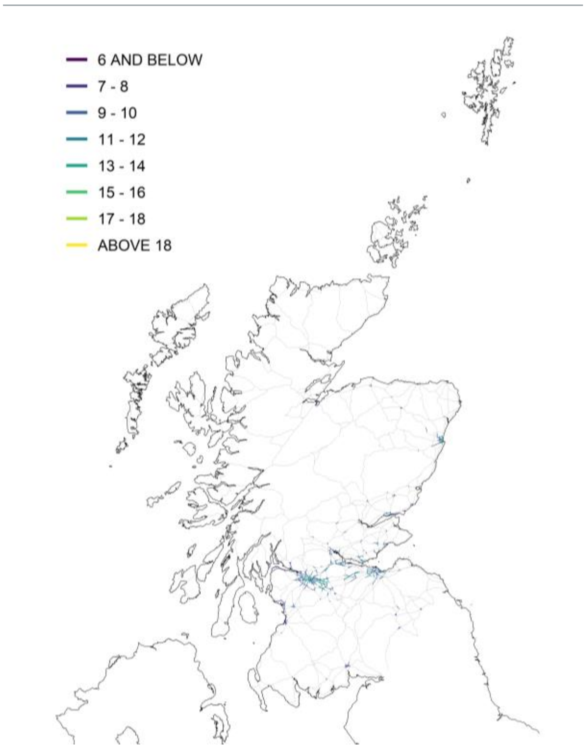


Table 7-3 shows that there were no modelled exceedances of the Scottish annual mean PM_{10} objective of 18 µg m^{-3} at background locations. Table 7-4 shows that there were no modelled exceedances of the Scottish annual mean PM_{10} objective of 18 µg m^{-3} at roadside locations.

Table 7-3 Annual mean exceedance statistics for background PM_{10} in Scotland based on the Scotland-specific model, 2021.[3]

	Area (km^2)	Population	Area (km^2)	Population
Glasgow Urban Area	367	1,080,395	0	0
Edinburgh Urban Area	134	441,849	0	0
Central Scotland	10,064	1,869,293	0	0
North East Scotland	19,057	1,049,238	0	0
Highland	44,116	368,884	0	0
Scottish Borders	11,403	254,166	0	0
Total	**85,141**	**5,063,824**	**0**	**0**

[3] Note: Totals may differ from sum of individual sub-totals due to rounding.

Table 7-4 Annual mean exceedance statistics for roadside PM_{10} in Scotland based on the Scotland-specific model, 2021.[4]

	Road links	Length (km)	Road links	Length (km)
Glasgow Urban Area	303	430.6	0	0
Edinburgh Urban Area	71	119.3	0	0
Central Scotland	315	508.8	0	0
North East Scotland	178	260.5	0	0
Highland	45	67.5	0	0
Scottish Borders	51	53.8	0	0
Total	**963**	**1,440.4**	**0**	**0**

[4] Note: Totals may differ from sum of individual sub-totals due to rounding.

7.1.3 $PM_{2.5}$ maps for 2021

2021 annual mean concentrations of $PM_{2.5}$ were modelled for Scotland at background and roadside locations. The modelling methodology used is consistent with the PM_{10} model and further detail can be found in the 2021 UK mapping report[6]. The 2021 maps have been calibrated using measurements from sites for which co-located PM_{10} measurements are also available.

Maps of the modelled 2021 annual mean $PM_{2.5}$ concentrations for Scotland's background and roadside locations are shown in Figures 7-5 and 7-6, respectively.

[6] Pugsley, K. L., Stedman, J. R., Brookes, D. M., Kent, A. J., Morris, R. J., Whiting, S. L., Wareham, J. V., Goodhand, A., Pepler, A., Thorp, T. M. and Gorji, S., 2022. "Technical Report on UK Supplementary Modelling Assessment Under the Air Quality Standards Regulations 2010 for 2021." Ricardo Energy & Environment. https://uk-air.defra.gov.uk/library/reports?report_id=1086.

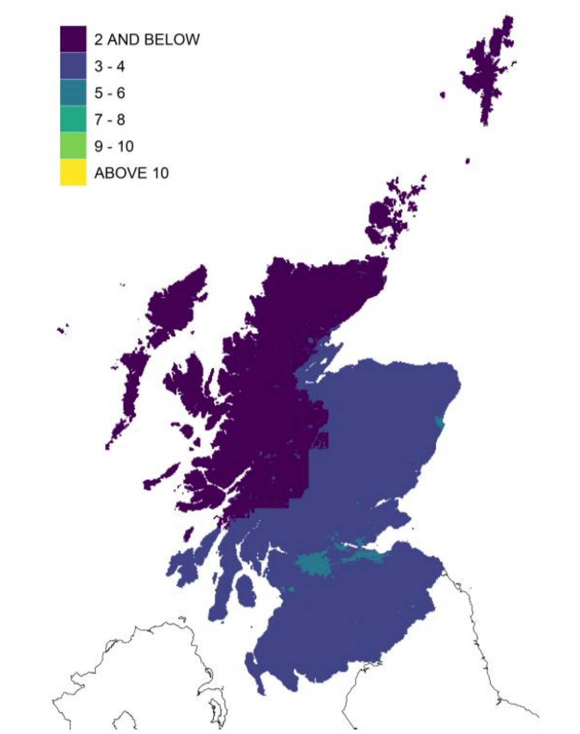
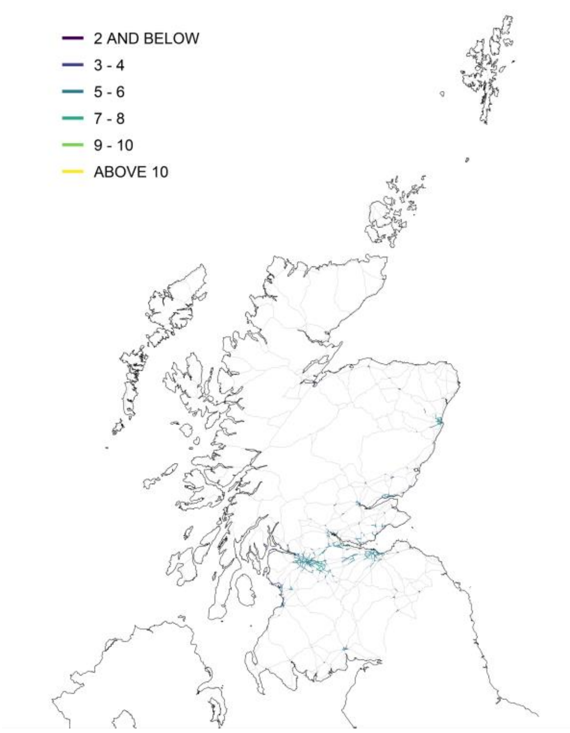
Figure 7-5 Background $PM_{2.5}$ map for 2021, µg m^{-3} (Scotland-specific model)	Figure 7-6 Roadside $PM_{2.5}$ map for 2021, µg m^{-3} (Scotland-specific model)
	

Table 7-5 shows that there were no modelled exceedances of the Scottish annual mean $PM_{2.5}$ objective of 10 µg m^{-3} at background locations. Table 7-6 shows that there were no modelled exceedances of the Scottish annual mean $PM_{2.5}$ objective of 10 µg m^{-3} at roadside locations.

Table 7-5 Annual mean exceedance statistics for background $PM_{2.5}$ in Scotland based on the Scotland-specific model, 2021.[5]

	Area (km²)	Population	Area (km²)	Population
Glasgow Urban Area	367	1,080,395	0	0
Edinburgh Urban Area	134	441,849	0	0
Central Scotland	10,064	1,869,293	0	0
North East Scotland	19,057	1,049,238	0	0
Highland	44,116	368,884	0	0
Scottish Borders	11,403	254,166	0	0
Total	**85,141**	**5,063,824**	**0**	**0**

[5] Note: Totals may differ from sum of individual sub-totals due to rounding.

Table 7-6 Annual mean exceedance statistics for roadside $PM_{2.5}$ in Scotland based on the Scotland-specific model, 2021.[6]

	Road links	Length (km)	Road links	Length (km)
Glasgow Urban Area	303	430.6	0	0
Edinburgh Urban Area	71	119.3	0	0
Central Scotland	315	508.8	0	0
North East Scotland	178	260.5	0	0
Highland	45	67.5	0	0
Scottish Borders	51	53.8	0	0
Total	**963**	**1,440.4**	**0**	**0**

[6] Note: Totals may differ from sum of individual sub-totals due to rounding.

7.1.4 Forward projections

Forward projections of air pollutant concentrations to future years are not produced annually. The most recently available forward projections are from a base year of 2018. Background maps of PM_{10}, NO_X and NO_2 for the years 2018 to 2030 are provided to assist Scottish local authorities in support of the review and assessment of local air quality. These are available for download from the Data for Local Authority Review and Assessment purposes page on the Air Quality in Scotland website[7]. Please note the available projections from 2018 are based on assumptions that were applicable prior to the Covid-19 pandemic, and as such, do not reflect short- or long-term impacts of the pandemic and associated lockdowns on emissions in 2020 and beyond.

[7] https://www.scottishairquality.scot/data/mapping/data

8 AIR POLLUTION TRENDS FOR SCOTLAND

This section of the report summarises how air quality in Scotland has changed in recent years. It focuses on those pollutants which have exceeded their Air Quality Strategy objectives in recent years in Scotland. These pollutants are NO_2 and PM_{10}. As well as PM_{10}, trend analysis will also be carried out for $PM_{2.5}$. Ozone will also be analysed as previous trend analysis has indicated an increasing trend in some instances.

Automatic monitoring of oxides of nitrogen and of ozone has been routinely carried out in Scotland since 1987, with automatic PM_{10} monitoring carried out since the 1990s. However, until 2000 there were relatively few automatic monitoring sites. Subsequent years have seen the number of monitoring sites in the Scottish Air Quality database increase from 20 sites (in 2000) to the current total of 100 sites (as of May 2022). The data produced by these monitoring sites have improved our understanding of Scotland's pollution climate. However, the increase in site numbers potentially complicates the investigation of trends in air quality. If trend investigation is based on all available data, the apparent trends we see may not reflect real changes in Scotland's air quality; instead, they may be due to the changes in the number of sites (and their distribution). Therefore, in reports in this series from 2010 onwards, investigation of trends has been based on subsets of long-running sites.

These subsets are separated by site type classification as stated in the LAQM Technical Guidance (TG22). The subsets are Urban Background (UB), Rural Background (RB), and Urban Traffic (UT). Other site classifications used within this analysis also include Urban industrial (UI) and Suburban (S). There are two set of site classification used within the UK networks, the LAQM description and the 2008 Air Quality Directive description. A description of these classifications is provided in Table 8-1.

Table 8-1 Site classifications

AQS Regulations 2010 Classification	LAQM Description	AQD 2008 Description
Urban Traffic	Roadside or Kerbside	Sites in an urban area at least 25 metres from the edge of major junctions and no more than 10 metres from the kerbside
Urban Background	Urban Background or Urban Centre	Sites in an urban area away from major roads that are representative of exposure of the general population. Urban background sites should not be dominated by single sources and should be representative of a wide area
Suburban Background	Suburban	Sites in a suburban area away from major roads that are representative of exposure of the general population. A suburban area is defined as a location type situated in a residential area on the outskirts of a town or city. Suburban background sites should not be dominated by single sources and should be representative of a wide area
Rural Background	Rural	Sites in a rural area away from roads that are representative of exposure of the general population. Rural background sites should not be influenced by agglomerations or industrial sources and should be representative of a wide area
Urban Industrial	Industrial	Site in an urban residential area downwind of specific industrial source
Suburban Industrial	Industrial	Site in a suburban area downwind of specific industrial source. A suburban area is defined as a location type situated in a residential area on the outskirts of a town or city

(Local Air Quality Management Technical Guidance (TG22), Feb 2022)

All the sites featured in this section have been in operation for a minimum of five consecutive years, as this is usually considered to be the minimum required in order to assess long-term trends at a monitoring site. In most cases it is now possible to do trend analysis for longer periods, for example 10 years.

The trend analysis presented in this section has been carried out using Openair: a free, open-source software package of tools for analysis of air pollution data. Openair was initially funded by the Natural Environment Research Council (NERC), with additional funds from Defra[8]. The Openair project is now maintained by Dr David Carslaw, of Ricardo Energy & Environment/ University of York and Dr Karl Ropkins of the University of Leeds. A range of Openair tools are available on the "Air Quality in Scotland" website: for more information on the tools and how to use them, please see:

https://www.scottishairquality.scot/data/openair

For this and previous reports the Openair "TheilSen" analysis tool was used. This uses the Theil-Sen statistical method to determine trends in pollutant concentrations over several years. The trend analysis is based on monthly mean pollutant concentrations. Openair includes an option to "de-seasonalise" the data (i.e. statistically modify the plotted data to remove the influence of seasonal cycles, thus providing a clearer indication of the overall trend over the relevant time). The "de-seasonalise" option has been used in all the Theil-Sen trend graphs presented here. When the de-seasonalise option is used, Openair fills in any gaps in the data using a linear interpolation method.

In these plots the trend line is shown by a solid red line, with 95% confidence intervals for the trend shown by dotted red lines. The trend is given at the top of the plot in green, with confidence intervals shown in square brackets. The trend is given as units (i.e. µg m^{-3}) per year, over the period shown. This may be followed by a number of stars, with * indicating that the trend is statistically significant at the 0.05 level (low significance), ** indicating significance at the 0.01 level (significant) and *** indicating significance at the 0.001 level (highly significant). The symbol + indicates that the trend is significant at the 0.1 level.

8.1 NITROGEN DIOXIDE

In Scotland (as elsewhere in the UK) the largest number of Air Quality Management Areas (AQMAs) has been declared in response to exceedances of objectives for nitrogen dioxide (NO_2). This is also reflected in the number of monitoring stations (both automatic and passive) historically reporting exceedances (in particular the annual mean NO_2 objective of 40 µg m^{-3}) for this pollutant. It is therefore important to understand how concentrations of this pollutant are varying with time.

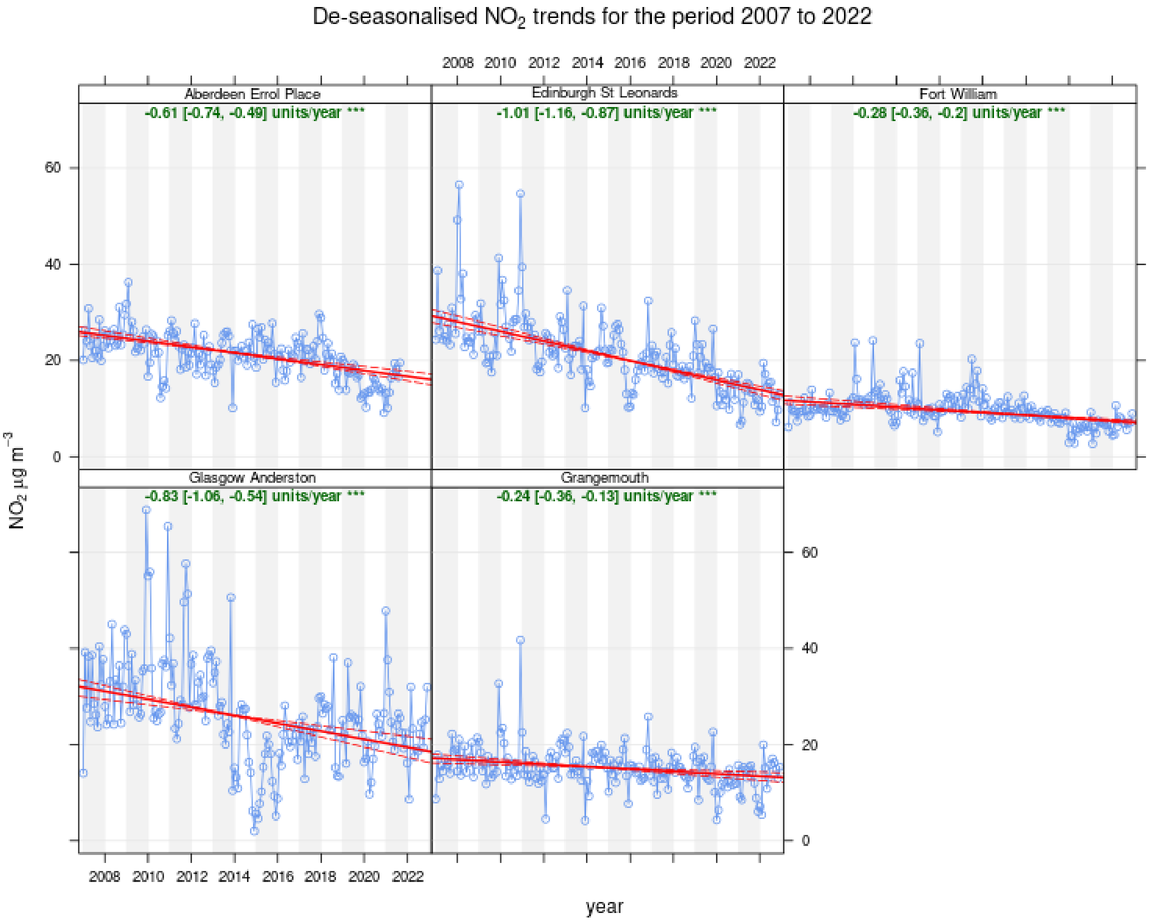
8.1.1 NO_2 at Urban Background Sites

There are relatively few long-running urban background monitoring stations in Scotland. Five urban background sites have been in operation for the past 15 years. These are as follows: Aberdeen Errol Place, Edinburgh St Leonards, Fort William, Glasgow Anderston and Grangemouth. Fort William is classified as a 'suburban' site, Grangemouth is an 'urban industrial' site, and the other three are 'urban background'. It should be noted that Aberdeen Errol Place was closed in 2021 and replaced by Aberdeen Errol Park, which is located several meters from the Errol Place sites so considered a new site. We have continued to use Errol place data even though there is no 2022 data to show background trends for Urban background locations in the northeast region.

The Openair Theil-Sen function has been used to quantify trends in NO_2 at these five urban non-roadside monitoring stations, over the 15-year period 2007-2021: the trend plots for NO_2 are shown in Figure 8-1. *Please note that both Edinburgh St Leonards and Glasgow Anderston have large gaps in their 2014 and 2015 datasets: as stated above, where there are gaps in the data, Openair fills these in using an interpolation method*.

[8] Carslaw DC and Ropkins K (2012). "Openair — An R package for air quality data analysis." Environmental Modelling & Software, 27–28(0), pp. 52–61. ISSN 1364-8152, doi: 10.1016/j.envsoft.2011.09.008.

Figure 8-1 Trends in NO_2 concentrations at five long-running Urban background sites, 2007-2022

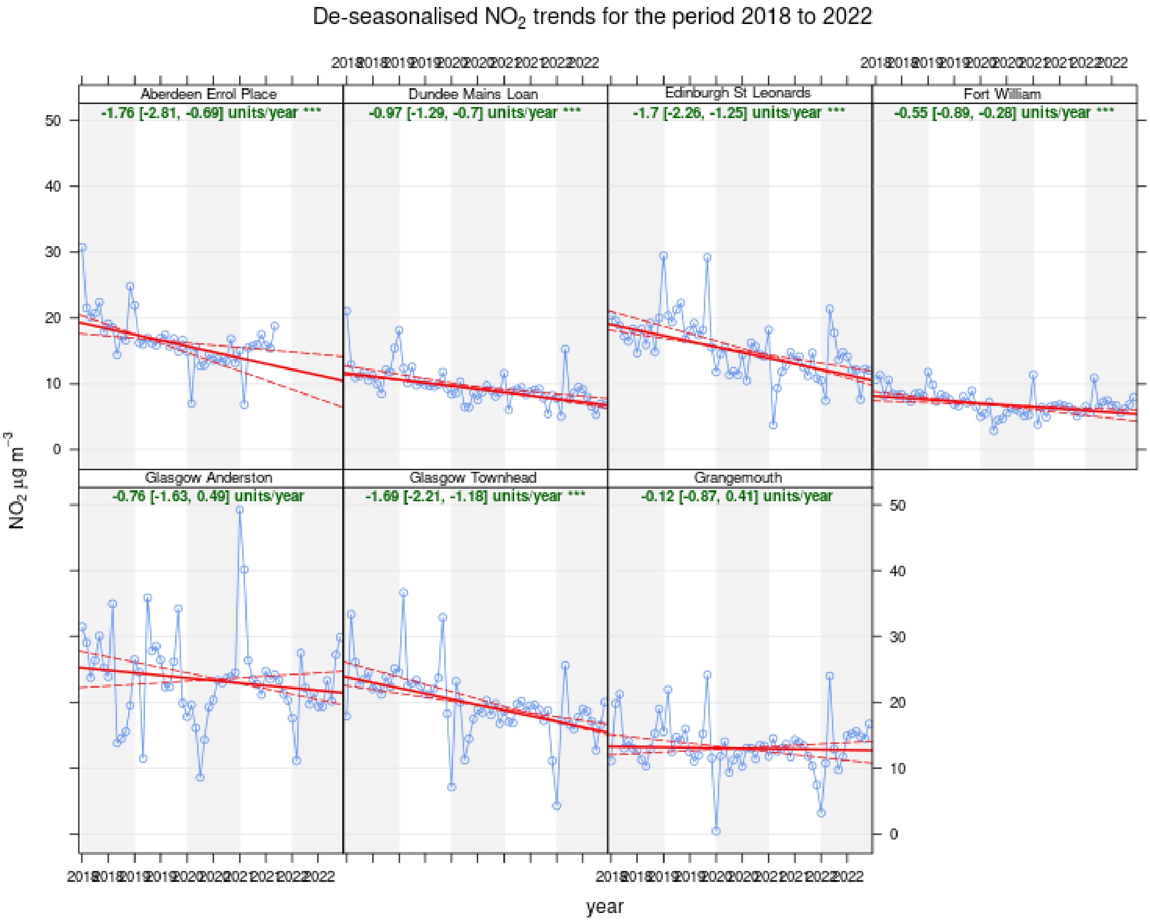


All sites display highly significant negative trends (at the 0.001 level) over the last 15 years. This analysis indicates that the decreasing trend in NO_2 concentrations is becoming more substantial over this time period.

Figure 8-2 takes into consideration all urban background sites in Scotland over the past five years, including the sites at Dundee Mains Loan and Glasgow Townhead. The more recent years analysis shows that the decreasing trend is consistent with the long-range trend, however the statistical significancy in more variable.

The impact of the Covid-19 lockdowns was a dramatic decrease in concentrations in the first half of 2020 and early 2021. Concentrations then quickly returned to what could be considered pre-lockdown levels once restrictions were lifted.

Figure 8-2 Trends in NO_2 concentrations at all Urban Background sites, 2018-2022



8.1.2 NO_2 at Rural Sites

There are three long-running rural sites which have monitored oxides of nitrogen for more than 10 years: Bush Estate (to the south of Edinburgh close to the Pentland Hills Regional Park), Eskdalemuir and Glasgow Waulkmillglen Reservoir. Figure 8-3 shows trends in NO_2 concentration at these sites since 2007.

All three sites show small but highly significant decreasing trends. In previous years Glasgow Waulkmillglen Reservoir showed no significant downward trend however there is now a highly significant decreasing trend. The drop in concentrations seen in 2020 and 2021, due to the lockdown restrictions may have influenced this change. It should be noted that Eskdalemuir has been off-line since 2021 due to power issues.

Figure 8-4 shows trends in NO_2 provides the trend over the last five years to illustrate what trends are like over more recent years and a shorter period of time. It shows that the decreasing trend is plateauing at all sites and no longer statistically significant. For Glasgow Waulkmillglen Reservoir the trend has changed to a slight increasing (but not statistically significant).

Figure 8-3 Trends in NO_2 concentrations at three Rural sites, 2007 – 2022

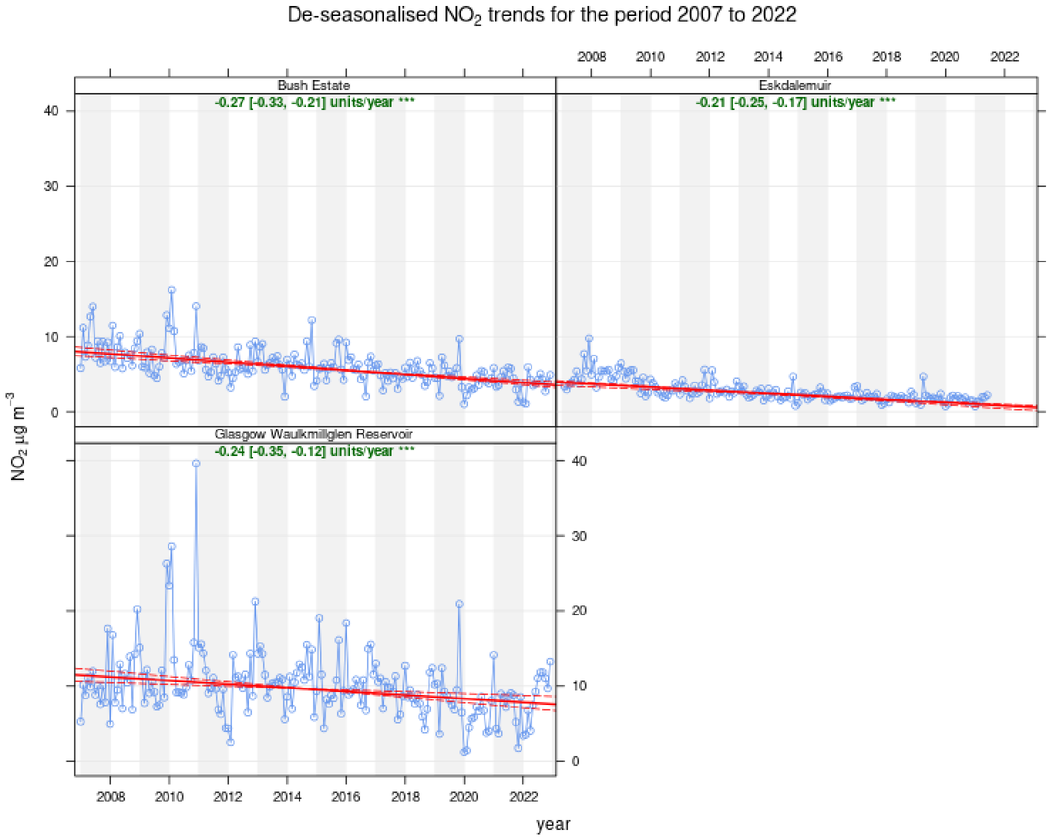
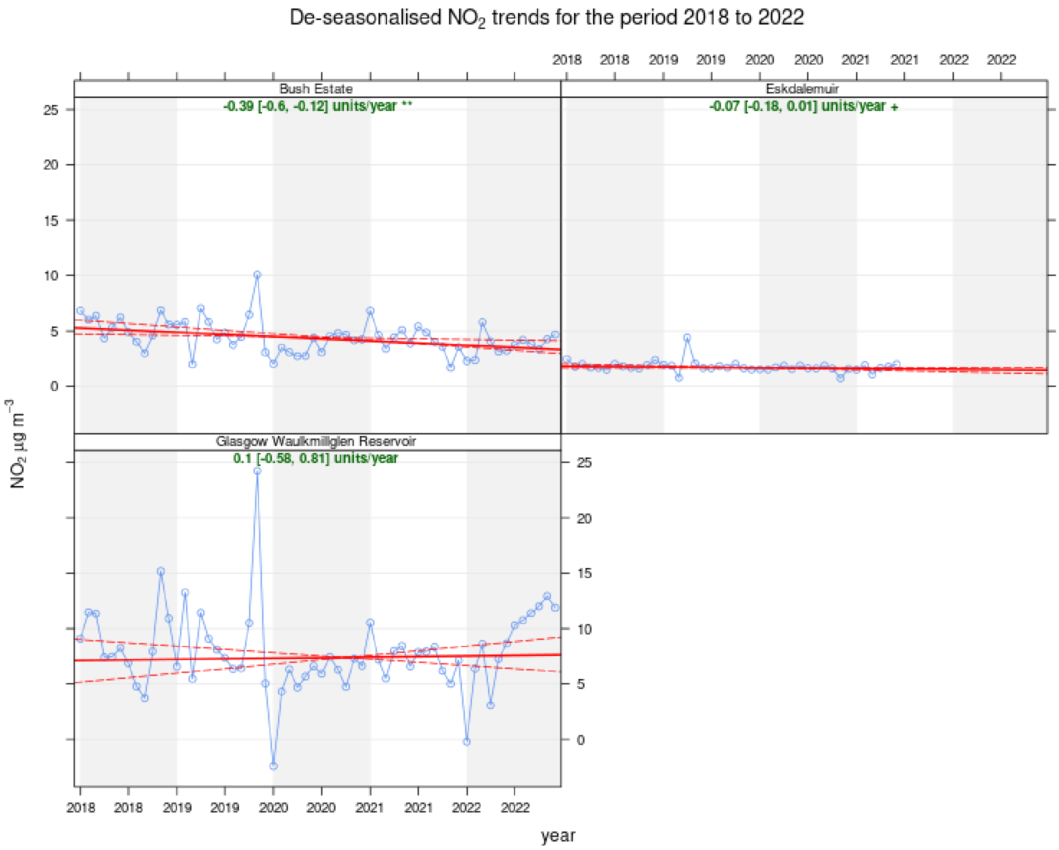


Figure 8-4 Trends in NO_2 concentrations at three Rural sites, 2018 – 2022



8.1.3 NO_2 at Urban Traffic Sites

There are now over 52 urban traffic (roadside and kerbside) monitoring stations that have been in operation for 10 years or more and are still in operation. These are as follows:

- Aberdeen Anderson Dr
- Aberdeen King Street
- Aberdeen Market Street 2
- Aberdeen Union Street Roadside
- Aberdeen Wellington Road
- Dundee Lochee Road
- Dundee Meadowside
- Dundee Seagate
- Dundee Whitehall Street
- East Dunbartonshire Bearsden
- East Dunbartonshire Bishopbriggs
- East Dunbartonshire Kirkintilloch
- East Dunbartonshire Milngavie
- East Lothian Musselburgh N High St
- Edinburgh Glasgow Road
- Edinburgh Gorgie Road
- Edinburgh Salamander St
- Edinburgh St John's Road
- Falkirk Grangemouth MC
- Falkirk Haggs
- Falkirk Hope St
- Falkirk Park St
- Falkirk West Bridge Street
- Fife Cupar
- Fife Dunfermline
- Fife Kirkcaldy
- Fife Rosyth
- Glasgow Anderston
- Glasgow Burgher St.
- Glasgow Byres Road
- Glasgow Dumbarton Road
- Glasgow Kerbside
- Inverness
- N Lanarkshire Chapelhall
- N Lanarkshire Croy
- N Lanarkshire Moodiesburn
- N Lanarkshire Shawhead Coatbridge
- North Ayrshire Irvine High St
- Perth Atholl Street
- Perth Crieff
- South Ayrshire Ayr Harbour
- South Ayrshire Ayr High St
- South Lanarkshire Hamilton
- South Lanarkshire Lanark
- South Lanarkshire Raith Interchange
- South Lanarkshire Rutherglen
- South Lanarkshire Uddingston
- Stirling Craig's Roundabout
- West Dunbartonshire Clydebank
- West Dunbartonshire Glasgow Road
- West Lothian Broxburn
- West Lothian Newton

There are a large number of long-running sites in operation, therefore for the purposes of this report eight were selected based on measured exceedances of the Air Quality Strategy Objective for annual mean NO_2 (40 µg m^{-3}) in recent years. These are as follows: Aberdeen Union Street, Aberdeen Wellington Road, Dundee Lochee Road, Dundee Seagate, Edinburgh St John's Road, Glasgow Kerbside (Hope Street), N Lanarkshire Chapelhall and Perth Atholl Street.

Figure 8-5 provides the 10-year trend analysis for these selected sites. It shows that all eight sites have statistically highly significant decreasing trends (at the 0.001 level).

Trends over the most recent five complete years, 2018 – 2022, have also been examined for these sites. These are shown in Figure 8-6Figure 8-. Comparing the 10-year and five-year trends, both show decreasing trends of high significance. At all sites except North Lanarkshire Chapelhall and Perth atholl Street, the decreasing trend has become greater in magnitude over the past five years.

Figure 8-5 Trends in NO_2 concentrations at eight long-running Urban Traffic sites with exceedances, 2013 – 2022

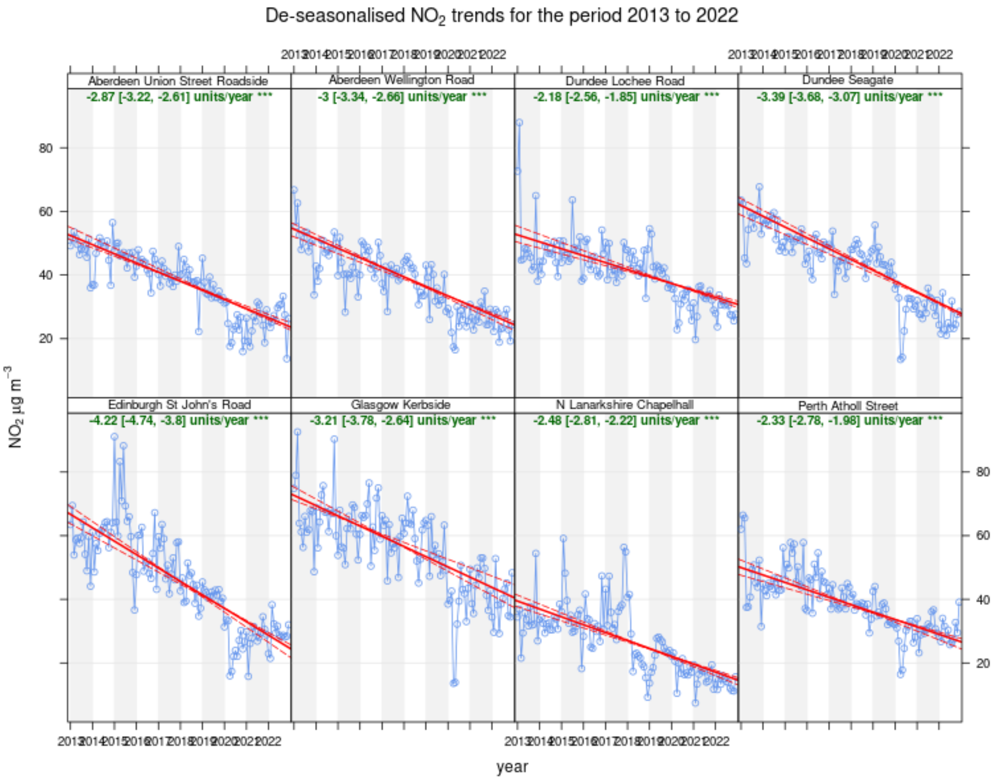
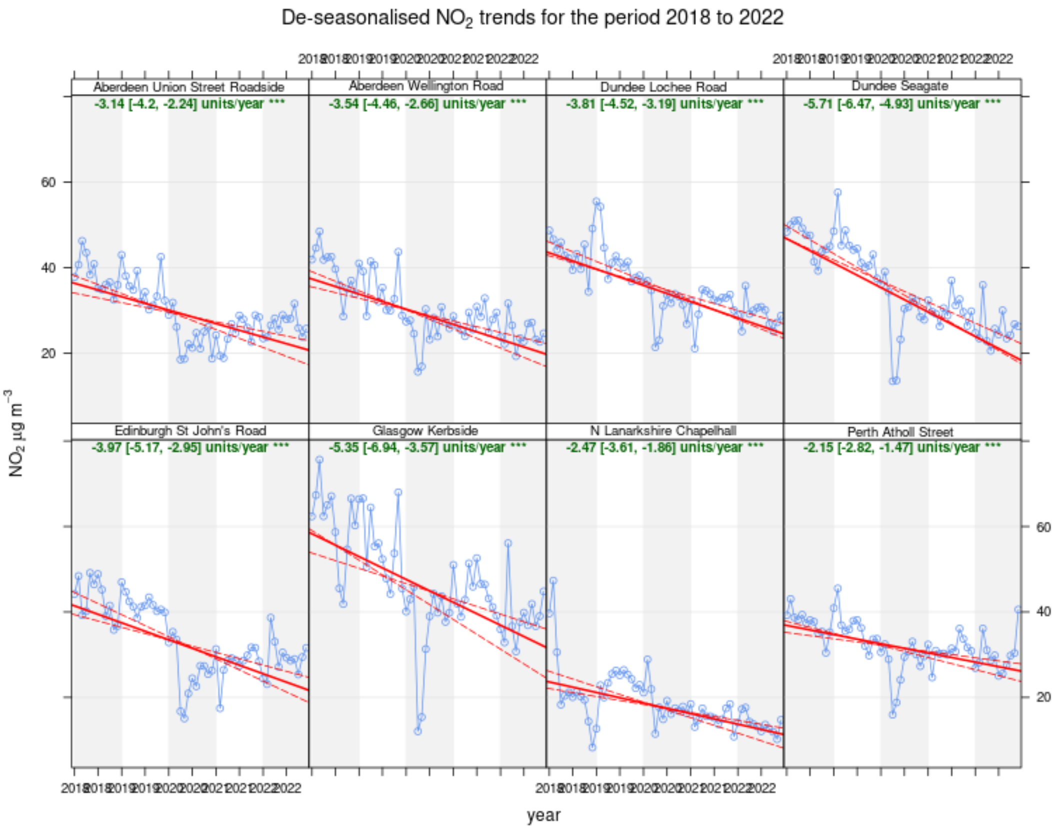


Figure 8-6 Recent trends in NO_2 concentrations at eight long-running Urban Traffic sites with exceedances, 2018-2022



8.2 PARTICULATE MATTER AS PM_{10}

This pollutant is of particular interest because:

- Current evidence suggests that there is no safe level of particulate matter in terms of human health effects.
- Scotland's current annual mean PM_{10} objective is 18 µg m^{-3}, which is more stringent than the objective of 40 µg m^{-3} adopted in the rest of the UK.
- In 2016 Scotland opted to make its annual mean $PM_{2.5}$ objective more stringent, by reducing it from 12 µg m^{-3} to 10 µg m^{-3} in line with the World Health Organization guideline.

It should be highlighted that FIDAS data used within this trend analysis for both PM_{10} and $PM_{2.5}$ has not been adjusted using correction factors identified by the Scottish Government report "Equilance Study to Investigate Moniorting in Scotland Using the FIDAS 200[9]". A guidance note[10] issued by the Scottish Government regarding this, states that Particulate matter data should only be corrected within the local authorities LAQM report system as the correction factors identified do not supersede the UK equivalence results.

8.2.1 PM_{10} at Urban Background Sites

There are now eight urban background sites in Scotland that have been monitoring PM_{10} for 10 years or longer. These are: Aberdeen Errol Place, Dundee Broughty Ferry Road, Dundee Mains Loan, Edinburgh St Leonards, Glasgow Anderston, Grangemouth, Falkirk Grangemouth MC, and North Lanarkshire Coatbridge Whifflet. Dundee Broughty Ferry Road and Grangemouth are urban industrial; the rest are urban background.

Figure 8-7 shows trends in de-seasonalised monthly mean PM_{10} at this subset of long-running sites. All eight sites showed a highly statistically significant (at the 0.001 level) decreasing trend. Trends in the most recent five years are also examined in Figure 8-8. Although the decreasing trend is still evident at all sites over the past five years it is no longer highly significant at all sites. The exception to this is Glasgow Anderston, which now shows a slight increasing trend with no statistical significancy. This analysis indicates that concentrations have plateaued over recent years at this location.

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[9] https://www.scottishairquality.scot/technical-reports/equivalence-study-investigate-particulate-matter-monitoring-scotland-using-fidas

[10] https://www.scottishairquality.scot/technical-reports/local-authority-guidance-note-laqm-reporting-scottish-pm-data

Figure 8-7 Trends in PM_{10} concentrations at six long-running Urban Background and Urban Industrial sites, 2008 – 2022

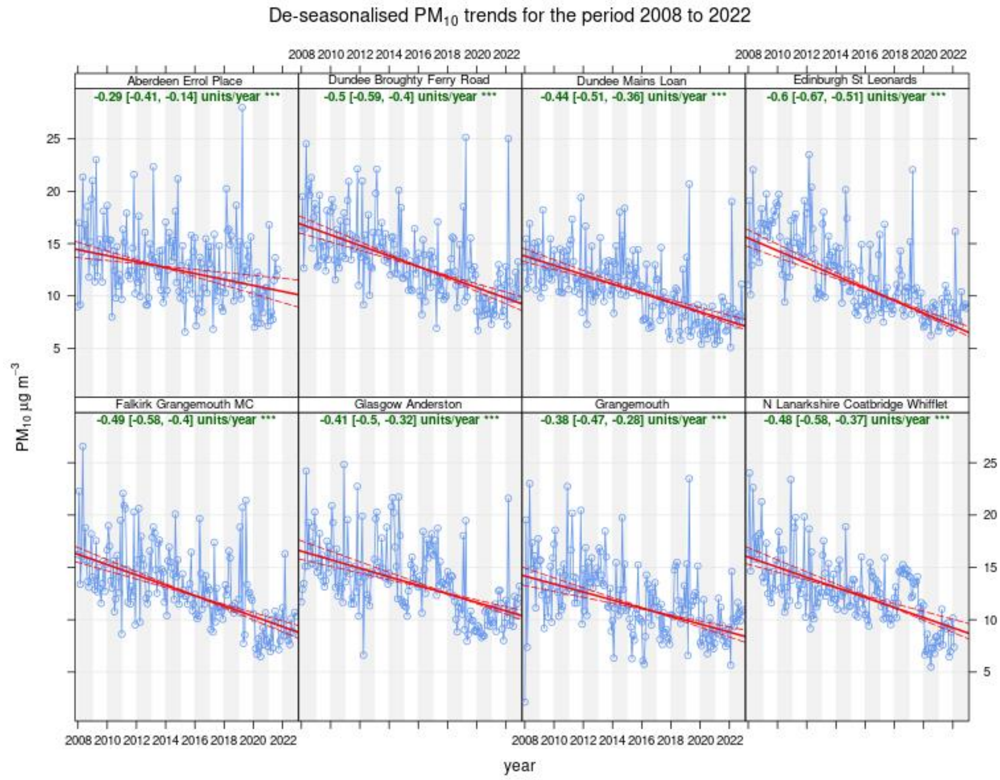
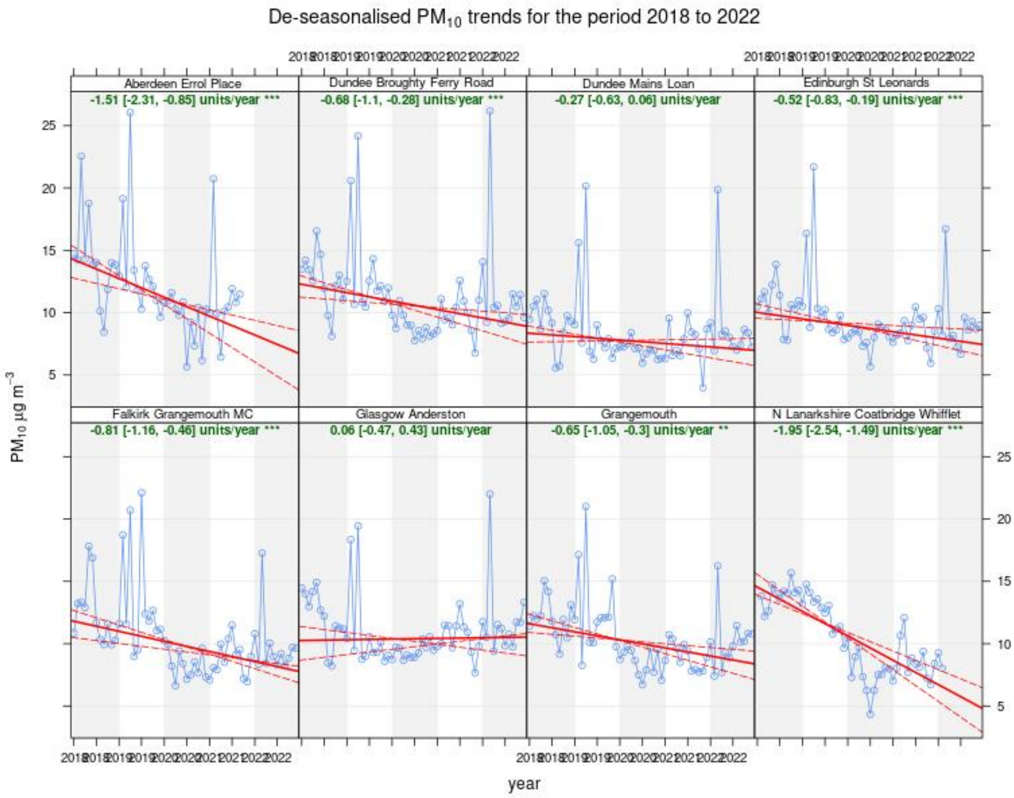


Figure 8-8 Trends in PM_{10} concentrations at six long-running Urban Background and Urban Industrial sites, 2018 – 2022



8.2.2 PM_{10} at Urban Traffic Sites

There are 51 PM_{10} monitoring sites in Scotland that have been monitoring for over 10 years. These are as follows:

- Aberdeen Anderson Dr
- Aberdeen King Street
- Aberdeen Market Street 2
- Aberdeen Union Street Roadside
- Aberdeen Wellington Road
- Alloa
- Dundee Broughty Ferry Road
- Dundee Lochee Road
- Dundee Meadowside
- Dundee Seagate
- Dundee Union Street
- E Ayrshire Kilmarnock St Marnock St
- East Dunbartonshire Kirkintilloch
- East Dunbartonshire Milngavie
- East Lothian Musselburgh N High St
- Edinburgh Glasgow Road
- Edinburgh Queen Street
- Edinburgh Queensferry Road
- Edinburgh Salamander St
- Falkirk Banknock
- Falkirk Grangemouth MC
- Falkirk Haggs
- Falkirk Park St
- Falkirk West Bridge Street
- Fife Dunfermline
- Fife Kirkcaldy
- Fife Rosyth
- Glasgow Abercromby Street
- Glasgow Anderston
- Glasgow Broomhill
- Glasgow Burgher St.
- Glasgow Dumbarton Road
- Glasgow Kerbside
- Inverclyde Greenock Dunlop Street
- N Lanarkshire Chapelhall
- N Lanarkshire Coatbridge Whifflet
- N Lanarkshire Croy
- N Lanarkshire Moodiesburn
- N Lanarkshire Motherwell
- N Lanarkshire Shawhead Coatbridge
- North Lanarkshire Cumbernauld
- Perth Atholl Street
- Perth Crieff
- Perth High Street
- Perth Muirton
- South Ayrshire Ayr High St
- South Lanarkshire East Kilbride
- South Lanarkshire Rutherglen
- Stirling Craig's Roundabout
- West Lothian Broxburn
- West Lothian Newton

Trends in de-seasonalised monthly mean PM_{10} concentrations for eight traffic-related sites in operation since 20 or earlier are shown in Figure 8-9. The sites selected for this analysis are Aberdeen Wellington Road, East Dunbartonshire Bearsden, Edinburgh Salamander, Fife Cupar, Glasgow Anderston, Glasgow Byres Road, Perth Crieff and West Lothian Broxburn. These sites were selected for analysis because of the length of time they have been monitoring (10 years or more), historical exceedances of the annual mean objective and geographical coverage.

All sites showed highly statistically significant decreasing trends (at the 0.001 level), with the exception of Glasgow Byres Road. The analysis indicates that PM_{10} over the past 10 years is decreasing year on year at all sites except Glasgow Byres Road where analysis shows that concentrations, though flucatating significantly over the years, have not changed.

Trends in monthly mean PM_{10} concentrations for the same eight sites (plus Edinburgh Queensferry Road), for the most recent five complete years 2018 – 2022, are shown in Figure 8-10. The analysis shows that the decreasing trend is plateauing at a number of sites with varying levels of statistical significancy. In contrast to the 10-year analysis, the five-year analysis for Glasgow Byres Road shows that concentrations are now decreasing with high statistical significancy.

Figure 8-9 Trends in PM_{10} concentrations at eight long-running Urban Traffic sites, 2013 – 2022

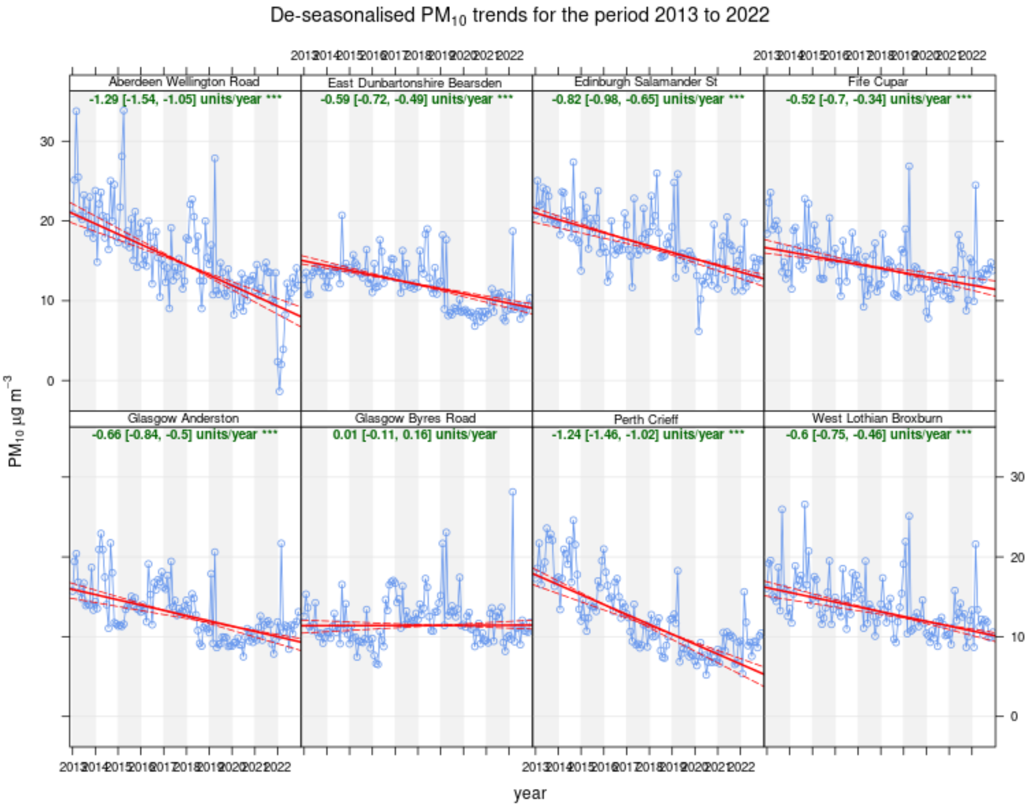
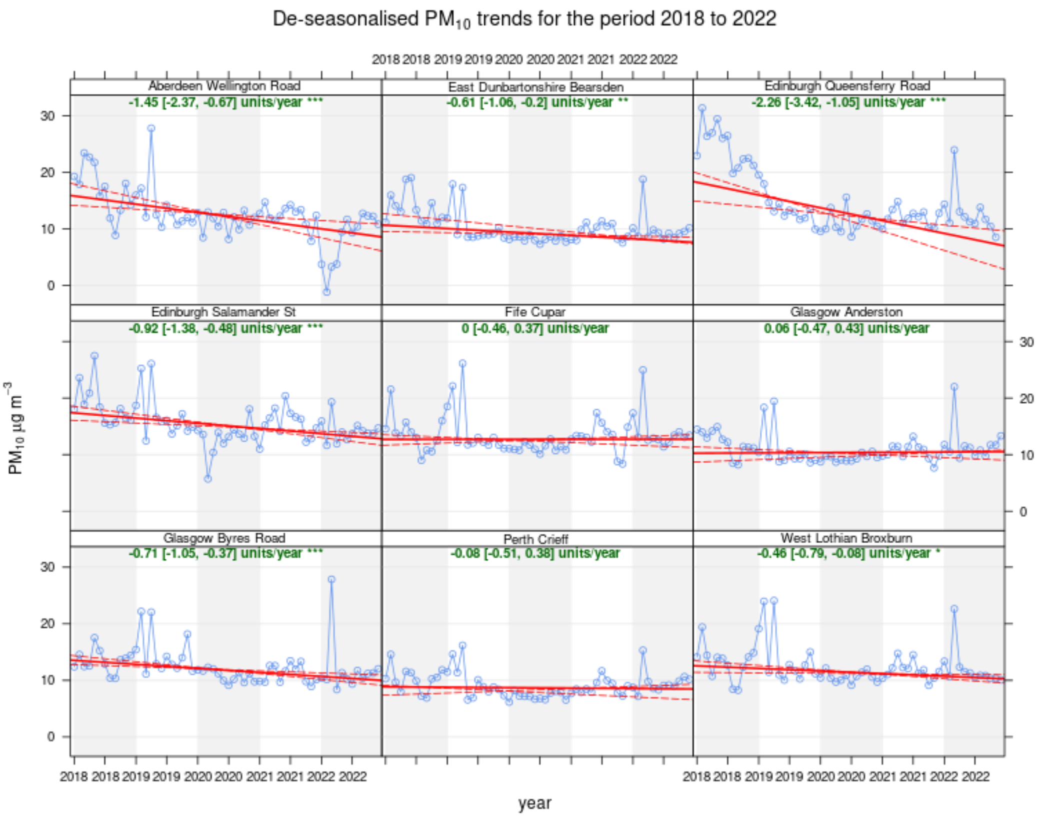


Figure 8-10 Trends in PM_{10} concentrations at eight long-running Urban Traffic sites, 2018 – 2022



8.3 PARTICULATE MATTER AS $PM_{2.5}$

In earlier years, most monitoring of particulate air pollution was focused on the PM_{10} size fraction. However, the finer fractions such as $PM_{2.5}$ are now of more interest in terms of health effects. Fine particles can be carried deep into the lungs where they can cause inflammation and a worsening of the condition of people with heart and lung diseases. They may also carry harmful compounds, adsorbed on their surfaces, into the lungs.

At the time of writing this report there are 84 sites monitoring $PM_{2.5}$ in Scotland. However, the vast majority of these sites started monitoring in the last six years with the introduction of the $PM_{2.5}$ objective and the requirement for local authorities to measure the pollutant. By the end of 2022 there were four sites with 10 consecutive years of $PM_{2.5}$ data. These sites are as follows: Aberdeen Errol Place (UB), Auchencorth Moss (RB), Edinburgh St Leonards (UB), and Grangemouth (UI). The trend plot for these sites is shown in Figure 8-11. As state previously Aberdeen Errol Place was replaced by Aberdeen Errol Park in September 2021.

The analysis shows that all sites show a slight decreasing trend over the 10-year time period at varying levels of statistical significancy.

As of the end of 2022, there were an additional 32 sites (all urban traffic) with more than five years' worth of data, the minimum required for this type of trend analysis. The sites are:

- Aberdeen Union Street Roadside
- Aberdeen Wellington Road
- Alloa A907
- Dundee Lochee Road
- E Ayrshire Kilmarnock St Marnock St
- East Dunbartonshire Kirkintilloch
- Edinburgh St John's Road
- Fife Cupar
- Fife Dunfermline
- Fife Kirkcaldy
- Fife Rosyth
- Glasgow Byres Road
- Glasgow Dumbarton Road
- Glasgow High Street
- Glasgow Nithsdale Road
- Inverclyde Greenock A8
- N Lanarkshire Chapelhall
- North Ayrshire Irvine High St
- Perth Atholl Street
- Perth Crieff
- Perth High Street
- Renfrewshire Johnston
- South Ayrshire Ayr Harbour
- South Lanarkshire Cambuslang
- South Lanarkshire East Kilbride
- South Lanarkshire Hamilton
- South Lanarkshire Lanark
- South Lanarkshire Rutherglen
- South Lanarkshire Uddingston
- West Dunbartonshire Clydebank
- West Lothian Broxburn
- West Lothian Linlithgow High Street 2

For this report nine sites that represent a good geographical coverage of Scotland were selected to carry out trend analysis for $PM_{2.5}$. Figure 8-12 illustrates the trend for the nine $PM_{2.5}$ sites selected. As can be seen, all nine sites are very similar with slight decreasing trends at varying statistical significance. This is relatively consistent with the 10-year analysis shown in Figure 8-11.

Figure 8-11 Trends in $PM_{2.5}$ concentrations at four long-running monitoring sites, 2013 – 2022

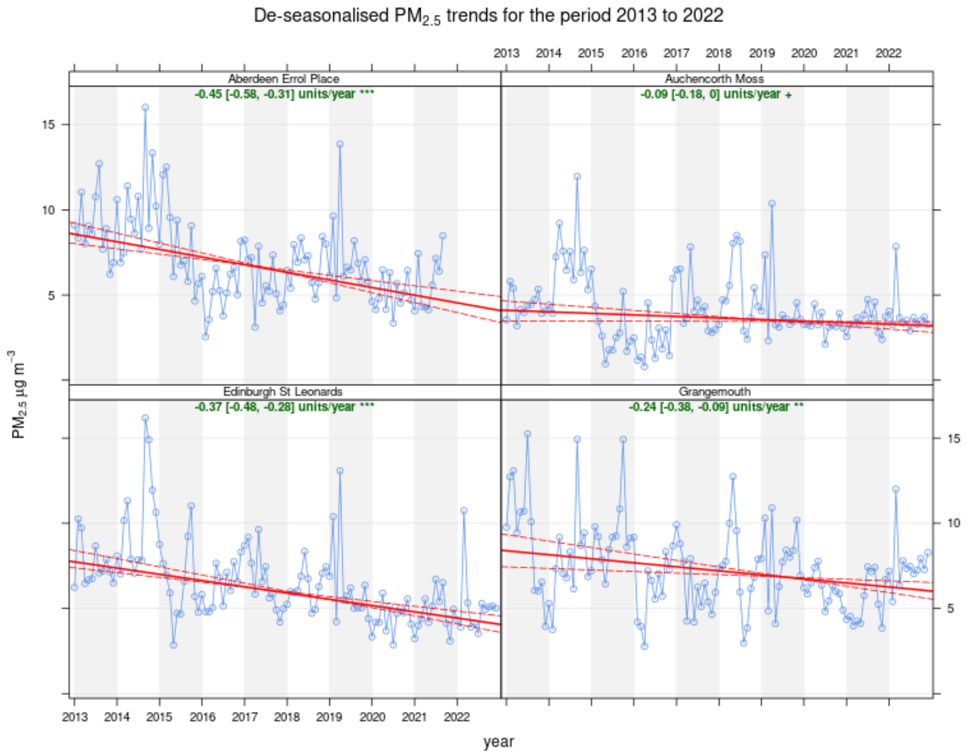
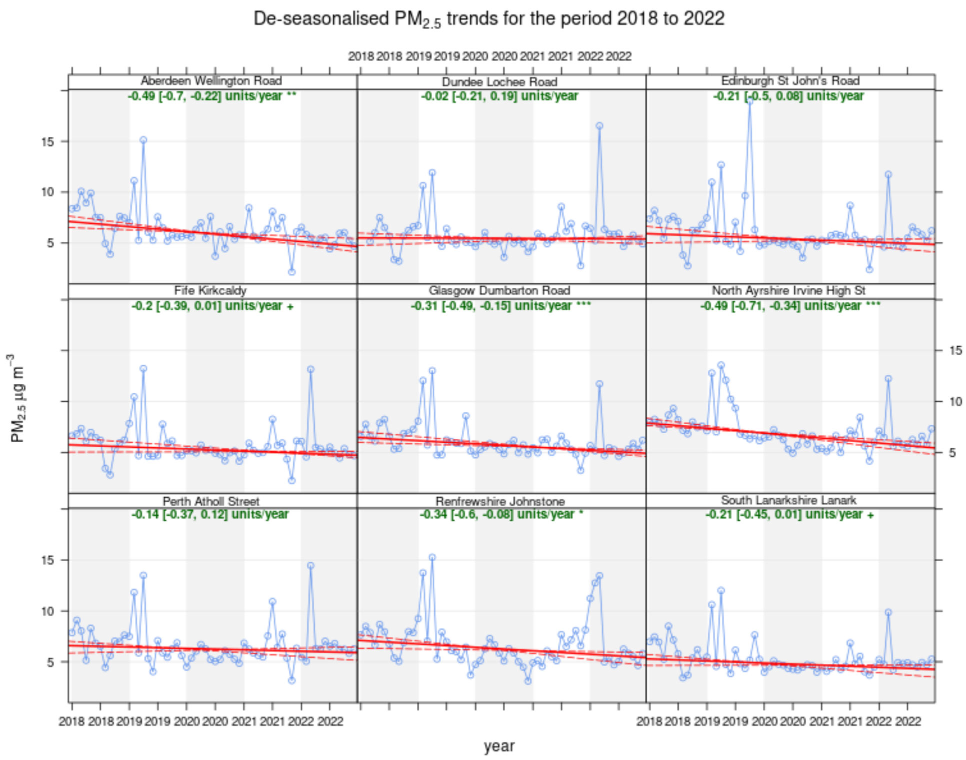


Figure 8-12 Trends in $PM_{2.5}$ concentrations at nine Urban traffic monitoring sites, 2018 – 2022



8.4 OZONE

8.4.1 Rural Ozone

Three of Scotland's rural air quality monitoring stations have been monitoring ozone for 32 years, 1986 – 2022. These are Bush Estate, Eskdalemuir and Strath Vaich. Figure 8-13 shows long-term trends in de-seasonalised monthly mean ozone (O_3) concentrations at these three exceptionally long-running rural monitoring sites. Bush Estate and Eskdalemuir both show small but statistically highly significant increasing trend in monthly mean rural ozone concentrations over this period. For Strath Vaich, there has been neither an increasing or decreasing trend over the same period with concentrations generally staying the same. The charts also show a significant amount of fluctuation; this may reflect the fact that ozone is formed by reactions involving other pollutant gases, in the presence of sunlight. Thus, ozone concentrations depend substantially on weather conditions. There is also evidence that the "hemispheric background" concentration of O_3 has increased since the 1950s due to the contribution from human activities.[11]

Six sites have been in operation for over 10 years. These are the above three sites, plus Auchencorth Moss, Glasgow Waulkmillglen Reservoir and Lerwick. Trends in ozone concentration at these six sites are shown in Figure 8-14. The ten-year trend analysis shows that three sites have increasing trends in O_3 concentrations at varying levels of statistical significance. The other three sites (Bush Estates, Eskdalemuir and Strath Vaich) have slight decreasing trends; however Bush Estate and Eskdalemuir shows no statistical significance and Strath Vaich is significant to 0.05.

[11] See the APIS webpage "Ozone" at http://www.apis.ac.uk/overview/pollutants/overview_O3.htm

Figure 8-13 Trends in O_3 concentrations at long-running rural sites, 1986 – 2022

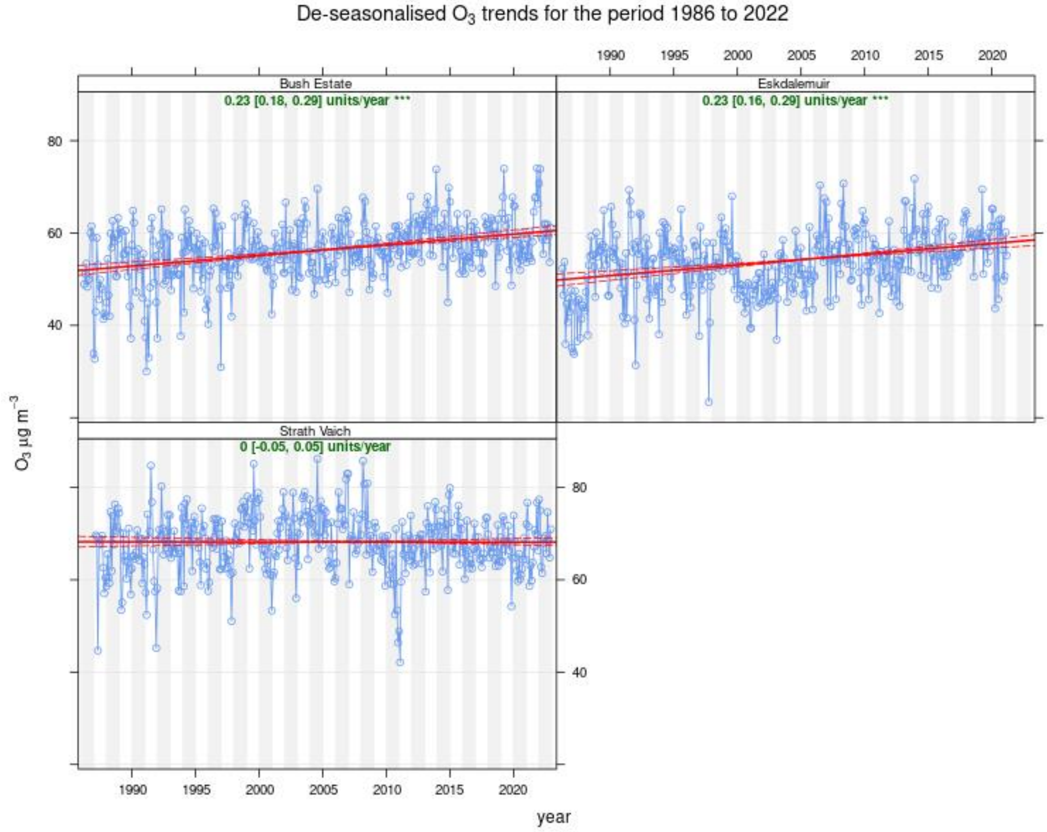
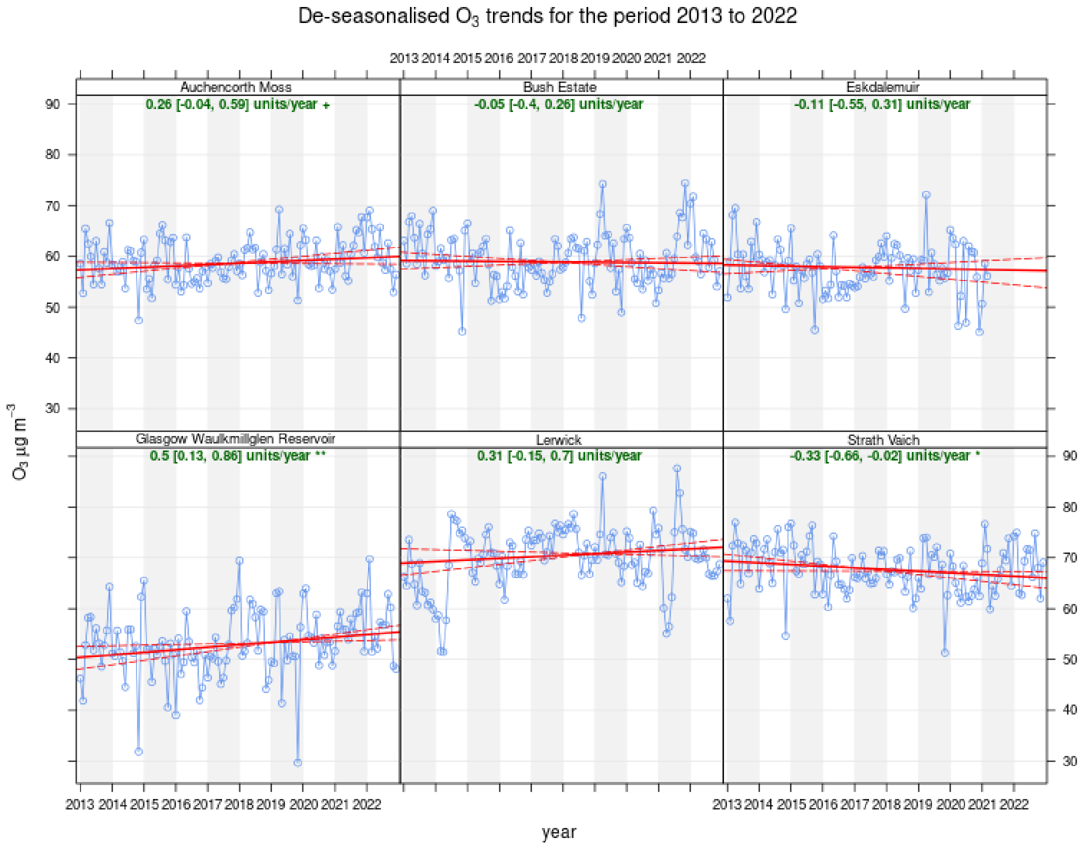


Figure 8-14 Trends in O_3 concentrations at six long-running Rural sites, 2013 – 2022



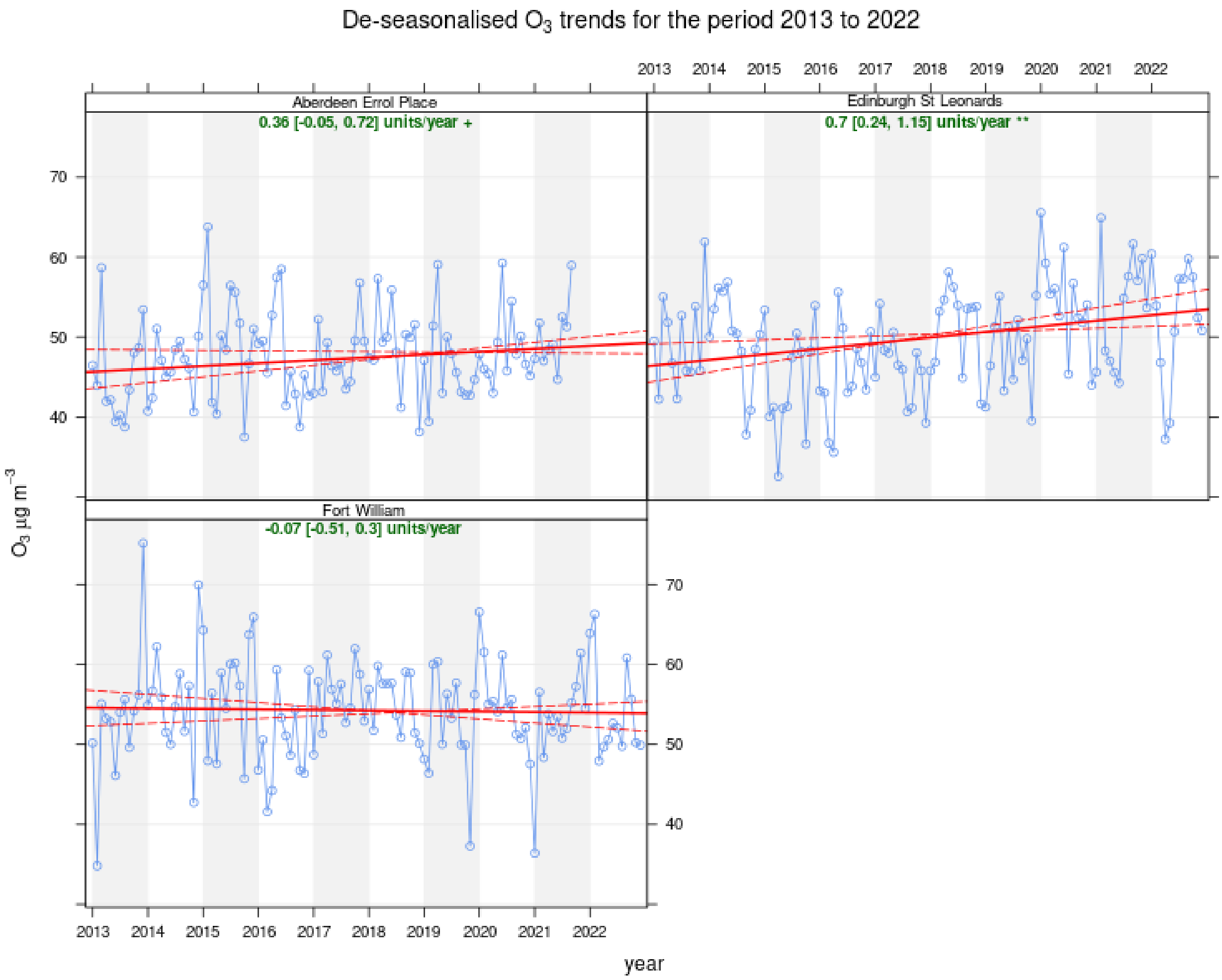
8.4.2 Urban Background Ozone

Figure 8-15 shows trends in de-seasonalised monthly mean ozone concentrations at the three Scottish urban background monitoring sites which have been monitoring ozone for the past 10 years, 2013-2022: Aberdeen Errol Place, Edinburgh St Leonards and Fort William.

Analysis shows that there is again increasing trends at two of the sites, Aberdeen Errol Place and St Leonards at varying statistical significancy. Fort William has a slight decreasing trend with no statistical significancy.

Contrary to other pollutants analysed in this section, there appears to be more of an (though not always statistically significant) increasing trend in ozone concentrations. This is consistent with previous years' reports.

Figure 8-15 Trends in O_3 concentrations at two long-running Urban Background sites, 2013 – 2022



8.5 ADDITIONAL TREND ANALYSIS

Additional analysis can be carried out on the SAQD monitoring data using analysis tools such as Openair. Openair provides free, open-source and innovative tools to analyse, interpret and understand air pollution data using R a free and open-source programming language designed for the analysis of data (https://www.r-project.org/). The Openair tools available on the Air Quality in Scotland website (http://www.scottishairquality.scot/data/openair) can be used to readily perform complex and innovative analysis of current and archived air pollutant data, allowing powerful data visualisation and interrogation capabilities. This annual analysis is also now provided in the local authority's annual statistical reports in an interactive format. These can be found here https://www.scottishairquality.scot/laqm/statistics. For this annual report a snapshot of this analysis has been carried out for four NO_2 automatic monitoring sites, located in the largest Scottish cities, that have historically measured exceedances. These sites are Aberdeen Wellington Road, Dundee Lochee Road, Edinburgh St Johns Road, and Glasgow Kerbside (Hope Street).

The analysis carried for this report includes polar plots, time variation plots, and calendar plots. An array of additional analysis techniques is available via the Openair tool.

Time variation analysis produces four separate panes combined into a single plot: The plotted output shows the average variation by day of the week and hour of the day combined (the top-most pane), hour of the day (diurnal variation, shown in the lower left pane), month of the year (seasonal variation in the lower middle pane) and day of week (lower right pane). The variation of a pollutant by time of day and day of week can reveal useful information concerning the likely sources at a particular site. In this report, time variation plots created using 2022 NO_2 data is compared to data from the previous 10 years.

Polar plots are useful to gain a quick graphical representation of the relationship between pollutant concentrations and the meteorological conditions. This can be useful in identifying potential sources of pollution affecting the location, for example particle suspension is increased at higher wind speeds. As with the time variation plots, polar plots created using 2022 NO_2 data are compared to plots generated using data from the previous 10 years. It should be noted that when comparing polar plots, the colour index can change so concentrations may relate to different colours in different plots.

Calendar plot analysis provides a way of visualising trends in daily pollutant concentrations across a year in the familiar form of a calendar. Concentrations are represented with a colour scale and the meteorological conditions can be represented using arrows giving the vector averaged modelled wind direction. In this way pollution episodes can be identified by date and sources potentially indicated by the combination of pollutant and meteorological conditions.

Figures 8-16 to 8-19 illustrate this analysis for the four sites discussed.

Figure 8-16 Openair analysis – Aberdeen Wellington Road

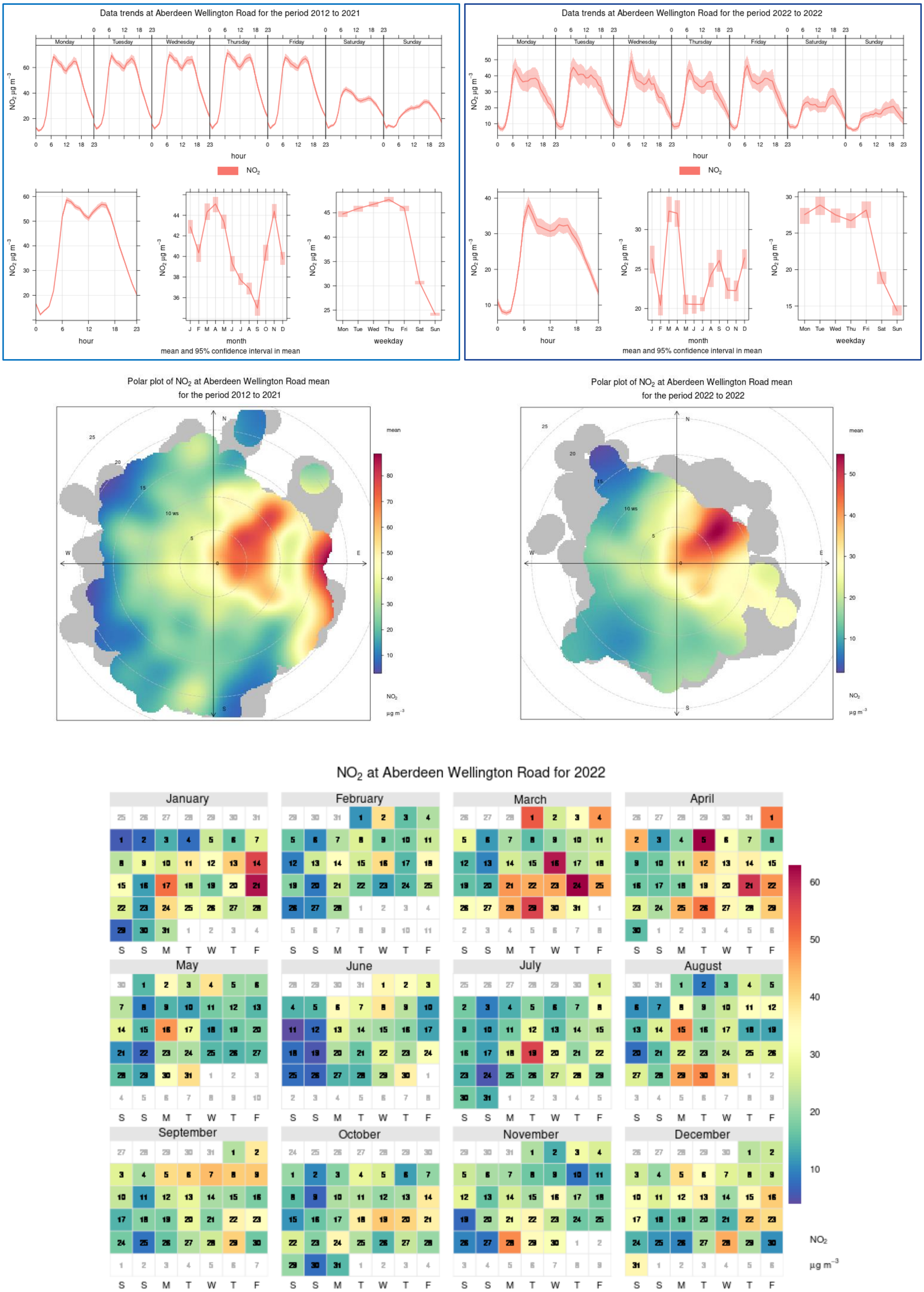


Figure 8-17 Openair Analysis – Dundee Lochee Road

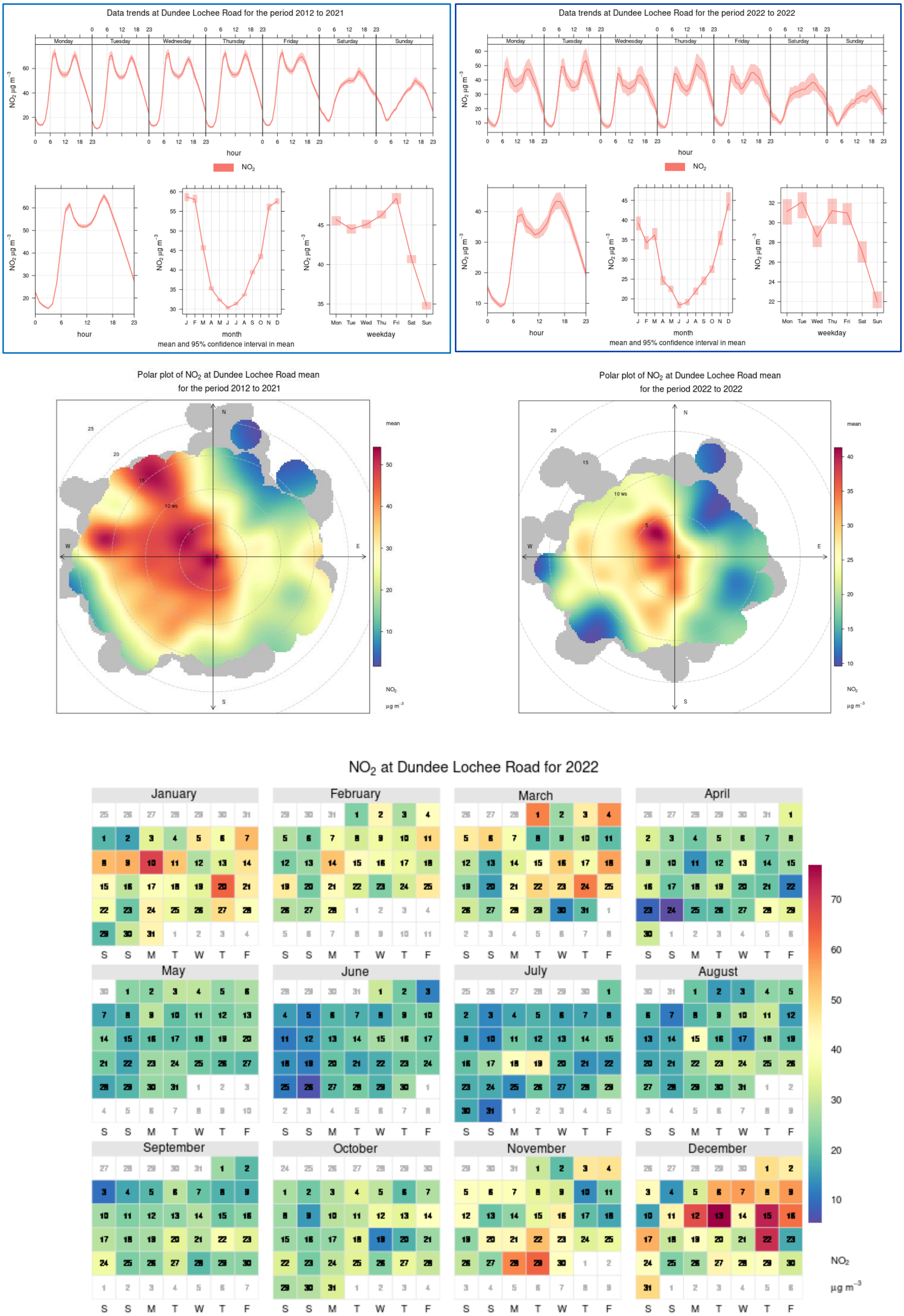


Figure 8-18 Openair Analysis – Edinburgh St Johns Road

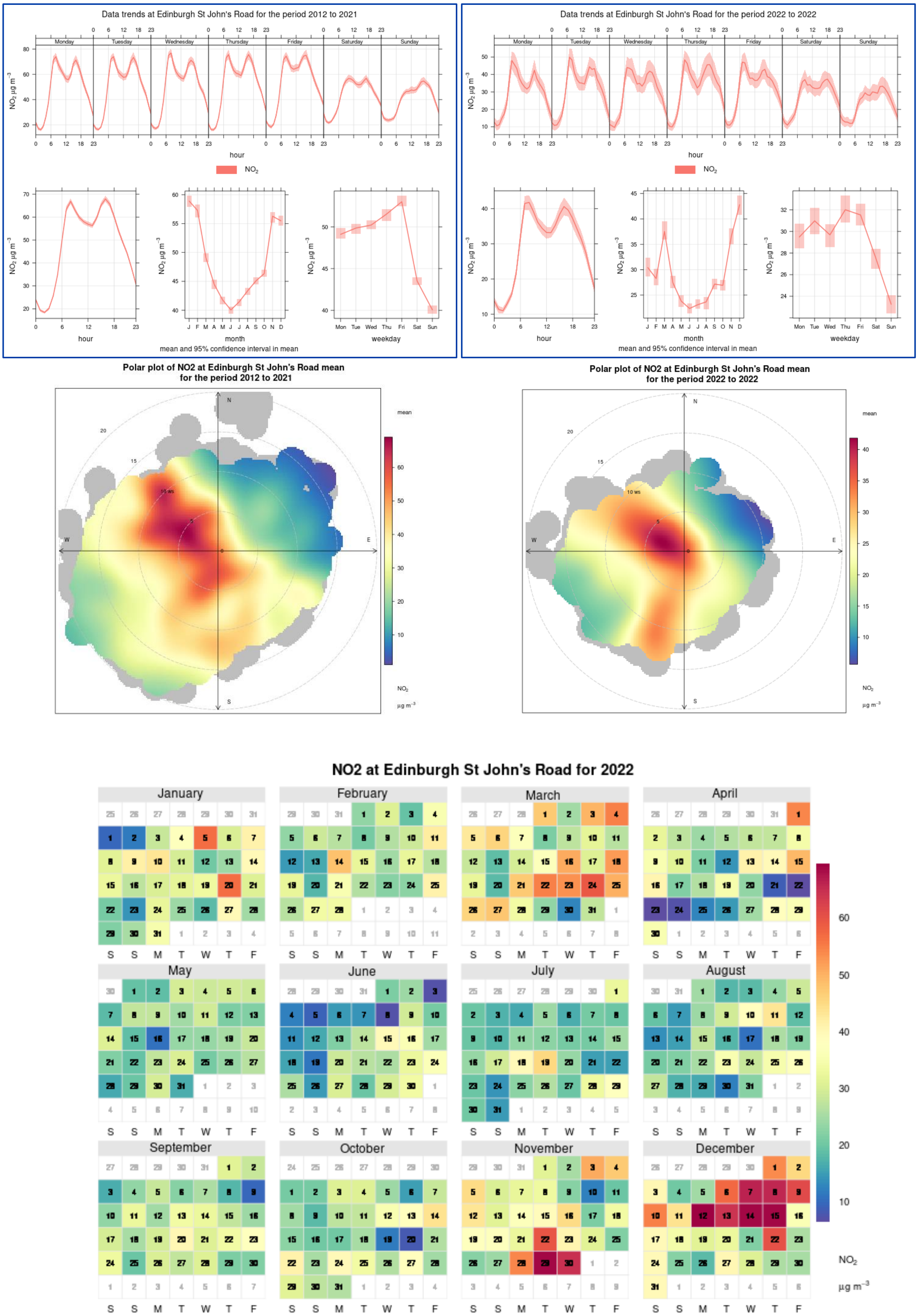
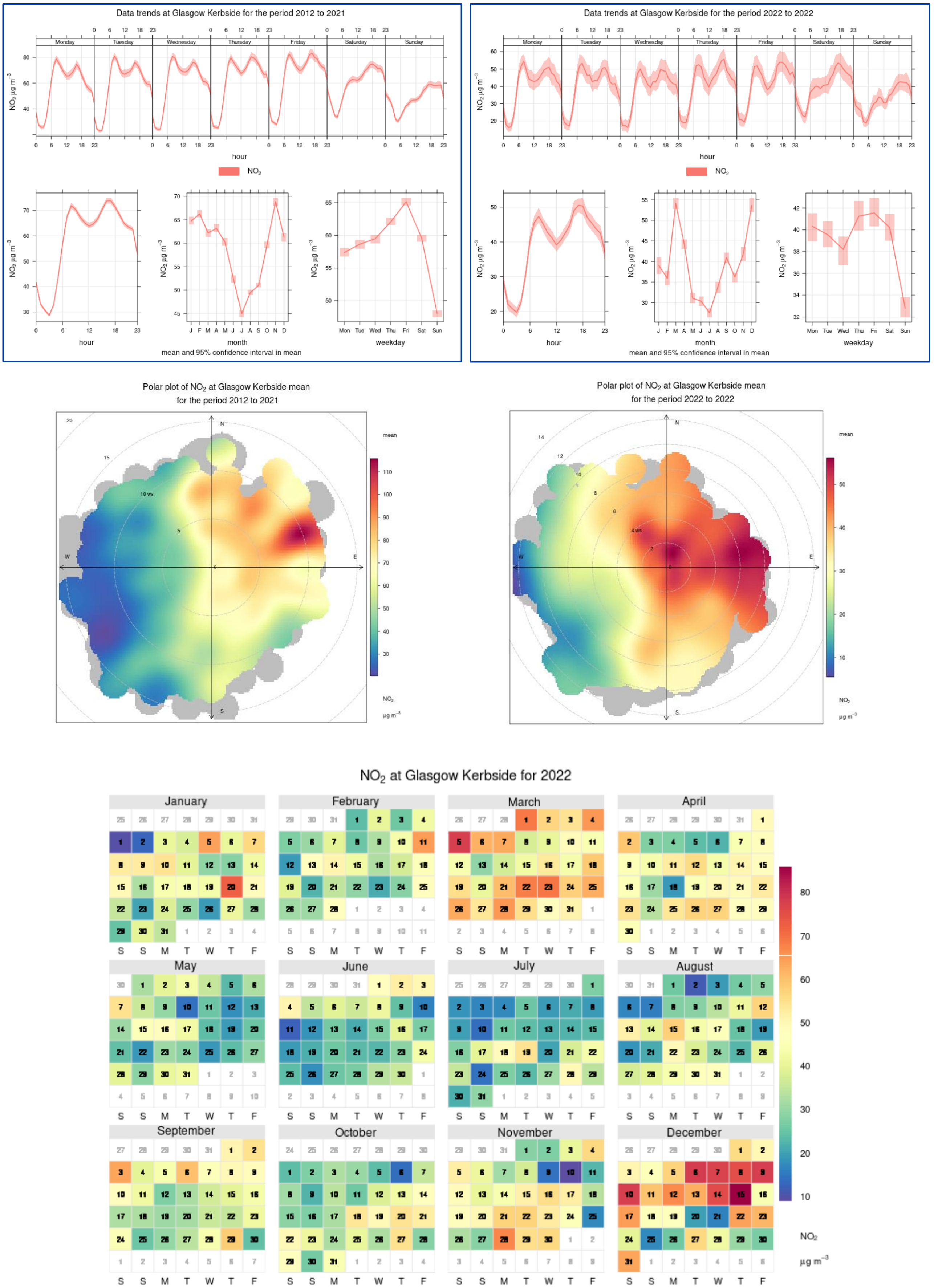


Figure 8-19 Openair Analysis – Glasgow Kerbside



9 EMISSION OF POLLUTION SPECIES

In this chapter we provide information on emissions of pollutants into the atmosphere in Scotland. The UK National Atmospheric Emissions Inventory (NAEI) calculates total emissions for the UK from a comprehensive range of sources including industry, domestic, transport etc. The UK inventory is now disaggregated into the UK constituent countries . The inventory covers a wide range of pollutants, but in this report will mainly focus on NOx, Particulate Matter (PM_{10}, and $PM_{2.5}$), Ammonia, CO, SO_2 and VOC. Data on Benzene (a) Pyrene (B(a)p), Dioxins, lead (Pb), and Mercury (Hg) can be found in appendix 4. Information on other pollutants can be found at www.naei.org.uk.

Within Scotland, SEPA collates the detailed information on emissions from industrial sources into the Scottish Pollution Release Inventory (SPRI); this includes emissions to water and soil as well as to air. Full details are available on the SEPA SPRI database:

http://www.sepa.org.uk/air/process_industry_regulation/pollutant_release_inventory.aspx

There is also a link to the SEPA SPRI website on the home page of http://www.scottishairquality.scot/data/emissions. The data from the SPRI form the basis of the industrial emission data for Scotland which are incorporated into the NAEI.

Information provided in Section 9.1 of this report on the main industrial emissions in Scotland has been compiled from the information presented on SEPA's SPRI database, with permission from SEPA. The data provided is up to 2021, which is the most recent data available at the time of writing this report.

In previous iterations of this report, data has been provided back to 1990. However, due to changes in the NAEI requirements and the fact that UK emission reduction targets for these air quality pollutants, under CLRTAP (Convention on Long-Range Transboundary Air Pollution) and the EU's NECD (National Emission Ceilings Directive) are based on a 2005 baseline, it was decided that reporting data from 1990 to 2004 was no longer required. This historic data was considered to be no longer relevant to either targets or policy.

For information on data back to 1990 and more detailed explanatory description of what is happening with individual emissions please refer to the "Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland" report series (naei.beis.gov.uk/reports/reports?report_id=1030) and also the Scottish Air Quality Database Annual Report series (https://www.scottishairquality.scot/news/reports/technical).

9.1 NAEI DATA FOR SCOTLAND

The NAEI data for Scotland are reported using the Nomenclature for Reporting (NFR) format. The Nomenclature for Reporting is a reporting structure that was introduced in 2001 and is used for submitting data to international organisations such as the United Nations Economic Commission for Europe (UNECE) and the European Monitoring and Evaluation Programme (EMEP).

Since the 2017 report, emissions data for $PM_{2.5}$ is included at the request of both the Scottish and UK Governments. It should be note however that the emissions dataset for $PM_{2.5}$ is very limited, and the inventory is heavily based on assumptions of $PM_{2.5}$ share of the PM_{10} for different emissions sources. In addition, it should also be noted that the indicative uncertainty rating for both PM_{10} and $PM_{2.5}$ is "High". For more information on the uncertainty assessment see section 1.4 of "Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2021"[12].

When comparing previously reported emissions with the most recent data, there may be a difference in the figures stated. This is because the emissions dataset is recalculated each year and a revision of historic time series is carried out if a more accurate and applicable data source becomes available.

Data and graphs provide in this report can also be found as interactive figures within the Air Quality in Scotland website Emissions Inventory page.

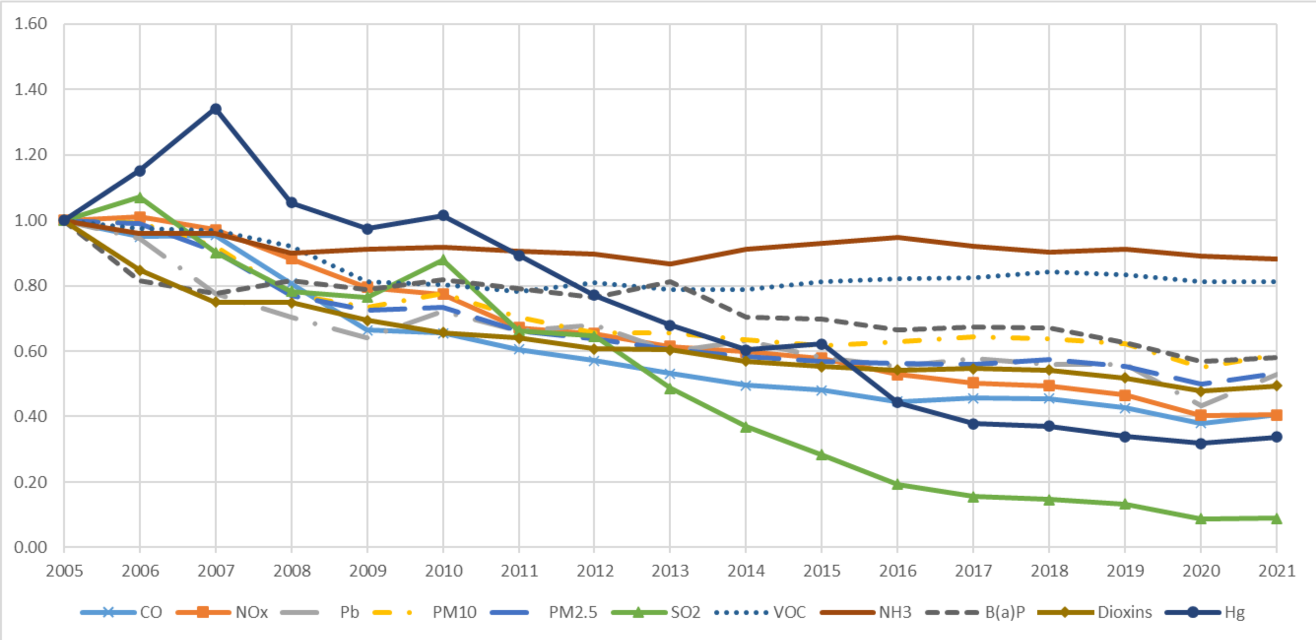
Figure 9-1 illustrates the change in emissions since 2005 of the eight pollutants stated, normalised to provide a relative rate of change. It shows that in general all emission levels have declined since 2005, however this decline has plateaued in recent years and in some cases begun to increase. In fact, VOCs emission levels

[12] https://naei.beis.gov.uk/reports/index

have increased since 2011. In terms of ammonia (NH_3), emission levels have not significantly changed at all since 2005 when compared to other pollutants and has seen no reduction since 2008. A number of pollutants have seen emission levels plateau over recent years.

It is worth noting that emissions across all sectors were impacted by the Covid-19 pandemic in 2020, due to various changes in activity by individuals, business, and industrial processes. As a result, greater emission increases are seen across most sectors between 2020 and 2021 than for other consecutive years in the time series. This is particularly true for pollutants for which the transport sector is a significant source, such as lead, as the lifting of travel restrictions resulted in an increase in traffic.

Figure 9-1 Scotland normalised trends for all monitored pollutants

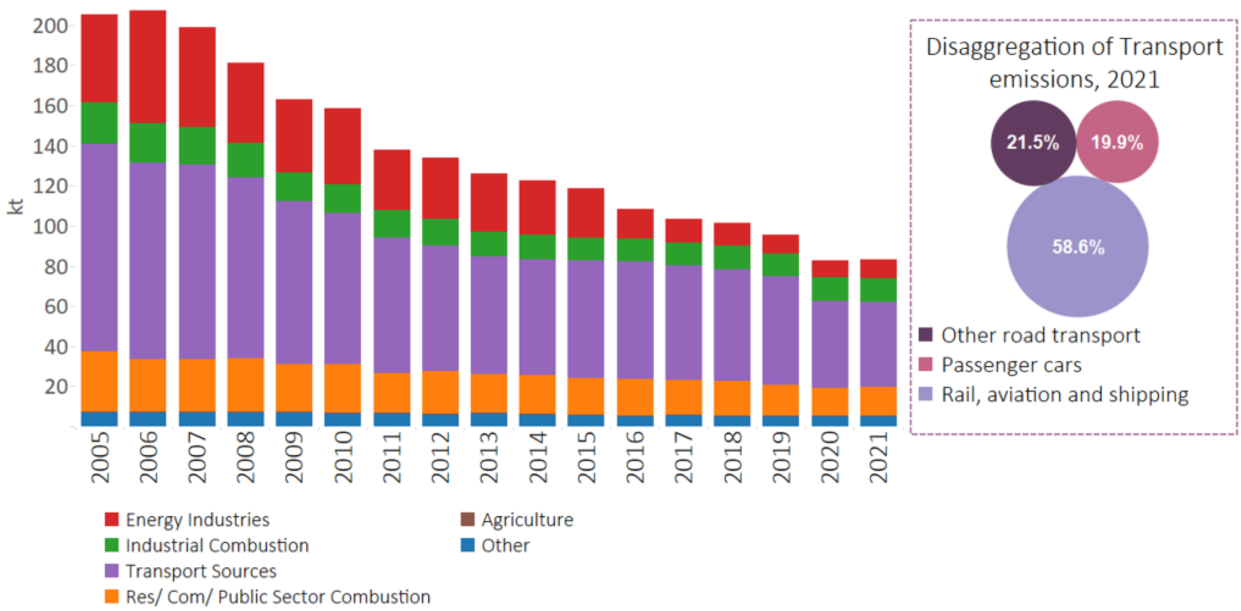


Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2021

9.2 NOX EMISSION ESTIMATES FOR SCOTLAND 2005 - 2021

Figure 9.2 provides a summary of NO_x emission estimates for Scotland by category. The detailed data are available in the report and website citied in the introduction to this chapter.

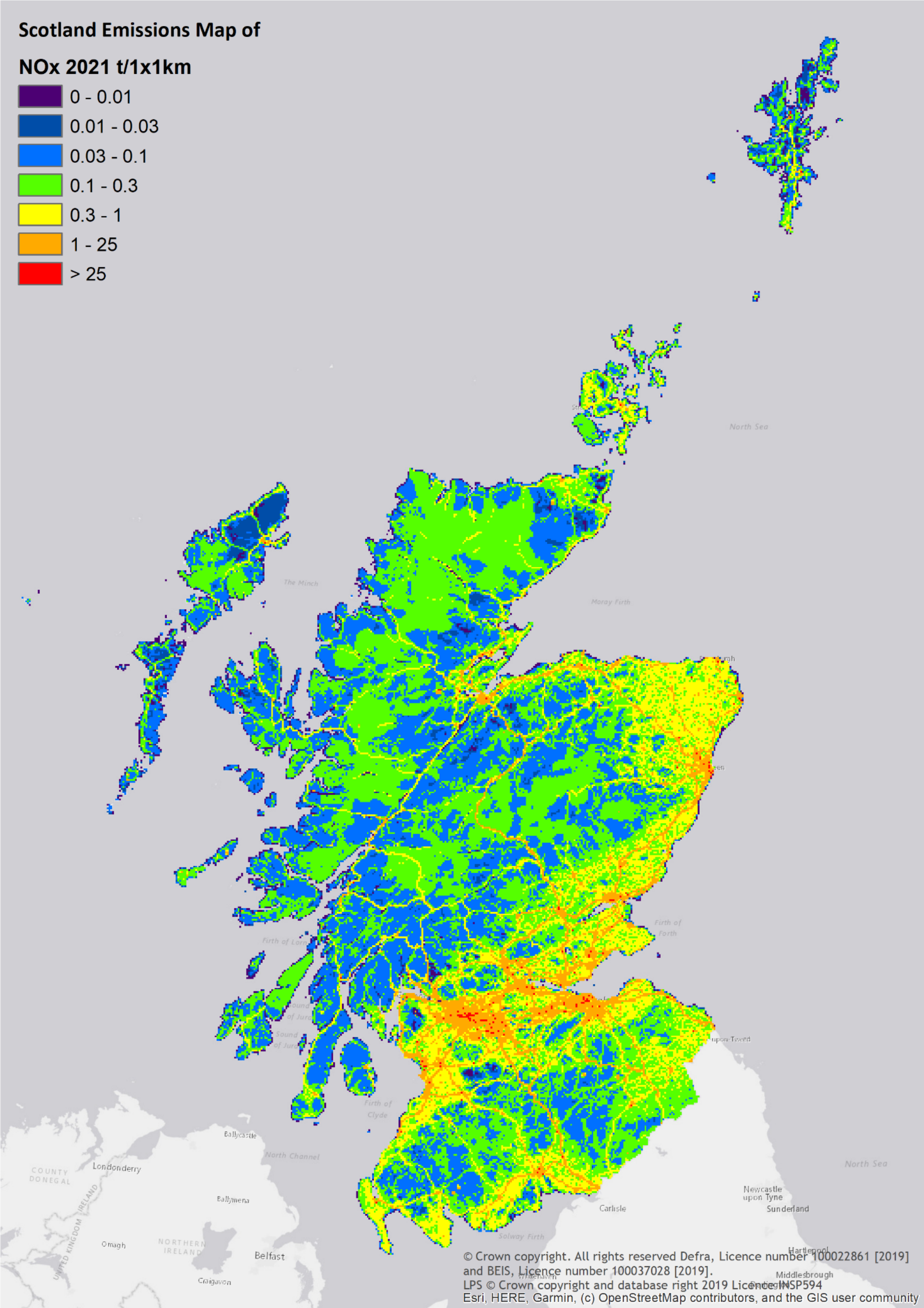
Figure 9-2 Time series of Scotland NO_x emissions 2005-2021



Units: kilotonnes (kt)
Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2021

Emissions of nitrogen oxides in Scotland were estimated to be 83 kt in 2021, representing 12% of the UK total for nitrogen oxides. Emissions have declined by 59% (61% in 2020) since 2005, mainly due to changes in transport sources, particularly in road transport. This decline is driven by the successive introduction of tighter Euro emission standards, and the continued penetration of vehicles which comply with these standards. In addition, improvements in catalyst repair rates resulting from regulations controlling the sale and installation of replacement catalytic converters and particle filters for light-duty vehicles contributes to the decline since 2008. However, the recent preferred uptake of diesel cars over petrol cars partly offsets these emissions reductions, because diesel cars emit higher NO_X relative to their petrol counterparts. The peak in NO_X emissions in 2006 is due to the increased use of coal at power stations that year. There was also a small increase in coal-fired generation in 2012 due to a UK-wide shift in power generation fuel mix from gas to coal in that year (BEIS, 2022a). Energy industry emissions have declined across the time series and is linked to Boosted Over-Fire Air (BOFA) abatement systems which were fitted to all four of Longannet's units, to reduce NO_X emissions from coal-fired generation by up to 25% (Scottish Power, 2012). BOFA systems were also fitted on all four units at Cockenzie power station which then closed in 2013 (Scottish Power, 2011). Longannet power station closed in March 2016 marking the end of coal combustion for power generation in Scotland and causing a step-change in emissions between 2015 and 2016. NO_X emissions increased by 0.6% between 2020 and 2021, with an associated 2.6% decrease in emissions in this period from the transport sector. 51% of the NO_X emissions were due to the transport sector in 2021. Figure 9.3 shows a map of Scotland's NO_x emissions in 2021.

Figure 9-3 Map of NO_x Emissions in Scotland, 2021

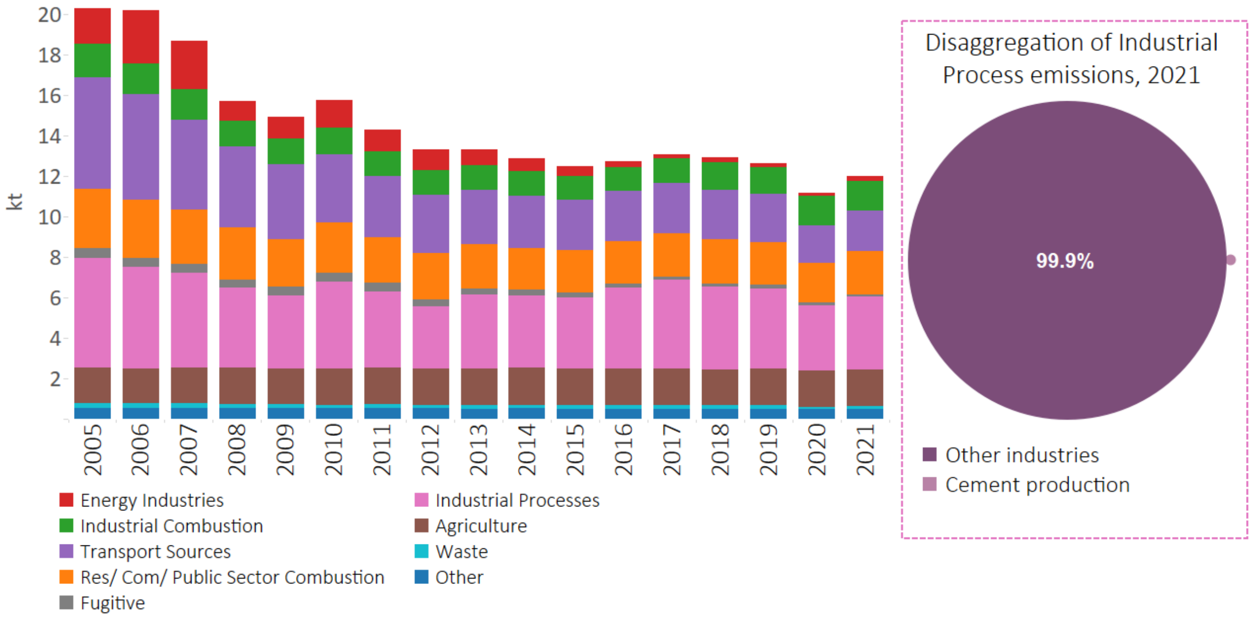


Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2021

9.3 PM_{10} EMISSIONS IN SCOTLAND

Figure 9-4 provides a summary of PM_{10} emission estimates for Scotland by category. The detailed data are available in the report and website cited in the introduction to this Chapter.

Figure 9-4 Time series of Scotland PM_{10} emissions 2005-2021

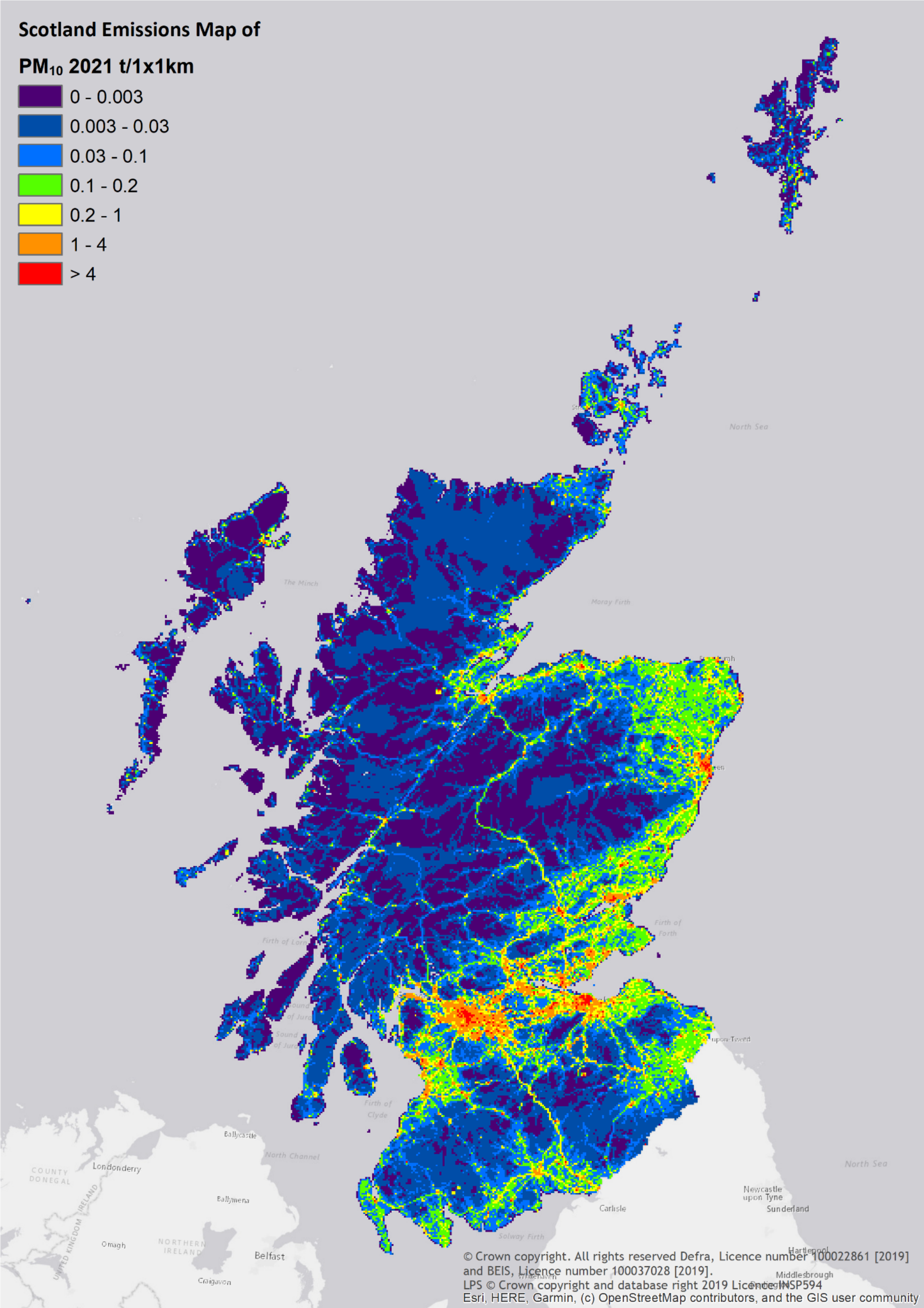


Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2021

Emissions of PM_{10} in Scotland were estimated to be 12 kt in 2021, declining by 41% (46% in 2020) since 2005. These emissions account for 8% of the UK total PM_{10} emissions. Unlike most other pollutants, the emissions profile of PM_{10} is diverse: transport sources, residential and industrial processes each accounted for over 15% of total PM_{10} emissions in 2021. Emissions from energy industries and transport sources have had the most notable impact on the trend. This reduction is primarily due to abatement at coal-fired stations, the increase in nuclear and renewable energy sources and the increase in the use of natural gas in energy generation (which has negligible PM_{10} emissions) in place of coal (BEIS, 2022a), as well as the continued increasing share of renewables in the energy mix. PM_{10} exhaust emissions from diesel-fuelled vehicles have been decreasing due to the continued fleet penetration of vehicles complying with more recent and more stringent Euro emissions standards. Increasingly non-exhaust sources of PM_{10} (for example tyre wear) have become more important to consider as exhaust PM_{10} has been reduced. In fact, in 2021, 84% of emissions from the road transport sector were related to non-exhaust sources. In recent years, emissions from the residential and other combustion sector have slightly increased, and this is due to an increasing quantity of wood fuel use, primarily in the residential sector (BEIS, 2022a). PM_{10} emissions increased by 7% between 2020 and 2021, led by increases in several sectors. The increase in emissions from the transport sector contributed to this trend by 21%, with PM_{10} emissions increasing by 9% from this sector between 2020 and 2021. This is primarily due to lifting of travel restrictions imposed during the onset of the COVID-19 pandemic. PM_{10} emissions also increased by 27% from the construction and demolition sector, accounting for 58% of the increase in PM_{10} emissions between 2020 and 2021. From 2020 to 2021, PM_{10} emission also increased by 36% from the aluminium production sector, accounting for 0.8% of the increase in PM_{10} emissions between these years.

Figure 9-5 shows a map of Scotland's PM_{10} emissions in 2021.

Figure 9-5 Map of PM_{10} Emissions in Scotland, 2021

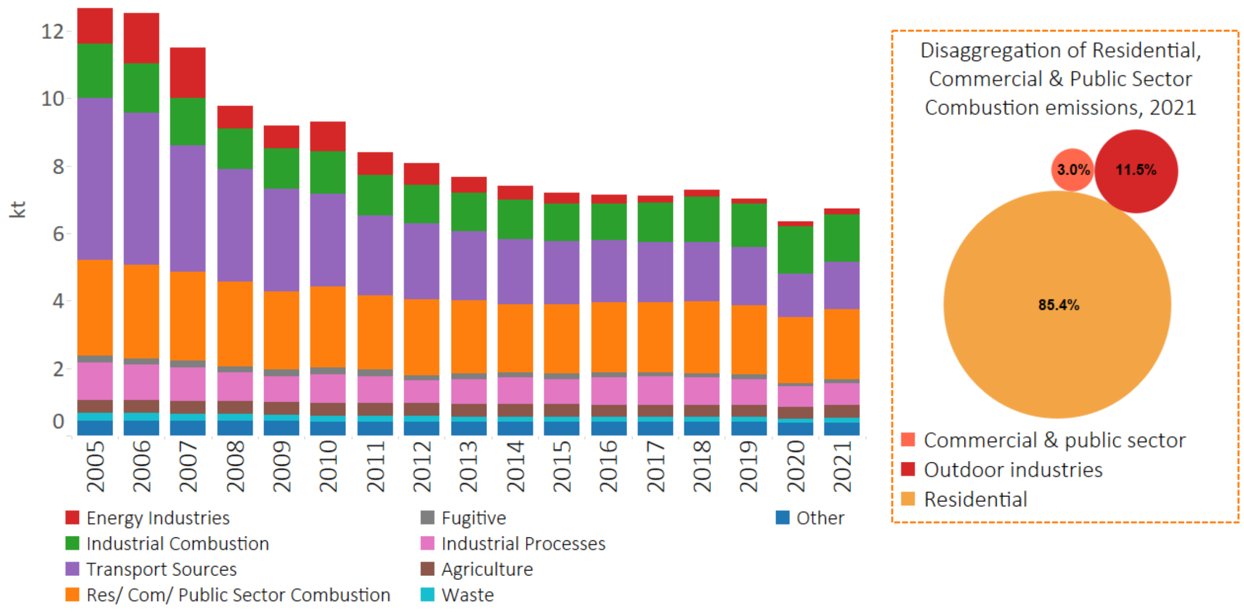


Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2021

9.4 $PM_{2.5}$ EMISSIONS IN SCOTLAND

Figure 9-6 provides a summary of $PM_{2.5}$ emission estimates for Scotland by category. The detailed data are available in the report and website citied in the introduction to this chapter.

Figure 9-6 Time series of Scotland $PM_{2.5}$ emissions 2005-2021

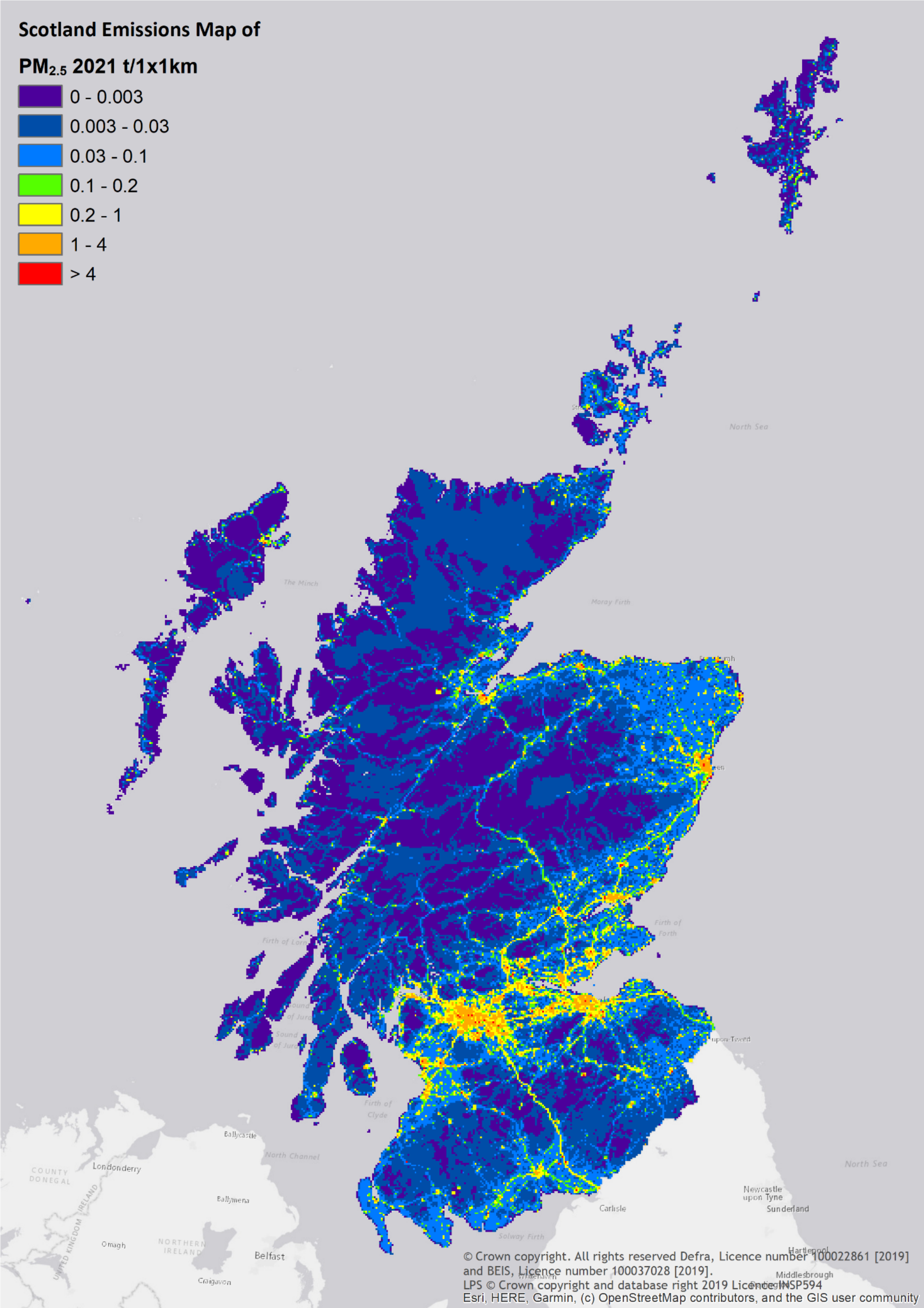


Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2021

Emissions of $PM_{2.5}$ in Scotland were estimated to be 7kt in 2021, declining by 47% (52% in 2020) since 2005. These emissions account for 8% of the UK total for $PM_{2.5}$ in 2021. As with PM_{10}, $PM_{2.5}$ emissions have a large number of significant sources. However, process emissions tend to produce coarser PM fractions and as such, combustion emissions are of greater importance for $PM_{2.5}$ compared to PM_{10}. For $PM_{2.5}$, the residential, commercial, and public sector combustion category (which includes agricultural combustion and fishing vessels – NFR code 1A4c) accounts for 31% of 2021 emissions. The primary drivers for the decline in emissions since 2005 are the continued switch from coal to natural gas in electricity generation, and reductions in emissions from the transport sector due to the introduction of progressively more stringent emissions standards through time. $PM_{2.5}$ emissions increased by 6% between 2020 and 2021, led by increases in several sectors. The increase in emissions from the transport sector contributed to this trend by 22%, with $PM_{2.5}$ emissions increasing by 7% from this sector between 2020 and 2021. This is primarily due to the lifting of travel restrictions imposed due to the COVID-19 pandemic. From 2020 to 2021, $PM_{2.5}$ emission also increased by 37% from the aluminium production sector, accounting for 1% of the increase in $PM_{2.5}$ emissions between these years.

Figure 9-7 shows a map of Scotland's PM_{10} emissions in 2021.

Figure 9-7 Map of $PM_{2.5}$ Emissions in Scotland, 2021

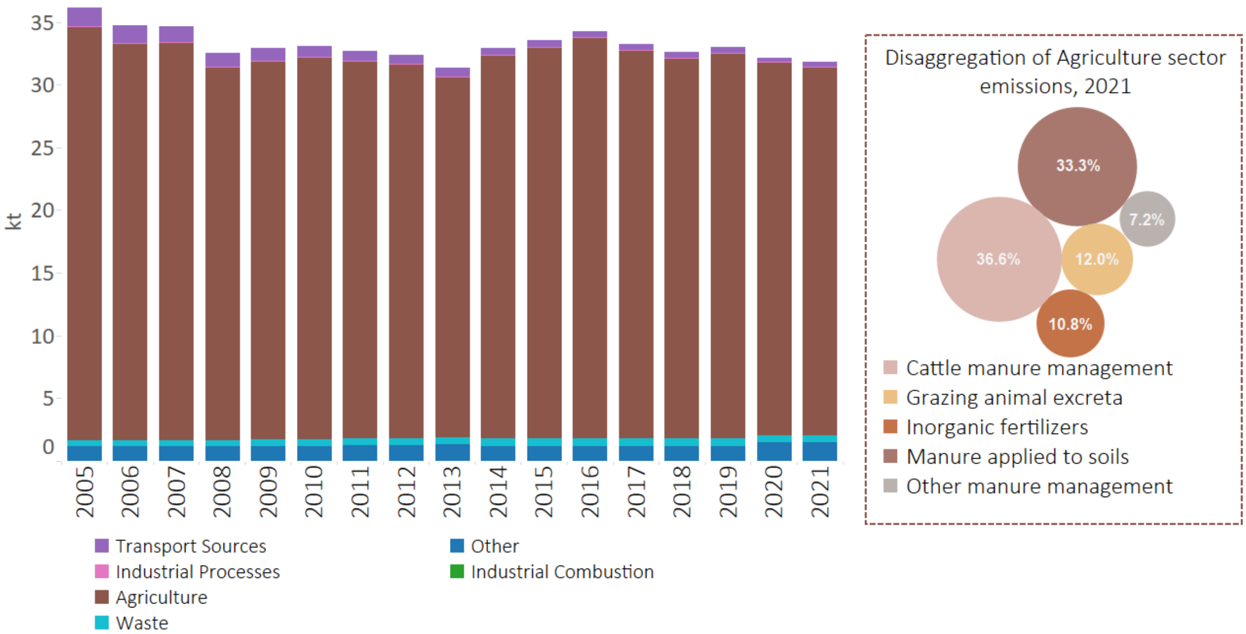


Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2021

9.5 AMMONIA EMISSIONS IN SCOTLAND

Figure 9-8 provides a summary of ammonia emission estimates for Scotland by category. The detailed data are available in the report and website citied in the introduction to this chapter.

Figure 9-8 Time series of Scotland Ammonia emissions 2005-2021

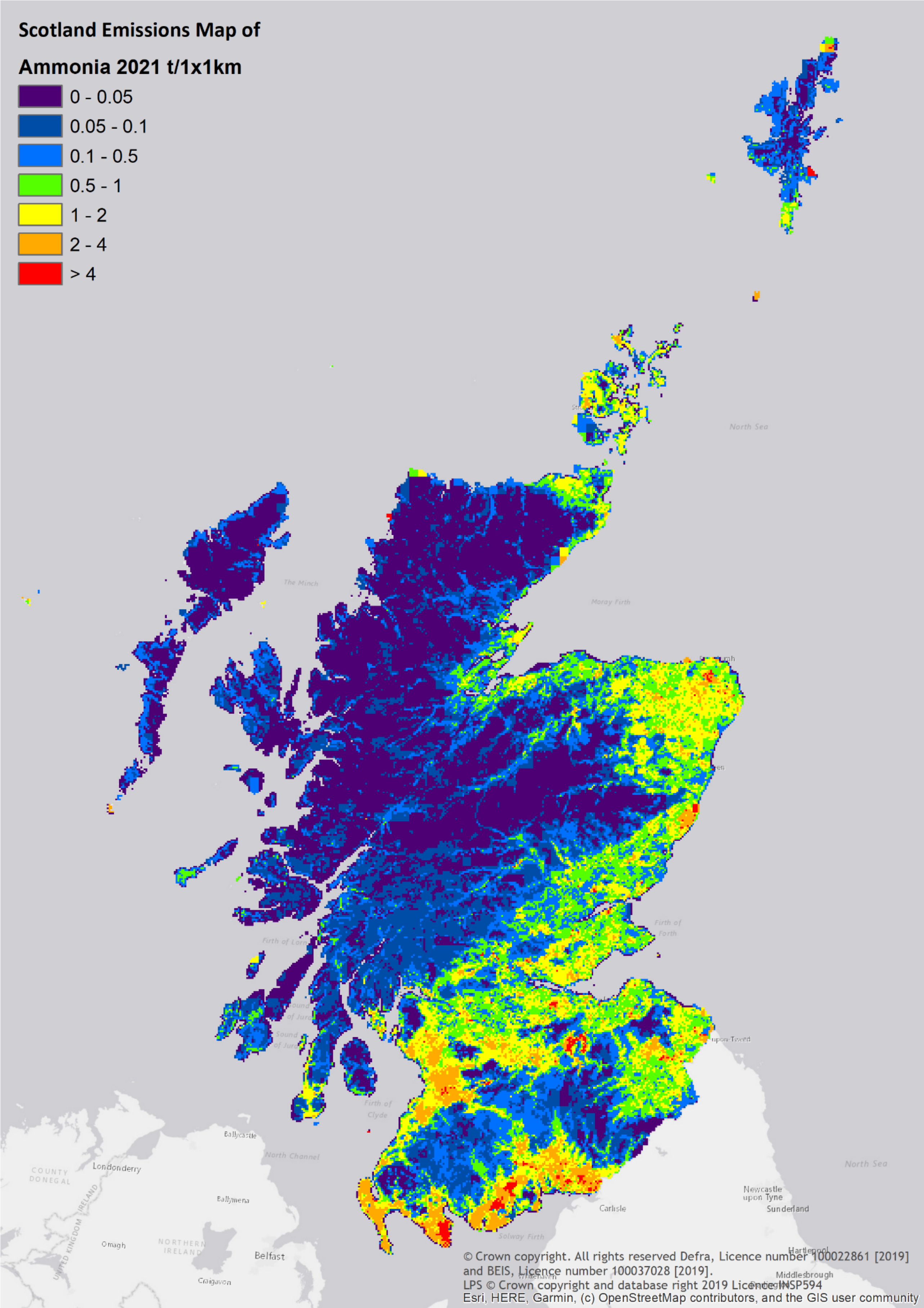


Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2021

Emissions of ammonia in Scotland were estimated to be 32 kt in 2021. These emissions have declined by 12% (10% in 2020) since 2005 and accounted for 12% of the UK total for ammonia in 2021. Agriculture sources have dominated the inventory throughout the time series, with cattle manure management accounting for at least 34% of the emissions from this sector across the entire time series. The initial trends in NH_3 emissions were primarily driven by decreases in livestock numbers (except for poultry) and declines in the use of nitrogen-based fertilisers. After 2010, however, the decline began to be offset by increased application of urea-based and organic fertilisers such as digestate to agricultural soils causing fluctuating emissions totals since 2008, with no significant trends across these years.

Figure 9-9 shows a map of Scotland's ammonia emissions in 2021.

Figure 9-9 Map of Ammonia Emissions in Scotland, 2021

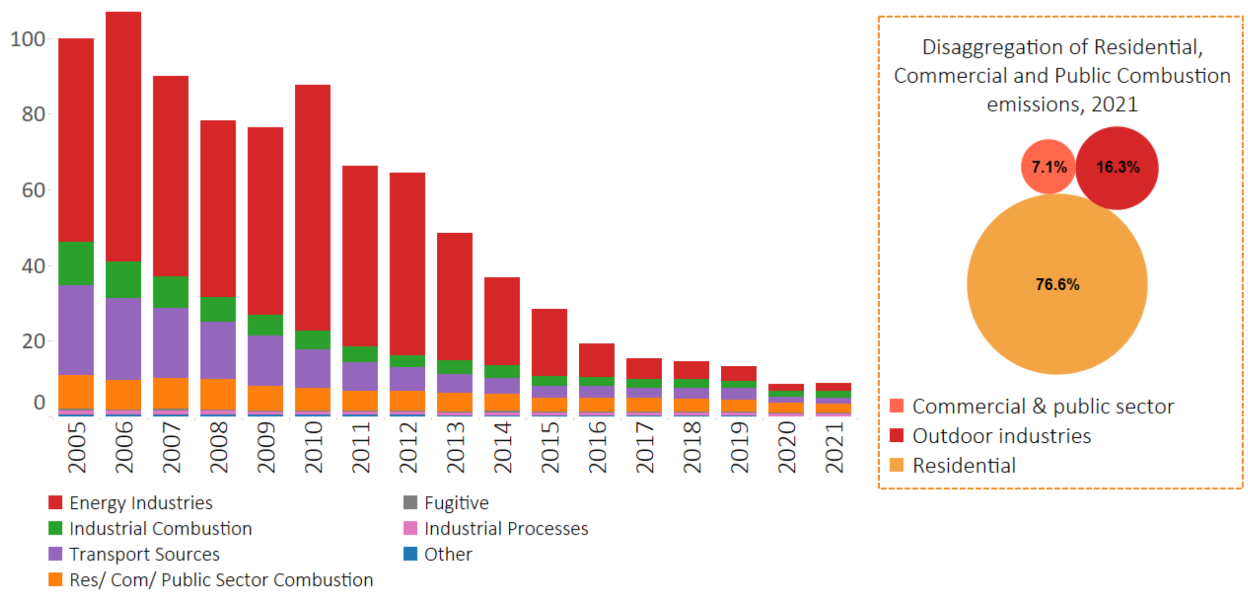


Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2021

9.6 SO_2 EMISSIONS IN SCOTLAND

Figure 9-10 provides a summary of sulphur dioxide (SO_2) emission estimates for Scotland by category. The detailed data are available in the report and website citied in the introduction to this chapter.

Figure 9-10 SO_2 Emissions in Scotland

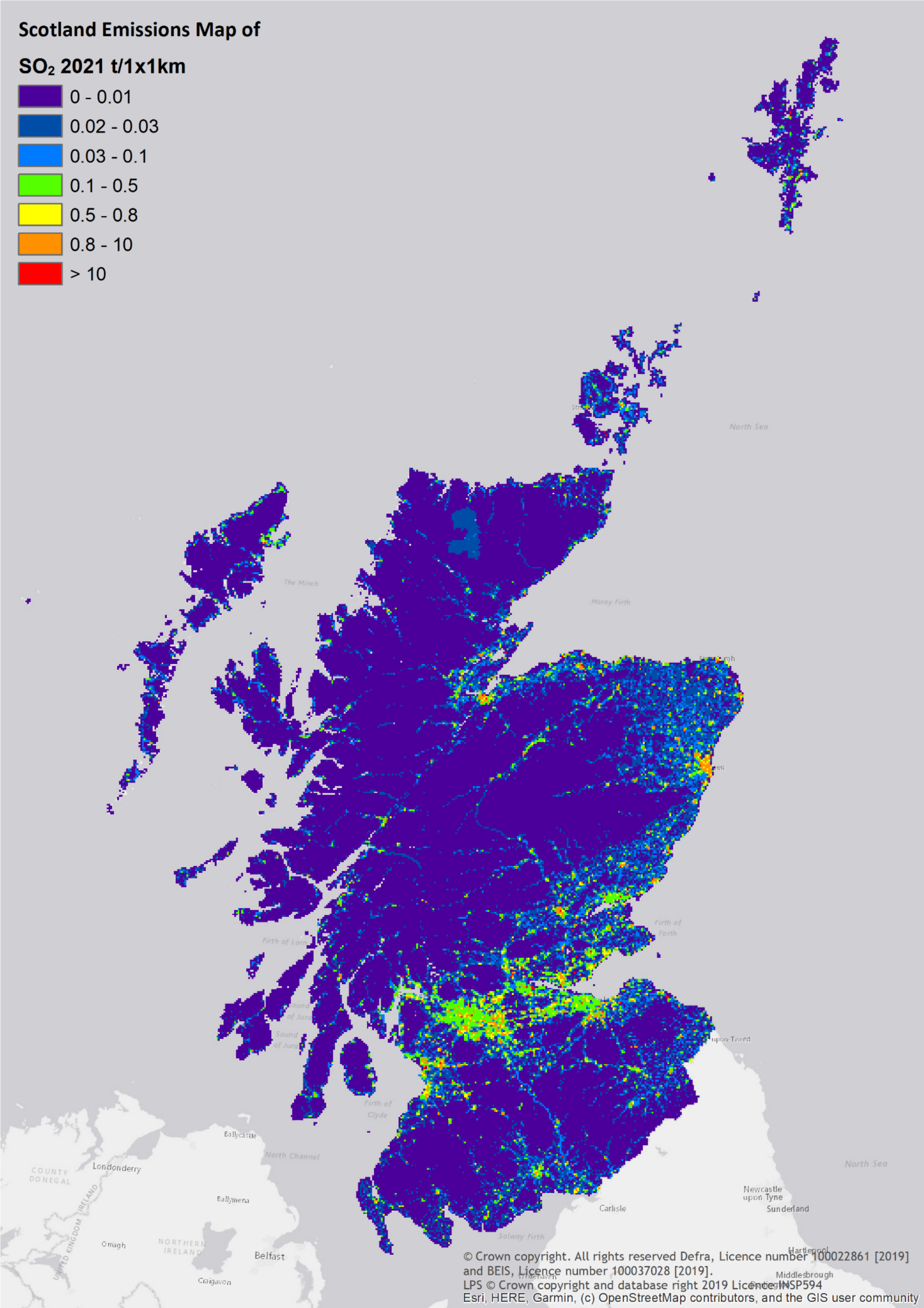


Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2021

Emissions of sulphur dioxide in Scotland were estimated to be 9 kt in 2021, representing 7% of the UK total in 2021 for sulphur dioxide. Emissions have declined by 91% (92% in 2020) since 2005 because of continued changes in the power generation sector. Since 2005, SO_2 emissions from power stations have reduced by 99%. Such changes include the reduction in coal fired power relative to other sources; improved emission controls on some large coal fired plants such as the installation of an FGD (flue-gas desulphurization) plant at Longannet power station; the use of coal of lower sulphur content in later years to Cockenzie (Scottish Power, 2012) before its closure in March 2013, and finally the complete cessation of coal combustion for power generation in Scotland in 2016 after the closure of Longannet. SO_2 emissions from transport sources have also declined, coincident with the reduced sulphur content of road fuels, for both petrol and diesel. Since 2020, SO_2 emissions have increased by 1.9%, likely due to the lifting of travel restrictions imposed due to the COVID-19 pandemic.

Figure 9-11 shows a map of SO_2 emissions in Scotland for 2021.

Figure 9-11 Map of SO_2 Emissions in Scotland, 2021

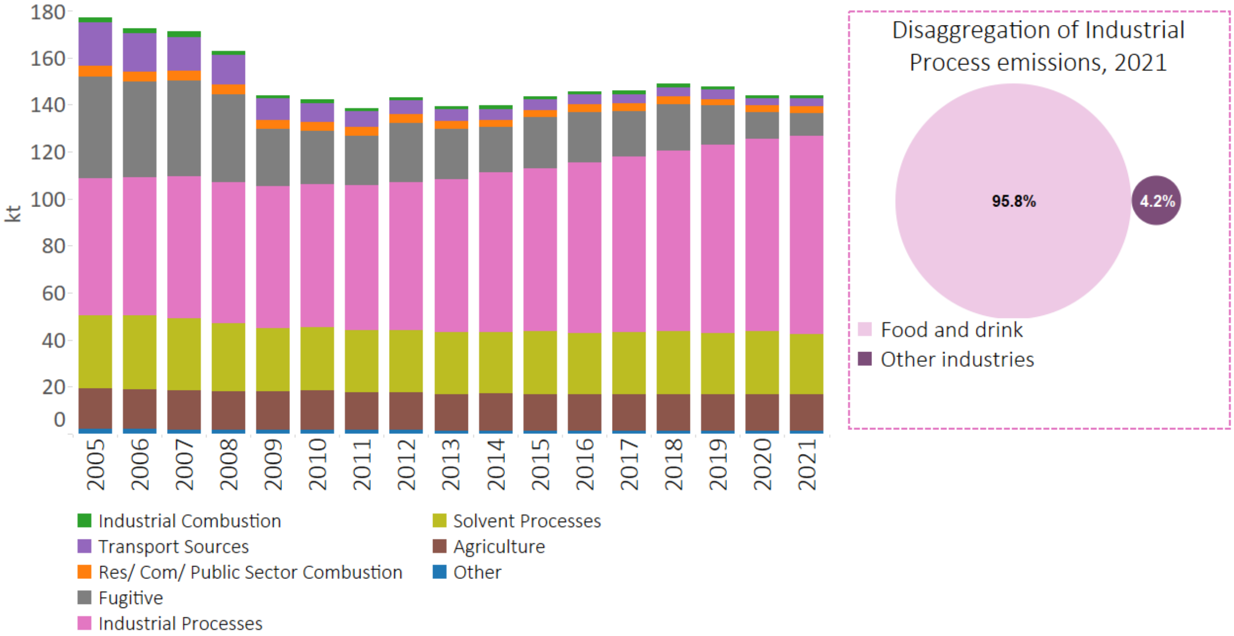


Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2021

9.7 NMVOC EMISSIONS IN SCOTLAND

Figure 9-12 provides a summary of Non- Methane Volatile Organic Compounds (NMVOC) emission estimates for Scotland by category. The detailed data are available in the report and website citied in the introduction to this chapter.

Figure 9-12 NMVOC Emissions in Scotland

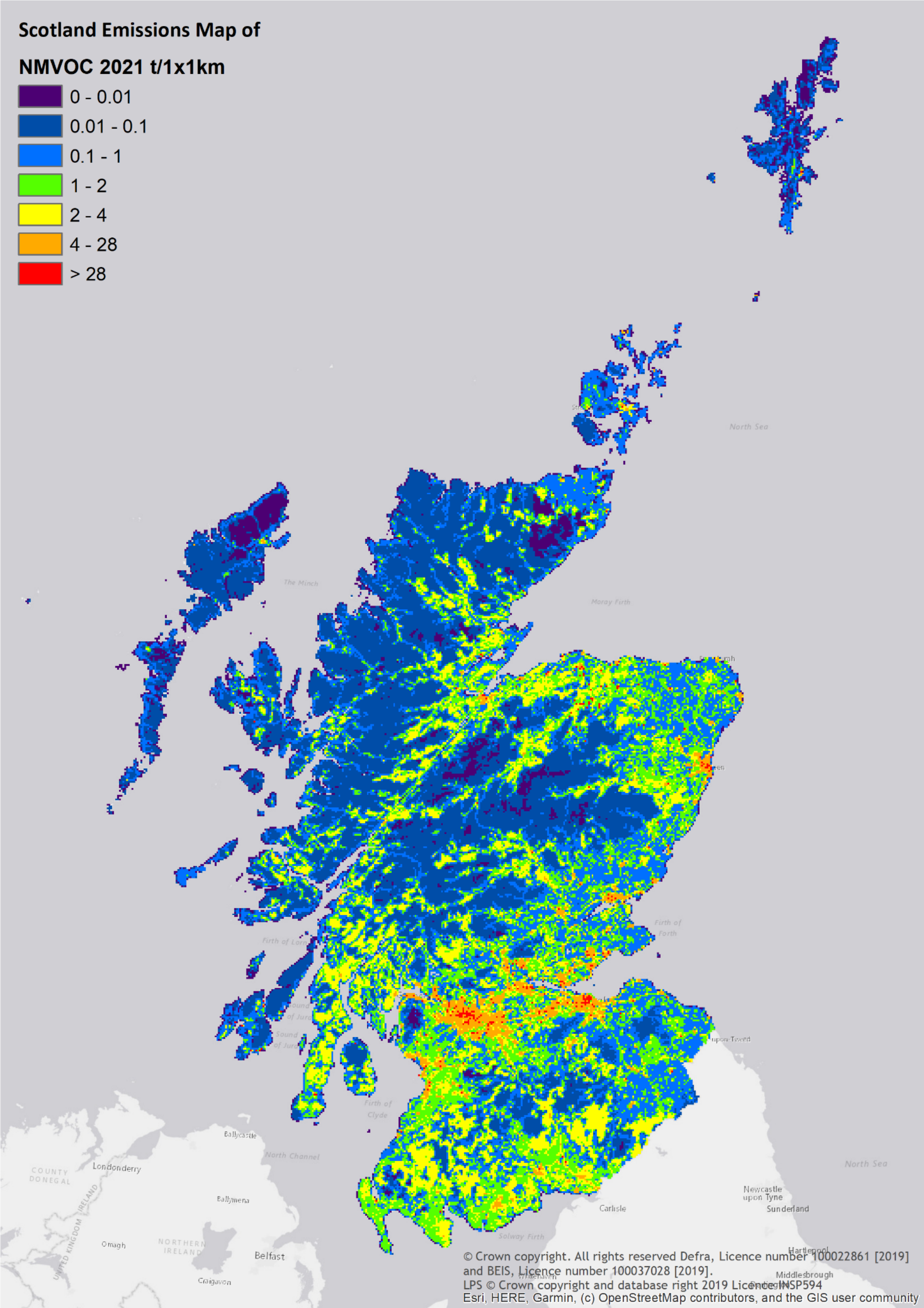


Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2021

Emissions of non-methane volatile organic compounds in Scotland were estimated to be 144 kt in 2021, representing 18% of the UK total for non-methane volatile organic compounds. Emissions have declined by 19% since 2005. This reduction is a result of reductions in fugitive and transport emissions which have each declined 82% since 2005. The declining trend seen in fugitive emissions is due to the decrease in emissions from the exploration, production, and transport of oil, specifically emissions from the onshore loading of oil. The decrease between 2008 and 2009 was due to reductions in fugitive NMVOC emissions from oil loading at the Sullom Voe terminal in Shetland. Emissions from the food and drink industry (which accounts for around 56% of industrial processes emissions in 2021) have increased since 2009 due to the increased production and storage of whisky. In total, spirit manufacture contributed approximately 54% of NMVOC emissions in Scotland in 2021. Emissions from road transport sources, including evaporative losses of fuel vapour from petrol vehicles have also declined over time due to emission control technologies that have progressively been introduced in new petrol vehicles since the early 1990s. The reduction in emissions also occurs to a lesser extent due to the introduction of petrol vapour recovery systems at filling stations.

Figure 9-13 shows a map of NMVOC emissions in Scotland for 2021.

Figure 9-13 Map of NMVOC Emissions in Scotland, 2021

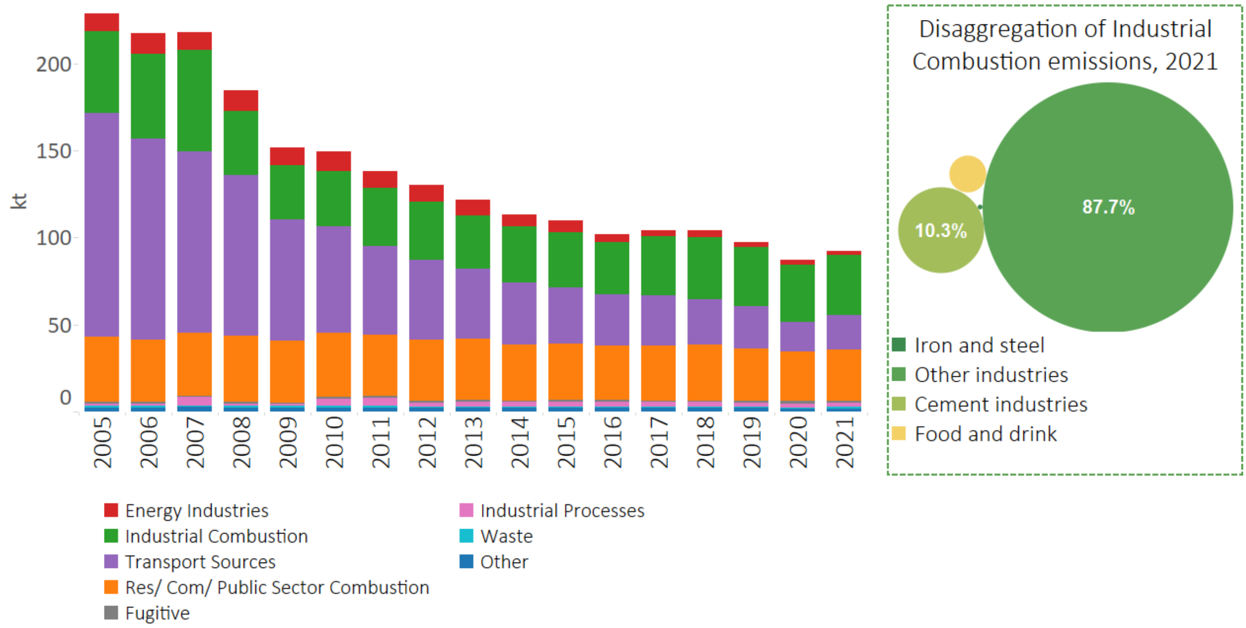


Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2021

9.8 CO EMISSIONS IN SCOTLAND

Figure 9-14 provides a summary of Carbon Monoxide (CO) emission estimates for Scotland by category. The detailed data are available in the report and website citied in the introduction to this chapter.

Figure 9-14 CO Emissions in Scotland

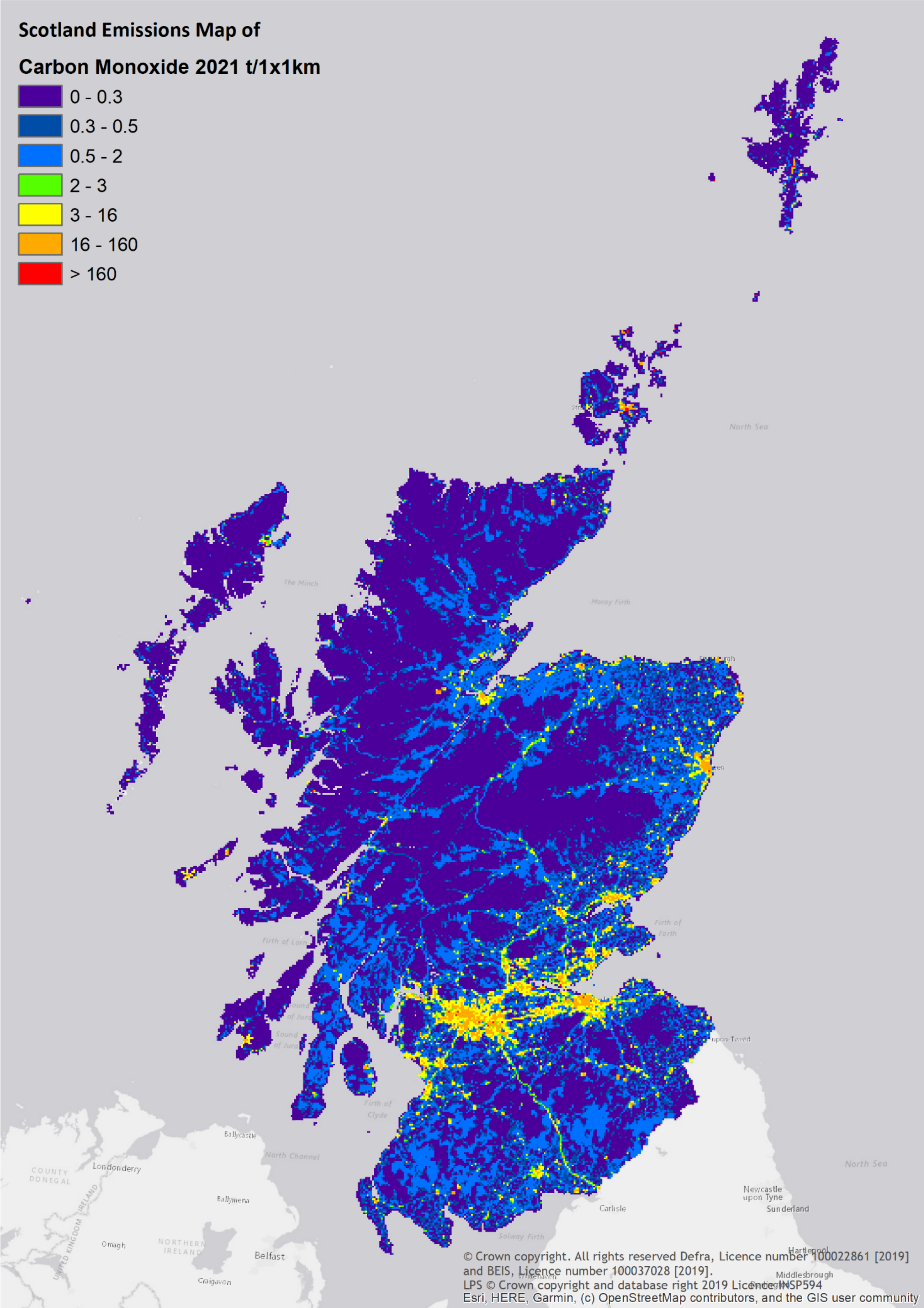


Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2021

Emissions of carbon monoxide in Scotland were estimated to be 93 kt in 2021 and have declined by 60% (62% in 2020) since 2005. Emissions in Scotland accounted for 7% of the UK total for carbon monoxide in 2021. This decline in emissions stems from changes in the contribution of transport sources, particularly in the road sector where emissions have declined by 89% since 2005 (contributing to 77% of the national trend in CO emissions). This decline is primarily to the penetration into the fleet of vehicles compliant with more recent Euro standards, which required the fitting of emission controls (e.g. three-way catalytic converters) in new petrol vehicles. Improved catalyst repair rates resulting from regulations controlling the sale and installation of replacement catalytic converters and particle filters for light-duty vehicles in 2008 also contribute to the trend. More recently, the switch from petrol cars to diesel cars, which have lower associated CO emissions rates, has also contributed to the observed trend. Emissions from the residential, commercial and public sector combustion have steadily increased since 2005, which corresponds with an increase in use of wood fuel in the domestic sector (BEIS, 2022a). CO emissions increased by 6% between 2020 and 2021, mainly driven by the 15% increase in emissions in this period from the transport sector.

Figure 9-15 shows a map of CO emissions in Scotland for 2021.

Figure 9-15 Map of CO Emissions in Scotland, 2021



Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2021

10 COVID-19 LOCKDOWN AND ITS EFFECT ON AIR QUALITY IN SCOTLAND UPDATE - 2022

10.1 BACKGROUND

This section provides an update on the assessment of NO_2 concentrations previously undertaken for the 2021 report. The results for 2021 indicated that concentrations remained below the levels measured pre-Covid-19, however, there were still restrictions in the first half of 2021 and traffic levels had not returned to 2019 levels. In 2022 there were no longer any Covid-19 related restrictions in place in Scotland. Here the analysis looks at how NO_2 concentrations have changed since the lifting of all restrictions.

10.2 METHODOLOGY

Weather conditions have a large impact on the concentrations of air pollutants, therefore, to assess how air quality has changed over time, it is important to consider variabilities due to the weather. Fortunately, techniques have been developed that can be used to “de-weather” the data. These techniques are based on statistical models that can be used to estimate the pollutant concentrations under various meteorological conditions, and in turn to predict what the concentrations would be if the weather was always the same[13,14].

Here, the deweather R package[15], was used to build the statistical models to de-weather the data. The deweather package uses a Boosted Regression Trees approach to model air quality data. This approach enables complex relationships between variables to be easily handled.

Model inputs included the daily average concentrations from the Scottish Air Quality Database and local meteorological data (wind speed, wind direction, air temperature) from the Weather Research and Forecasting (WRF) regional scale model.

From the model outputs, the trend component can be extracted. The trend provides information on the variation in the pollutant with fixed average meteorology and can be used to investigate changes that are not due to the weather.

10.3 RESULTS

NO_2 measurements from the same fourteen monitor sites across Glasgow and Edinburgh (seven in each location) used in the analysis for 2021 are assessed here. The locations of the monitoring sites are shown in Figure 10-1.

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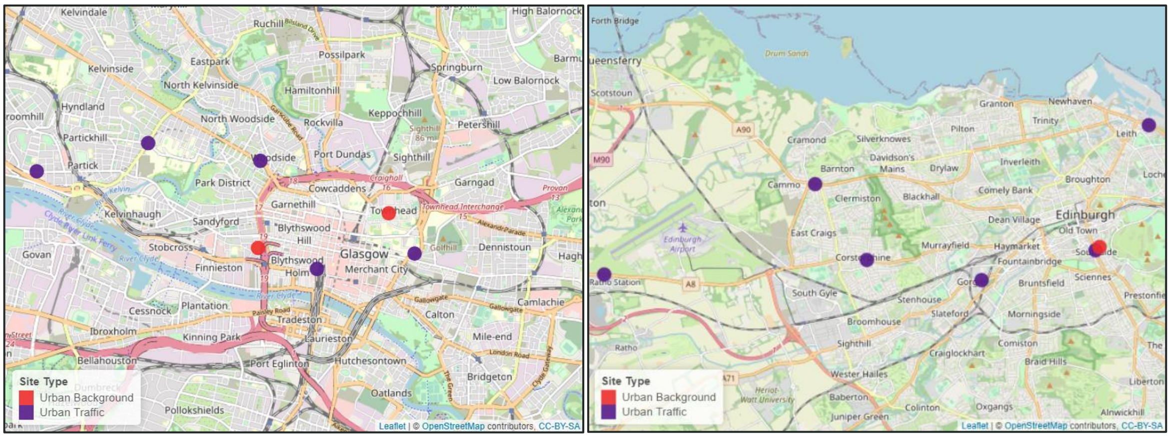
[13] Grange, Stuart K., and David C. Carslaw. 2019. “Using Meteorological Normalisation to Detect Interventions in Air Quality Time Series.” Science of The Total Environment 653 (February): 578–88. https://doi.org/10.1016/j.scitotenv.2018.10.344.

[14] Carslaw, David C., and Paul J. Taylor. 2009. “Analysis of Air Pollution Data at a Mixed Source Location Using Boosted Regression Trees.” Atmospheric Environment 43 (22-23): 3563–70. https://doi.org/10.1016/j.atmosenv.2009.04.001.

[15] https://github.com/davidcarslaw/deweather

Figure 10-1 Location of the monitoring sites in Glasgow (left) and Edinburgh (right) selected for the analysis.



Annual traffic data from the Department for Transport in Glasgow and Edinburgh between 2017 to 2022 is shown in Figure 10-2. The data shows the estimated number of vehicle miles travelled for all motor vehicles, and is based on the average annual daily flow, days in the year, and length of the road[16]. The data shows a large dip in vehicle miles travelled in 2020 in both cities, followed by an increase in 2021. Traffic levels have continued to increase in 2022 to just below those observed in 2019.

Figure 10-2 Annual vehicle miles (in millions) for Glasgow City and the City of Edinburgh local authorities, between 2017 and 2022 (source: Department for transport (https://roadtraffic.dft.gov.uk/)).

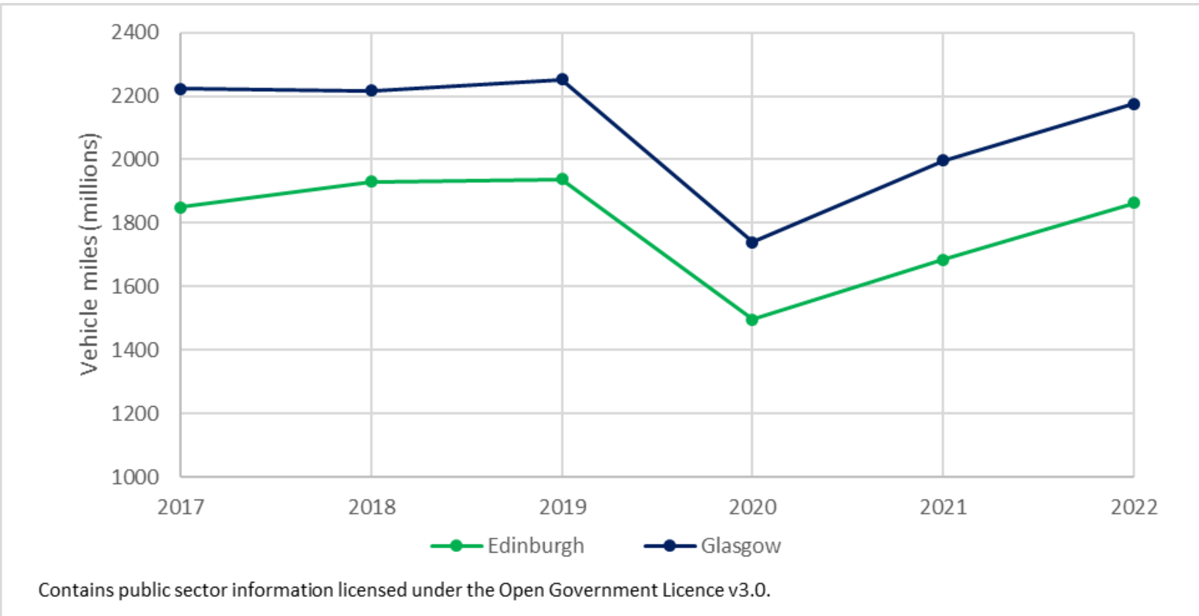


Figure 10-3 shows meteorologically normalised trends of NO_2 concentrations for urban traffic and urban background sites in the Glasgow area from 2017 to 2022. For all sites shown, there is a clear decrease in NO_2 concentrations coinciding with the start of the first lockdown in 2020. This is then followed by an increase in NO_2 concentrations during late summer. However, for most of the sites, the NO_2 concentrations have not increased to the levels observed pre-lockdown, even when you take into consideration the downward trend pre-covid. The exception is Glasgow Anderston, an urban background site, where it can be observed that the NO_2 levels in 2021 and 2022 are similar to those before lockdown. An urban background site is one that is located away from major roads; therefore it is expected to be less influenced by changes in traffic volumes when compared to urban traffic sites. Interestingly, at some sites (e.g. Glasgow Kerbside, Glasgow Dumbarton), further decreases in concentrations can be observed in 2022. The largest difference in concentrations of NO_2 between pre-lockdown and 2022 is observed at Glasgow Kerbside monitoring site. This

[16] https://roadtraffic.dft.gov.uk/regions/3

site is located on Hope Street, next to Glasgow Central train station and as can be seen by Figure 10.3 has historically reported the highest concentrations of NO_2.

Figure 10-3 Meteorologically normalised trends of NO_2 concentrations measured at selected sites in Glasgow from 2017 to 2022.

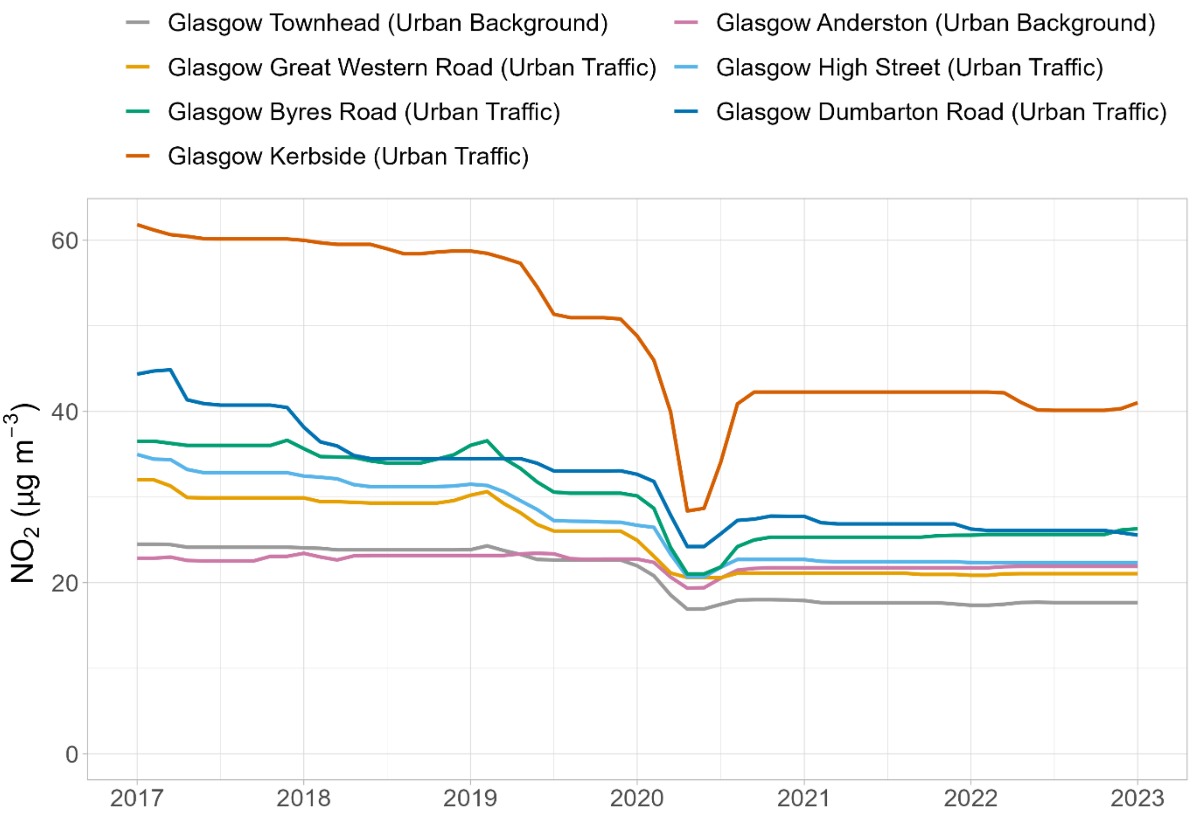
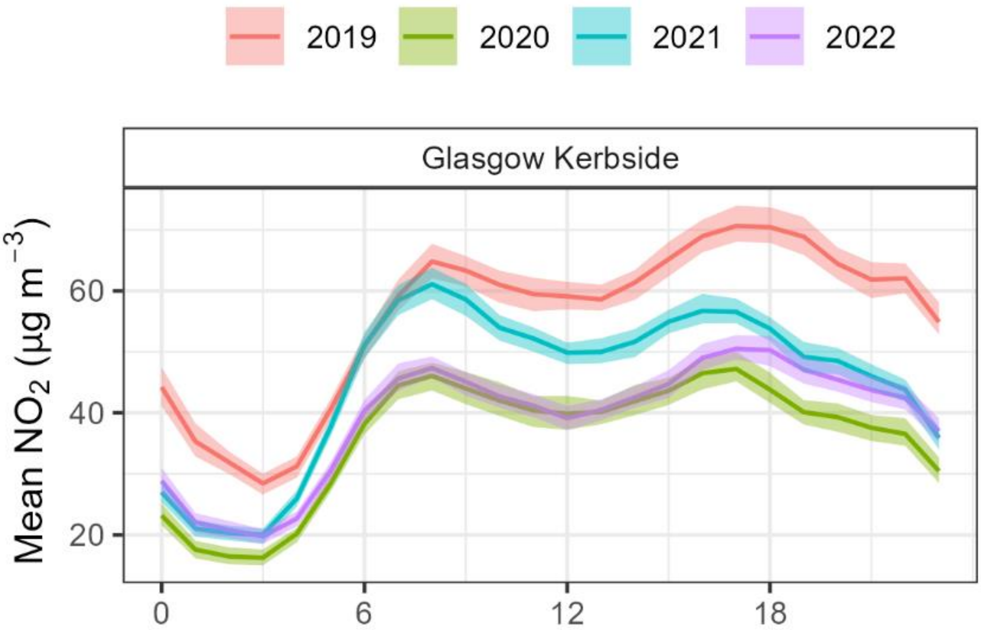


Figure 10-4 shows the average change in NO_2 concentrations during the day (over the year stated) at Glasgow Kerbside for years 2019 to 2022. Mean NO_2 concentrations during the morning rush hour (7-10 am) in 2021 are very similar to those in 2019. However, late afternoon/early evening the mean NO_2 concentrations remain lower in 2021 when compared to 2019, suggesting that traffic patterns may have changed since the lockdowns. For 2022, though the trend pattern is similar to 2021 the concentrations have dropped off significantly in the morning and afternoon to levels similar to that seen in 2020. This drop in concentrations does not correspond with the increase seen in traffic data which suggests that there has been a change in the fleet in terms of emissions produced.

Figure 10-4 Mean NO_2 concentrations for each hour of day at Glasgow Kerbside monitoring site from 2019 - 2022.The shaded region represents the 95% confidence interval in the mean.



Meteorologically normalised trends of NO_2 concentrations for urban traffic and urban background sites in the Edinburgh area (Figure 10-5) show similar variability to the sites in Glasgow, with an initial increase after the lockdown in 2020, and concentrations remaining below 2019 levels. A further decrease in NO_2 concentrations is observed at Nicolson Street and Salamander Street in 2022. For three sites (Glasgow Road, Salamander Street and St Leonard's) the meteorologically normalised NO_2 concentrations increased only very slightly, or not at all after the first lockdown. The analysis also indicates that the sites that historically had the higher NO_2 concentrations experience the larger decreases.

It should be noted that although the NO_2 concentrations measured at Nicolson Street in 2020 appear to decrease earlier than at other sites, this is due to a gap in the measured data between January and April 2020.

Figure 10-5 Meteorologically normalised trend of NO_2 concentrations measured at selected sites in Edinburgh from 2017 to 2022.

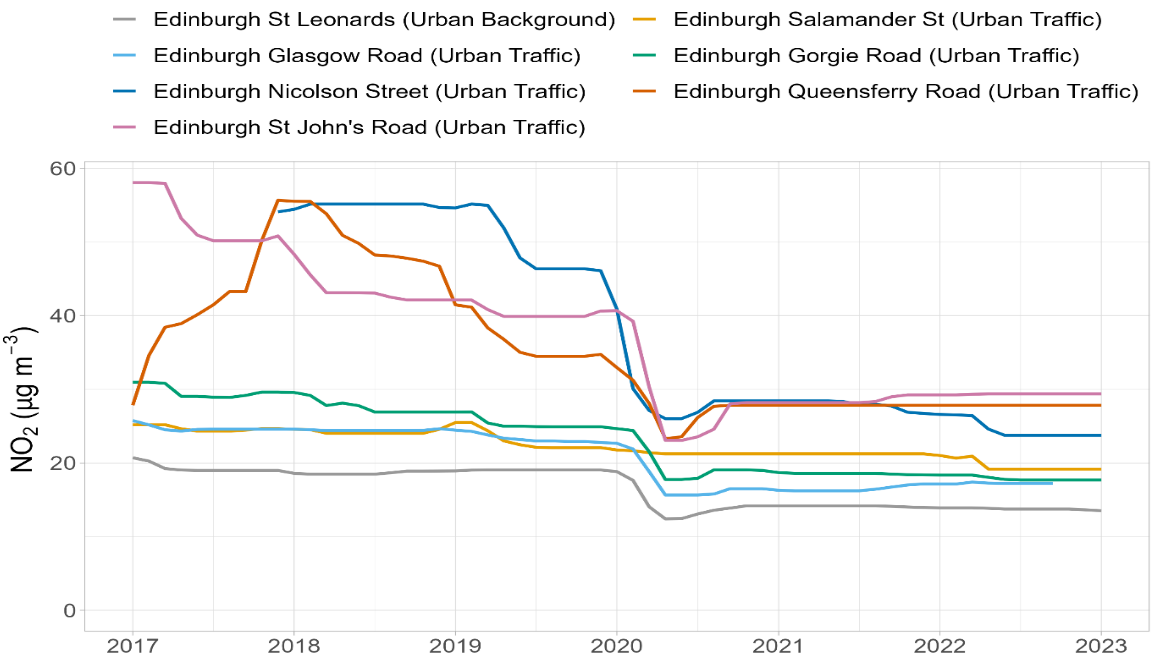
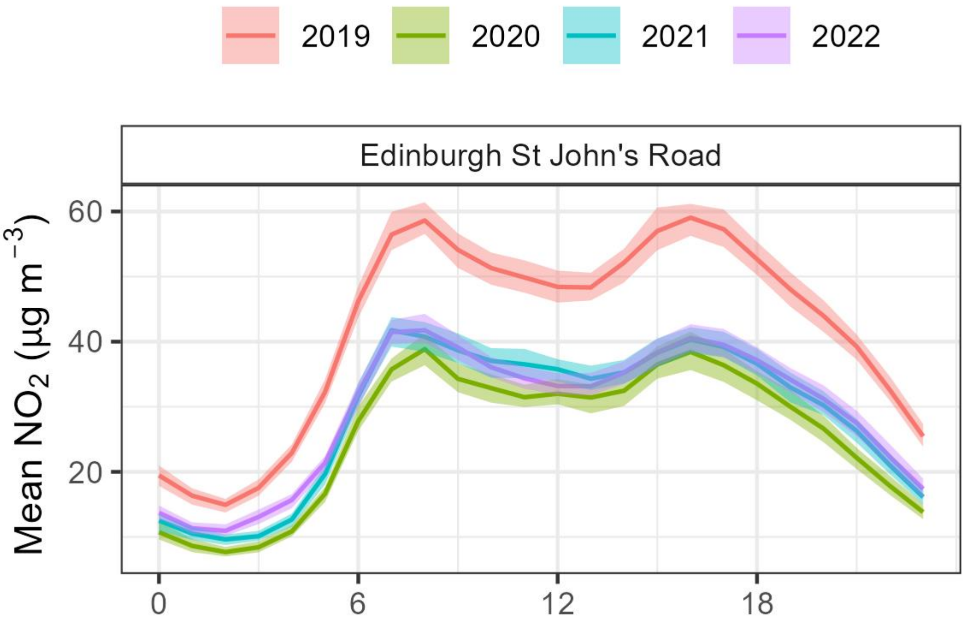


Figure 10-6 shows the average change in NO_2 concentrations during the day (over the year stated) at Edinburgh St Johns Road for years 2019 to 2022. It illustrates that though daily trends have generally stayed the same over the years (i.e. peaking at rush hours in the morning and evening then dropping off significantly during the night) the 2022 concentrations are significantly lower than pre-covid (2019). Again when you consider the increase in traffic levels back to almost 2019 levels this suggests a change in the vehicle fleet and the emissions it produces.

Figure 10-6 Mean NO_2 concentrations for each hour of day at Edinburgh Nicolson Street from 2019 - 2022. The shaded region represents the 95% confidence interval in the mean.



10.4 COVID-19 LOCKDOWN AND ITS EFFECT ON AIR QUALITY IN SCOTLAND UPDATE - SUMMARY

By 2022 all Covid-19 restrictions had been lifted, and traffic data from Glasgow and Edinburgh areas show that annual vehicle miles travelled in these areas continued to increase in 2022 reaching near pre-Covid levels.

The analysis of meteorologically normalised trends in NO_2 concentrations from a selection of sites in the Glasgow and Edinburgh, however, show that NO_2 concentrations have not continued to increase considerably since the initial increase after the first lockdown in 2020. Interestingly, at some sites, there have been further decreases in 2022. This suggests a change in vehicle fleet at both locations in terms of emissions produced.

11 SUMMARY AND CONCLUSIONS

In April 2007, Ricardo Energy & Environment (Ricardo) were commissioned by the Scottish Government to undertake a three-year project to develop an Air Quality Database and Website for Scotland. This contract has been renewed in consecutive years, with the latest contract running from 2019-2024 (including extensions).

This report brings together all the Scottish Air Quality Database data for calendar year 2022 and associated work relating to project deliverables including: data management; QA/QC services; liaison with stakeholders; website development; spatial analysis of air quality data; trend analysis.

In addition, this year's report provides updated analysis on how the Covid-19 pandemic affected air quality in Scotland. This analysis follows on from the 2021 annual report Covid-19 analysis.

Legislation and Policy

Air quality management is shaped by requirements of EU, UK and Scottish legislation and policies. Following the UK's exit from the EU, under retained EU law, Scotland is required to continue to meet limit and target values for a range of air pollutants and other legal obligations covered by EU directives.

In July 2021, accompanied by a Delivery Plan, and replacing "Cleaner Air for Scotland – The Road to a Healthier Future", the Scottish Government published Scotland's second air quality strategy called "Cleaner Air for Scotland 2 – Towards a Better Place for Everyone" (CAFS2). CAFS2 is shaped around 10 general themes. These are:

11. Health – A Precautionary Approach
12. Integrated Policy
13. Placemaking
14. Data
15. Public Engagement and Behavioural Change
16. Industrial Emissions Regulation
17. Tackling Non-Transport Emission Sources
18. Transport
19. Governance, Accountability and Delivery
20. Further Progress Review

Air Quality Monitoring in Scotland

Air pollution data for 99 automatic monitoring sites throughout Scotland are available in the database for all or part of 2022. All automatic data maintained within the Scottish database are subject to the same QA/QC procedures as the UK Automatic Urban and Rural Network (AURN).

In 2022, no automatic monitoring site exceeded the annual mean or hourly AQS objective for NO_2. In 2022, Seven passive diffusion tube monitoring sites exceeded the NO_2 annual mean objective.

In 2022, no automatic monitoring sites measuring Particulate Matter (PM_{10} and $PM_{2.5}$) measured exceedances of the Scottish 24 hour or annual mean objectives for both PM_{10} and $PM_{2.5}$. One site (Edinburgh St Johns Road) exceeded the 24-hour mean objective of 50 μgm^{-3} not to exceed more than 7 times per year.

In 2022, no exceedances of AQS objectives were observed for the pollutants ozone (O_3), sulphur dioxide (SO_2), carbon monoxide (CO), benzene, 1,3-butadiene, benzo(a)pyrene, and lead (Pb).

Air Quality Mapping of Scotland

The 2021 annual mean NO_2 concentrations for Scotland were modelled for background and roadside locations for NO_2, PM_{10} and $PM_{2.5}$.

For NO_2, there were no modelled exceedances of the Scottish annual mean objective of 40 $\mu g\ m^{-3}$ at background or roadside locations.

For PM_{10}, there were no modelled exceedances of the Scottish annual mean PM_{10} objective of 18 $\mu g\ m^{-3}$ at background or roadside locations.

For $PM_{2.5}$, there were also no modelled exceedances of the Scottish annual mean $PM_{2.5}$ objective of 10 $\mu g\ m^{-3}$ at both background and roadside locations.

Air Quality Trends for Scotland

NO_2

Trend analysis of nitrogen dioxide concentrations at Scotland's five long-running urban background sites shows that NO_2 concentrations are displaying highly significant decreasing trends. The more recent five years analysis shows that the decreasing trend is consistent with the long-range trends.

Analysis shows that NO_2 concentrations at Scotland's three long-running rural sites showed small decreasing trends.

Of the eight selected NO_2 urban traffic monitoring sites selected for analysis; all eight sites showed highly significant decreasing trends for both five and ten year analysis.

PM_{10}

PM_{10} trend analysis at Scotland's eight long-running urban background sites showed highly significant decreasing trends at all sites. Seven out of Scotland's eight long-running urban traffic sites also showed statistically highly significant decreasing trends at all sites. More recent years trend analysis indicates that the decreasing trend is plateauing for all the sites analysed. Trend analysis was carred out for a subsection of the traffic related sites with very similar results to background sites.

$PM_{2.5}$

By the end of 2021 there were four sites with 10 consecutive years of $PM_{2.5}$ data. The analysis shows that all sites show a slight decreasing trend over the 10-year time period at varying levels of statistical significancy. Anaysis carried out on a subsection of urban traffic sites showed all sites having a slight decreasing trend at varying statistical significance.

Ozone

Ozone has been measured at three rural sites in Scotland for 30 years. Two sites showed small but statistical highly significant increasing trends whereas the other showed no obvious trend. Ozone has been measured for the past 10 years at six rural sites. In contrast to the 30-year trends, the 10-year trends were less consistent. Four sites have increasing trends in O_3 concentrations at varying levels of statistical significance. The other two sites have slight decreasing trends

10-year trend analysis of ozone concentrations showed increasing trends (at varying statistical significance) at three Scottish urban background sites whereas the other three sites show slight decreasing trends (at varying statistical significance).

Additional Trend Analysis

Additional trend analysis was carried out at four sites located within the four major cities in Scotland. This analysis was carried out using the Openair analysis tool and compared 2022 data with data from the previous 10 years using a variety of analytical techniques.

Emissions of Pollution Species

Emissions of **nitrogen oxides** in Scotland were estimated to be 83kt in 2021, representing 12% of the UK total for nitrogen oxides. Emissions have declined by 59% (61% in 2020) since 2005, mainly due to changes in transport sources.

Emissions of **PM_{10}** in Scotland were estimated to be 12kt in 2021, declining by 41% (46% in 2020) since 2005. These emissions account for 8% of the UK total PM_{10} emissions. Unlike most other pollutants, the emissions profile of PM_{10} is diverse: transport sources, residential and industrial processes each accounted for over 15% of total PM_{10} emissions in 2021.

Emissions of **$PM_{2.5}$** in Scotland were estimated to be 7kt in 2021, declining by 47% (52% in 2020) since 2005. These emissions account for 8% of the UK total for $PM_{2.5}$ in 2021. As with PM_{10}, $PM_{2.5}$ emissions have a large number of significant sources. For $PM_{2.5}$, the residential, commercial, and public sectors accounts for 31% of

2021 emissions. The primary drivers for the decline in emissions since 2005 are the continued switch from coal to natural gas in electricity generation, and reductions in emissions from the transport sector.

Emissions of **carbon monoxide** in Scotland were estimated to be 93kt in 2021 and have declined by 60% (62% in 2020) since 2005. Emissions in Scotland accounted for 7% of the UK total for carbon monoxide in 2021. This decline in emissions stems from changes in the contribution of transport sources, particularly in the road sector where emissions have declined by 89% since 2005

Emissions of **sulphur dioxide** in Scotland were estimated to be 9kt in 2021, representing 7% of the UK total in 2021 for sulphur dioxide. Emissions have declined by 91% (92% in 2020) since 2005 because of continued changes in the power generation sector. Since 2005, SO_2 emissions from power stations have reduced by 99%.

Emissions of **ammonia** in Scotland were estimated to be 32kt in 2021. These emissions have declined by 12% (10% in 2020) since 2005 and accounted for 12% of the UK total for ammonia in 2021. Agriculture sources have dominated the inventory throughout the time series, with cattle manure management accounting for at least 34% of the emissions from this sector across the entire time series.

Emissions of **non-methane volatile organic compounds** in Scotland were estimated to be 144kt in 2021, representing 18% of the UK total for non-methane volatile organic compounds. Emissions have declined by 19% since 2005. This reduction is a result of reductions in fugitive and transport emissions.

Covid-19 lockdown and its effect on air Quality in Scotland

During 2022 there were no travel restrictions relating to the Covid-19 pandemic as was seen in 2020 and 2021. Anaysis shows that though traffic levels have returned to almost pre-covid levels in 2019, NO_2 concentrations at locations in Edinburgh and Glasgow have remain low and comparable and, in some cases, lower to 2020 and 2021. With daily trend analysis remaining similar this suggests that low NO_2 concentrations maybe related to a change in the vehicle fleet in these areas.

APPENDICES

Appendix 1 Ratification Procedures

A1.1 Intercalibration and Audit procedures

The audit and intercalibration procedures adopted by Ricardo Energy & Environment rely upon the principle that a set of recently certified gas cylinders (called "audit gas") is taken to all the stations in a monitoring network. This gas is certified at the Ricardo Energy & Environment Gas Calibration Laboratory. At each station, analyser response to audit gas is recorded to check if the expected concentration (i.e. the certified value for the cylinder) is obtained. The analyser response to audit gas is obtained using calibration factors obtained from the site operator. The audit procedure checks the validity of the provisional data, the correct overall operation of the analyser and the reliability of calibrations undertaken routinely at that station. These site audit procedures are compliant with the requirements of the CEN standard methods of measurement and are used throughout the UK AURN network.

The results of the audit exercises form an integral part of the data management system and are fed directly into the data ratification process. After the audit exercise, data from all the stations visited are traceable to recently calibrated UKAS accredited gas calibration standards (the audit gas).

A1.1.1 Detailed instrumentation checks

The following instrument functional checks are undertaken at an audit:

- Analyser accuracy and precision, as a basic check to ensure reliable datasets from the analysers.
- Instrument linearity, to check that doubling a concentration of gas to the analyser results in a doubling of the analyser signal response. If an analyser is not linear, data cannot be reliably scaled into concentrations.
- Ozone analyser calibration against a traceable ozone photometer
- Instrument signal noise, to check for a stable analyser response to calibration gases.
- Analyser response time, to check that the analyser responds quickly to a change in gas concentrations.
- Leak and flow checks, to ensure that ambient air reaches the analysers, without being compromised in any way.
- NO_X analyser converter efficiency, via gas phase titration, to ensure reliable operation. The converter must be more than 95% efficient to ensure that the NO_2 data are of the required accuracy.
- TEOM k_0 evaluation. The factor is used to calculate particulate mass concentrations.
- Particulate analyser flowrates. Any error in the flow through these particulate analysers is directly reflected in an error in the final measure of particulate concentration.
- SO_2 analyser hydrocarbon interference, certain hydrocarbons are known to interfere with the SO_2 detector.
- Evaluation of site cylinder concentrations, with reference to the certified audit gas taken to the stations. This procedure allows for the correction of data from stations where the site calibration cylinder concentration is slowly changing and for identification of any unstable cylinders that require replacement.
- Assessing changes in local site environment. During the visit, a record of any changes in the site environment, for example any increase or decreased traffic flow due to road layout changes, construction activity, encroachment of the site by vegetation etc.
- Assessment of station infrastructure and operational procedures. Any deficiencies in site infrastructure or operational procedures, which may affect data quality or safe operation of the site, are noted.
- Ensure Local Site Operators (LSO) understand calibration procedures correctly. It is the calibrations by the LSOs that are used to scale pollution datasets and hence, it is important to check that these are undertaken reliably.

The procedures used to determine instrument performance are documented in Ricardo Energy & Environment Work Instructions. These methods are regularly updated and improved and have been evaluated by the United Kingdom Accreditation Service (UKAS). Tests are performed on the analysers, cylinders and ambient air inlet systems. Checks are made on the environment around the site, including the continued representative nature of the site and safety assessments. The data collected from the instrument and cylinder tests are collated on site, using a controlled and protected Excel spreadsheet, which automatically undertakes all calculations and alerts the audit staff to any unusual results. The completed spreadsheets are then returned for further checking, before being used within the data management process and in production of accredited Certificates of Calibration.

A1.1.2 UKAS Accreditation

Ricardo Energy & Environment holds UKAS accreditation to ISO 17025 for the on-site calibration of the gas analysers (NO_X, CO, SO_2, O_3), for flow rate checks on particulate (PM_{10}) analysers and for the determination of the spring constant, k_0, for the TEOM analyser.

ISO17025 accreditation provides complete confidence that the analyser calibration factors are traceable to national metrology standards, that the calibration methods are sufficient and fit for purpose, and that the uncertainties are appropriate for data reporting purposes. Ricardo Energy & Environment also holds ISO17025 accreditation for laboratory certification of NO, NO_2, CO and SO_2 gas cylinders.

A1.1.3 Zero air

The reliability of the zero-air supply at each station is of fundamental importance in the determination of ambient concentrations. A reference zero air source is held at the Ricardo Energy & Environment Gas Calibration Laboratory, which is traceable to international standards. A transfer standard, checked against this standard, is used to evaluate the site zero sources at the QA/QC audits. The zero-air supply at a site will be either:

- A zero-air cylinder.
- A series of chemical scrubbers, connected to a pumped delivery system.
- A pollutant specific chemical scrubber system to connect directly into the analyser.

A1.1.4 Ozone Photometers

Ozone photometers are calibrated every six months against the NIST Reference Photometer, held at NPL, before use at the station audits.

A1.2 Data Acquisition and Processing

The Scottish local authority monitoring stations are polled three times a day to retrieve 15-minute averages of raw output from instruments. This is a balance between regular updating of the database and web site yet minimising the associated telecoms costs. UK National network stations are polled hourly as these data are used for the air quality forecast system.

The data are transmitted via MODEM or internet connection, depending on type of logging system used at the site, and automatically appended to the air quality site database. The results of automatic overnight autocalibration checks are also retrieved and databased. Appropriate scaling factors based on the most recent calibration information are applied to the pollutant measurements to produce concentrations in the relevant units.

From the 15-minute values, the hourly averaged results are calculated. This is the averaging period used for the reporting of both validated and ratified data for all pollutants. Additionally, the 15-minute data files are provided for SO_2 to allow direct comparison with the 15-minute objective. Once the raw data from the stations has been acquired the next step in the data management process is data validation.

A1.2.1 Validation of Data

All incoming data from the monitoring station are automatically screened prior to the release of validated data sets. Experienced staff will check the data daily, to monitor satisfactory data acquisition and to investigate instances of suspect data. This daily checking ensures rapid diagnosis of any instrument malfunctions.

The automatic screening procedures, and the many years of experience held by our team, enables us to ensure that only the highest quality data are released to the Scottish Air Quality Database and Website as validated data.

Should equipment or site problems be identified, it is possible for data management staff to contact the monitoring station manually, in order to access further information. If necessary, the relevant LSO is contacted to undertake further investigation.

A1.3 Data Ratification

This section provides details of the procedures and the software tools we use for data ratification.

Our software runs a number of protocols to automatically flag data anomalies in the provisional data received from the stations, these are examined in detail during the ratification process. These include identifying the following:

- Negative data
- High data peaks
- Calibrations which are more than 5% different from previous values
- Peaks with a maximum 15-minute concentration significantly above the hourly mean value
- Measurements which are outside the normal range of expected data e.g. elevated ozone concentrations during the winter months
- Long periods of constant or zero concentrations
- Data gaps of more than six hours.

A1.3.1 Ratification tasks and output

When ratifying data, the following are closely examined:

- Issues that have been flagged up automatically by the software.
- Zero and sensitivity factors used on each day.
- General review of the result to make sure that there are no other anomalies.

A1.3.2 Ratified Data Checking

Once the data have been initially ratified proforma reports is produced and passed to the data checker The role of the data checker is to:

- Assess if there are any station problems if not the data can be marked as ratified.
- Return the station to the data ratifier if there are any issues requiring further action by the data ratifier.
- Forward the report to the project Quality Circle if there are data quality issues which require a group discussion to resolve.

Following the Quality Circle meeting the data are then corrected if required and uploaded as ratified to the database and web site.

Appendix 2 Sites audited, and data ratification undertaken during 2022

A2 1. Air quality site intercalibration and audits conducted during 2022

Site Name	Winter 2021/22	Summer 2022	Site Name	Winter 2021/22	Summer 2022
Aberdeen Anderson Dr	✓	✓	Glasgow Kerbside	✓	✓
Aberdeen Errol Park	✓	✓	Glasgow Great Western Road	✓	✓
Aberdeen King Street	✓	✓	Glasgow High Street	✓	✓
Aberdeen Market Street 2	✓	✓	Glasgow Nithsdale Road	✓	✓
Aberdeen Union Street Roadside~	✓	✓	Glasgow Townhead	✓	✓
Aberdeen Wellington Road	✓	✓	Glasgow Waulkmillglen Reservoir	✓	✓
Alloa A907	✓	✓	Grangemouth	✓	✓
Angus Forfar Glamis Road	✓	✓	Grangemouth Moray~	✓	✓
Auchencorth Moss	✓	✓	Grangemouth Moray Scot Gov~	✓	✓
Bush Estate	✓	✓	Inverclyde Greenock A8	✓	✓
Dumbarton Roadside	✓	✓	Inverness*	✓	✓
Dumfries	✓	✓	Inverness Academy Street	✓	✓
Dundee Broughty Ferry Road	✓	✓	Inverness Academy Street 1st Floor	✓	✓
Dundee Lochee Road	✓	✓	Lerwick~	✓	✓
Dundee Mains Loan	✓	✓	N Lanarkshire Airdrie Kenilworth Dr	✓	✓
Dundee Meadowside	✓	✓	N Lanarkshire Chapelhall	✓	✓
Dundee Seagate	✓	✓	N Lanarkshire Coatbridge Whifflet	✓	-
Dundee Whitehall Street	✓	✓	N Lanarkshire Coatbridge Whifflet A725	✓	✓
East Ayrshire Kilmarnock St Marnock St	✓	✓	N Lanarkshire Croy	✓	✓
East Dunbartonshire Bearsden	✓	✓	N Lanarkshire Kirkshaws	✓	✓
East Dunbartonshire Bishopbriggs	✓	✓	N Lanarkshire Motherwell	✓	✓
East Dunbartonshire Kirkintilloch	✓	✓	N Lanarkshire Motherwell Adele Street	✓	✓
East Dunbartonshire Milngavie	✓	✓	N Lanarkshire Ravenscraig Plantation Rd	✓	✓
East Lothian Musselburgh N High St	✓	✓	N Lanarkshire Shawhead Coatbridge	✓	✓
Edinburgh Currie	✓	✓	N Lanarkshire Uddingston New Edinburgh Rd	✓	✓
Edinburgh Glasgow Road	✓	✓	North Ayrshire Irvine High Street	✓	✓
Edinburgh Gorgie Road	✓	✓	Paisley Gordon Street	✓	✓
Edinburgh Nicolson Street	✓	✓	Peebles	✓	✓
Edinburgh Queensferry Road	✓	✓	Perth Atholl Street	✓	✓
Edinburgh Salamander St	✓	✓	Perth Bridgend	✓	✓
Edinburgh St John's Road	✓	✓	Perth Crieff	✓	✓
Edinburgh St Leonards	✓	✓	Perth Muirton	✓	✓
Edinburgh Tower Street	✓	✓	Renfrew Cockels Loan	✓	✓
Eskdalemuir	✓	✓	Renfrew Inchinnan Road	✓	✓
Falkirk Banknock	✓	✓	Renfrewshire Johnston	✓	✓
Falkirk Bo'ness	✓	✓	Shetland Lerwick~	✓	✓
Falkirk Grangemouth MC	✓	✓	South Ayrshire Ayr Harbour	✓	✓
Falkirk Grangemouth Zetland Park	✓	✓	South Ayrshire Ayr High St	✓	✓
Falkirk Haggs	✓	✓	South Lanarkshire Blantyre	✓	✓
Falkirk Hope St	✓	✓	South Lanarkshire Cambuslang	✓	✓
Falkirk Main St Bainsford	✓	✓	South Lanarkshire East Kilbride	✓	✓
Falkirk West Bridge Street	✓	✓	South Lanarkshire Hamilton	✓	✓

Site Name	Winter 2021/22	Summer 2022	Site Name	Winter 2021/22	Summer 2022
Fife Cupar	✓	✓	South Lanarkshire Lanark	✓	✓
Fife Dunfermline	✓	✓	South Lanarkshire Raith Interchange 2	✓	✓
Fife Kirkcaldy	✓	✓	South Lanarkshire Rutherglen	✓	✓
Fife Rosyth	✓	✓	South Lanarkshire Uddingston	✓	✓
Fort William	✓	✓	Stirling Craig's Roundabout	✓	✓
Glasgow Abercromby Street	✓	✓	Strath Vaich	✓	✓
Glasgow Anderston	✓	✓	West Dunbartonshire Clydebank	✓	✓
Glasgow Broomhill	✓	✓	West Lothian Broxburn	✓	✓
Glasgow Burgher Street	✓	✓	West Lothian Linlithgow High St 2	✓	✓
Glasgow Byres Road	✓	✓	West Lothian Newton	✓	✓
Glasgow Dumbarton Road	✓	✓			

The column headings labelled Q1 – Q4 refer to the quarter periods of the calendar year:

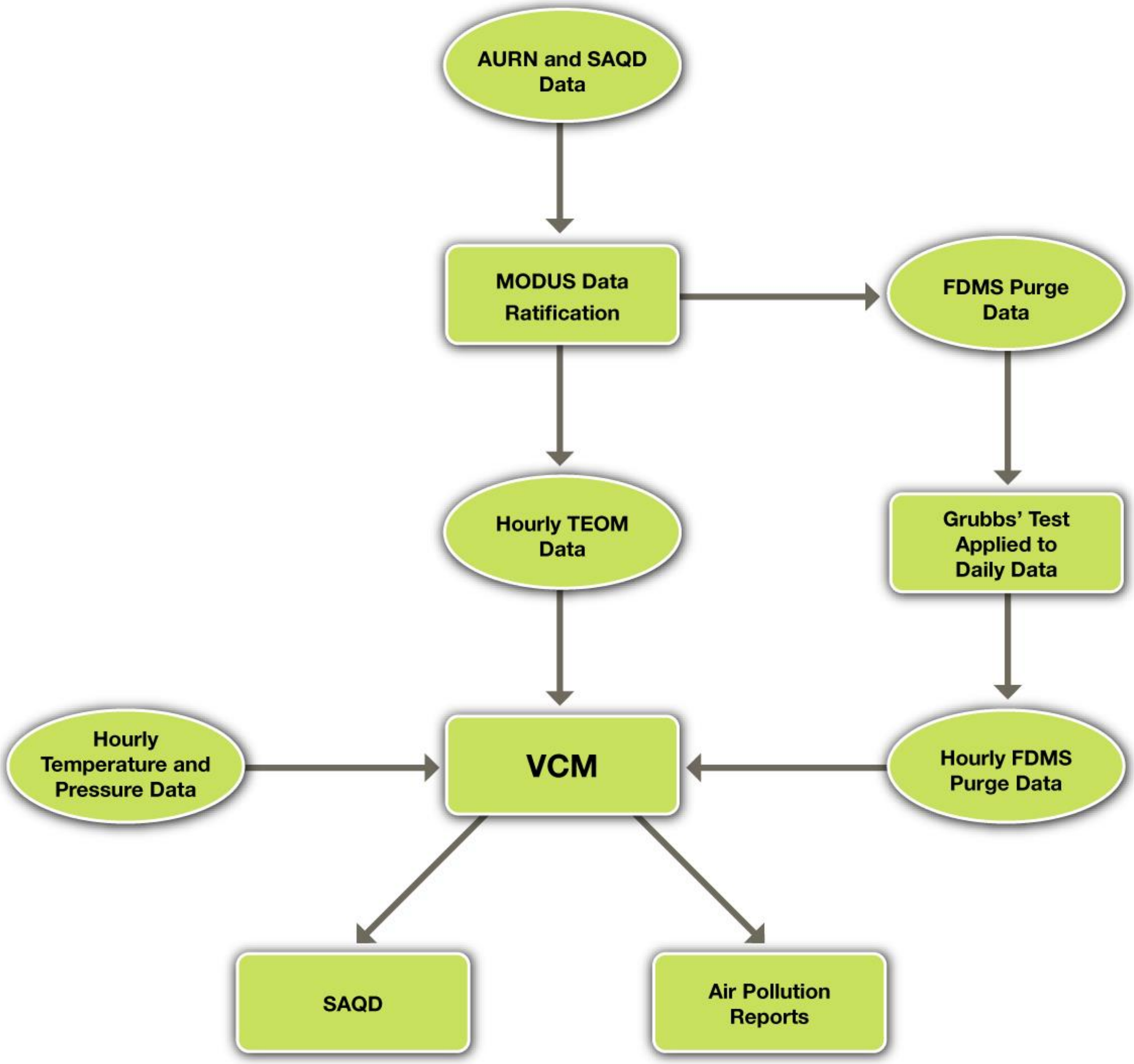
- Q1 = January to March
- Q2 = April to June
- Q3 = July to September
- Q4 = October to December

A2 2. Data ratification undertaken during 2022

Site Name	Q1	Q2	Q3	Q4	Site Name	Q1	Q2	Q3	Q4
Aberdeen Anderson Dr	✓	✓	✓	✓	**Glasgow Great Western Road**	✓	✓	✓	✓
Aberdeen Errol Park	✓	✓	✓	✓	**Glasgow High Street**	✓	✓	✓	✓
Aberdeen King Street	✓	✓	✓	✓	**Glasgow Nithsdale Road**	✓	✓	✓	✓
Aberdeen Market Street 2	✓	✓	✓	✓	**Glasgow Townhead**	✓	✓	✓	✓
Aberdeen Union Street Roadside~	✓	✓	✓	✓	**Glasgow Waulkmillglen Reservoir**	✓	✓	✓	✓
Aberdeen Wellington Road	✓	✓	✓	✓	**Grangemouth**	✓	✓	✓	✓
Alloa A907	✓	✓	✓	✓	**Grangemouth Moray~**	✓	✓	✓	✓
Angus Forfar Glamis Road	✓	✓	✓	✓	**Grangemouth Moray Scot Gov~**	✓	✓	✓	✓
Auchencorth Moss	✓	✓	✓	✓	**Inverclyde Greenock A8**	✓	✓	✓	✓
Bush Estate	✓	✓	✓	✓	**Inverness***	✓	✓	✓	✓
Dumfries	✓	✓	✓	✓	**Inverness Academy Street**	✓	✓	✓	✓
Dundee Broughty Ferry Road	✓	✓	✓	✓	**Inverness Academy Street 1st Floor**	✓	✓	✓	✓
Dundee Lochee Road	✓	✓	✓	✓	**Lerwick~**	✓	✓	✓	✓
Dundee Mains Loan	✓	✓	✓	✓	**N Lanarkshire Airdrie Kenilworth Dr**	✓	✓	✓	✓
Dundee Meadowside	✓	✓	✓	✓	**N Lanarkshire Chapelhall**	✓	✓	✓	✓
Dundee Seagate	✓	✓	✓	✓	**N Lanarkshire Coatbridge Whifflet**	✓	-	-	-
Dundee Whitehall Street	✓	✓	✓	✓	**N Lanarkshire Coatbridge Whifflet A725**	✓	✓	✓	✓
East Ayrshire Kilmarnock St Marnock St	✓	✓	✓	✓	**N Lanarkshire Croy**	✓	✓	✓	✓
East Dunbartonshire Bearsden	✓	✓	✓	✓	**N Lanarkshire Kirkshaws**	✓	✓	✓	✓
East Dunbartonshire Bishopbriggs	✓	✓	✓	✓	**N Lanarkshire Motherwell**	✓	✓	✓	✓
East Dunbartonshire Kirkintilloch	✓	✓	✓	✓	**N Lanarkshire Motherwell Adele Street**	✓	✓	✓	✓
East Dunbartonshire Milngavie	✓	✓	✓	✓	**N Lanarkshire Coatbridge Whifflet A725**	✓	✓	✓	✓

Site Name	Q1	Q2	Q3	Q4	Site Name	Q1	Q2	Q3	Q4
East Lothian Musselburgh N High St	✓	✓	✓	✓	N Lanarkshire Ravenscraig Plantation Rd	✓	✓	✓	✓
Edinburgh Currie	✓	✓	✓	✓	N Lanarkshire Shawhead Coatbridge	✓	✓	✓	✓
Edinburgh Glasgow Road	✓	✓	✓	✓	N Lanarkshire Uddingston New Edinburgh Rd	✓	✓	✓	✓
Edinburgh Gorgie Road	✓	✓	✓	✓	North Ayrshire Irvine High Street	✓	✓	✓	✓
Edinburgh Nicolson Street	✓	✓	✓	✓	Paisley Gordon Street	✓	✓	✓	✓
Edinburgh Queensferry Road	✓	✓	✓	✓	Peebles	✓	✓	✓	✓
Edinburgh Salamander St	✓	✓	✓	✓	Perth Atholl Street	✓	✓	✓	✓
Edinburgh St John's Road	✓	✓	✓	✓	Perth Bridgend	-	✓	✓	✓
Edinburgh St Leonards	✓	✓	✓	✓	Perth Crieff	✓	✓	✓	✓
Edinburgh Tower Street	✓	✓	✓	✓	Perth Muirton	✓	✓	✓	✓
Eskdalemuir	✓	✓	✓	✓	Renfrew Cockels Loan	✓	✓	✓	✓
Falkirk Banknock	✓	✓	✓	✓	Renfrew Inchinnan Road	✓	✓	✓	✓
Falkirk Bo'ness	✓	✓	✓	✓	Renfrewshire Johnston	✓	✓	✓	✓
Falkirk Grangemouth MC	✓	✓	✓	✓	Shetland Lerwick~	✓	✓	✓	✓
Falkirk Grangemouth Zetland Park	✓	✓	✓	✓	South Ayrshire Ayr Harbour	✓	✓	✓	✓
Falkirk Haggs	✓	✓	✓	✓	South Ayrshire Ayr High St	✓	✓	✓	✓
Falkirk Hope Street	✓	✓	✓	✓	South Lanarkshire Blantyre	✓	✓	✓	✓
Falkirk Main St Bainsford	✓	✓	✓	✓	South Lanarkshire Cambuslang	✓	✓	✓	✓
Falkirk West Bridge Street	✓	✓	✓	✓	South Lanarkshire East Kilbride	✓	✓	✓	✓
Fife Cupar	✓	✓	✓	✓	South Lanarkshire Hamilton	✓	✓	✓	✓
Fife Dunfermline	✓	✓	✓	✓	South Lanarkshire Lanark	✓	✓	✓	✓
Fife Kirkcaldy	✓	✓	✓	✓	South Lanarkshire Raith Interchange 2	✓	✓	✓	✓
Fife Rosyth	✓	✓	✓	✓	South Lanarkshire Rutherglen	✓	✓	✓	✓
Fort William	✓	✓	✓	✓	South Lanarkshire Uddingston	✓	✓	✓	✓
Glasgow Abercromby Street	✓	✓	✓	✓	Stirling Craig's Roundabout	✓	✓	✓	✓
Glasgow Anderston	✓	✓	✓	✓	Strath Vaich	✓	✓	✓	✓
Glasgow Broomhill	✓	✓	✓	✓	West Dunbartonshire Clydebank	✓	✓	✓	✓
Glasgow Burgher Street	✓	✓	✓	-	West Dunbartonshire Glasgow Road	✓	✓	✓	✓
Glasgow Byres Road	✓	✓	✓	✓	West Lothian Broxburn	✓	✓	✓	✓
Glasgow Dumbarton Road	✓	✓	✓	✓	West Lothian Linlithgow High St 2	✓	✓	✓	✓
Glasgow Kerbside	✓	✓	✓	✓	West Lothian Newton	✓	✓	✓	✓

A3.1. Process used for VCM correcting SAQD TEOM data



Appendix 3 National Monitoring Networks in Scotland 2022

Table A.3 1 AURN Measurement Sites in Scotland 2022

Site Name	Site Type	Species Measured	Grid Reference
Aberdeen Erroll Park	URBAN BACKGROUND	NO NO_2 NO_X O_3 PM_{10}, $PM_{2.5}$	394416,807408
Aberdeen Union St Roadside	ROADSIDE	NO NO_2 NO_X	396345,805947
Aberdeen Wellington Road	ROADSIDE	NO NO_2 NO_X	394397, 804779
Auchencorth Moss	RURAL	O_3 PM_{10} $PM_{2.5}$	322167, 656123
Bush Estate	RURAL	NO NO_2 NO_X O_3	324626,663880
Dumbarton Roadside	ROADSIDE	NO NO_2 NO_X	240234,675193
Dumfries	ROADSIDE	NO NO_2 NO_X	297012,576278
Dundee Mains Loan	URBAN BACKGROUND	NO NO_2 NO_X	340971, 731892
Edinburgh Nicolson St	ROADSIDE	NO NO_2 NO_X	326150, 673046
Edinburgh St Leonards	URBAN BACKGROUND	CO NO NO_2 NO_X O_3 PM_{10} $PM_{2.5}$ SO_2	326265, 673136
Eskdalemuir	RURAL	NO NO_2 NO_X O_3	323552,603018
Fort William	RURAL	NO NO_2 NO_X O_3	210830,774410
Glasgow Great Western Road	ROADSIDE	NO NO_2 NO_x	258007,666651
Glasgow High Street	URBAN TRAFFIC	NO NO_2 NO_X PM_{10}, $PM_{2.5}$	260014,665349
Glasgow Kerbside	KERBSIDE	NO NO_2 NO_X PM_{10}, $PM_{2.5}$	258708,665200
Glasgow Townhead	KERBSIDE	NO NO_2 NO_X PM_{10}, $PM_{2.5}$	259692,665899
Grangemouth	URBAN INDUSTRIAL	NO NO_2 NO_X PM_{10}, $PM_{2.5}$, SO_2	293840,681032
Grangemouth Moray	URBAN BACKGROUND	NO NO_2 NO_X	296436,681344
Greenock A8 Roadside	ROADSIDE	NO NO_2 NO_X	229332, 675715
Inverness	ROADSIDE	PM_{10}, $PM_{2.5}$, NO NO_2 NO_X	265720,845680
Lerwick	RURAL	O_3	445337,113968
Peebles	SUBURBAN	NO NO_2 NO_X O_3	324812,641083
Strath Vaich	REMOTE	O_3	234787,875022

Table A.3 2 Automatic Hydrocarbon Network Sites in Scotland 2022

Site Name	Site Type	Species Measured	Grid Reference
Auchencorth Moss	RURAL	Benzene and 1,3-butadiene and 24 other ozone precursor hydrocarbon species*	322167, 656123

Table A.3 3 Non-Automatic Hydrocarbon Network Sites in Scotland 2022

Site Name	Site Type	Species Measured	Grid Reference
Glasgow Kerbside	KERBSIDE	Benzene	258708, 665200
Grangemouth	URBAN INDUSTRIAL	Benzene	293840, 681032

EU requirement and part of the EMEP long-range transboundary air pollution monitoring programme.

Table A.3 4 PAH Monitoring Sites in Scotland 2022

Site	Address	Grid Reference
Auchencorth Moss	Rural site in Scotland, South of Edinburgh	322167, 656123
Edinburgh	145 Pleasance Edinburgh EH8 9RU	326265, 673136
Glasgow Townhead	Townhead Glasgow G4 0PH	259692, 665899
Kinlochleven 2	Electrical Substation Kinlochleven	219280, 761986

Table A.3 5 Heavy Metals Monitoring Network Sites in Scotland 2022

Site Name	Site Type	Species Measured	Grid Reference
Auchencorth Moss	Rural	As, Cd, Cr, Co, Cu, Fe, Mn, Ni, Pb, Se, V, Zn	322167, 656123
Eskdalemuir	Rural	As, Cd, Cr, Co, Cu, Fe, Mn, Ni, Pb, Se, V, Zn	323552, 603018

Table A.3 6 Rural Metal Deposition Monitoring sites in Scotland 2022

Site	Location Grid Ref.	Heavy metals			Mercury	
		In Particles	In Rain	In Cloud	In Air	In Rain
Inverpolly	218776, 908833		✓			
Banchory	367694, 798519	✓	✓		✓	✓
Bowbeat	328289, 647302		✓	✓		
Auchencorth Moss	322167, 656123	✓	✓		✓	✓

United Kingdom Eutrophying & Acidifying Network (UKEAP)

Table A.3 7 The Precipitation Network (PrecipNet) Sites in Scotland 2022

Site Name	Grid Reference	Species Monitored
Auchencorth Moss	322167, 656123	Na^+, Ca^{2+}, Mg^{2+}, K^+, PO_4^{3-}, NH_4^+, NO_3, SO_4^{2-}, Cl^-
Allt a'Mharcaidh	287691, 805223	
Balquhidder 2	254465, 720706	
Eskdalemuir	323552, 603018	
Forsinard RSPB	289309, 942826	
Glensaugh	366329, 780027	
Loch Dee	246907, 577768	
Polloch	179244, 768951	
Strathvaich	234787, 875022	
Whiteadder	366180, 663116	

Table A.3 8 Acid Gas and Aerosol Network (AGANet) and Ammonia Network (NAMN) Sites in Scotland 2022

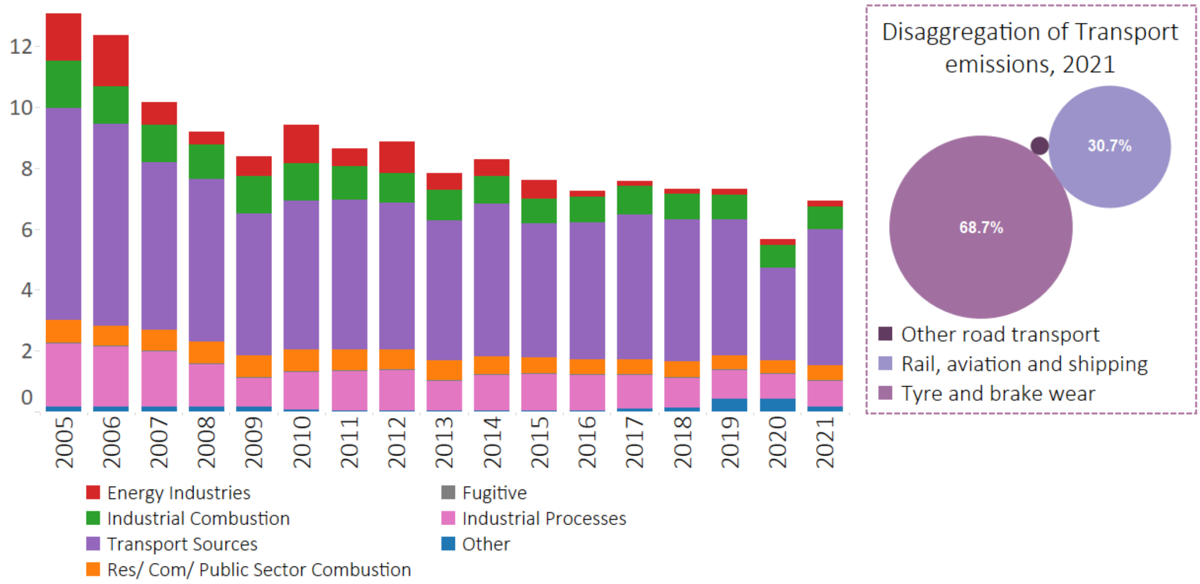
Name	Grid Ref	Ammonia	Nitric Acid
Allt a Mharcaidh	287691, 805223	✓	✓
Allt a Mharcaidh ECN	289160, 804162	✓	
Auchencorth Moss	322188, 656202	✓	✓
Auchincruive	238018, 623382	✓	
Bush	324629, 663891	✓	✓
Carradale	179870, 637801	✓	✓
Eskdalemuir	323588, 602997	✓	✓
Forsinard RSPB	289309, 942826	✓	✓
Glensaugh	366329, 780027	✓	✓
Glen Shee Dalmunzie Estate	312187, 769016	✓	
Inverpolly	218695, 908820	✓	
Loch Awe	96537, 711570	✓	
Loch Dee	246801, 577889	✓	
Oldmeldrum	383297, 827323	✓	
Polloch	179244, 768951	✓	✓
Sourhope	386796 621798	✓	
Strathvaich	234787, 875022	✓	✓

Appendix 4: Pollution Emissions data for Pb, B(a)p, Dioxins, Hg

Scotland lead (pb) Inventory by NFR Sector 2005 – 2021

Figure A4.1 provides a summary of Lead (Pb) emission estimates for Scotland by category. The detailed data are available in the report and website citied in the introduction to chapter 9 of this report.

A4.1 Time Series of Scotland's Pb Emissions 2005-2021

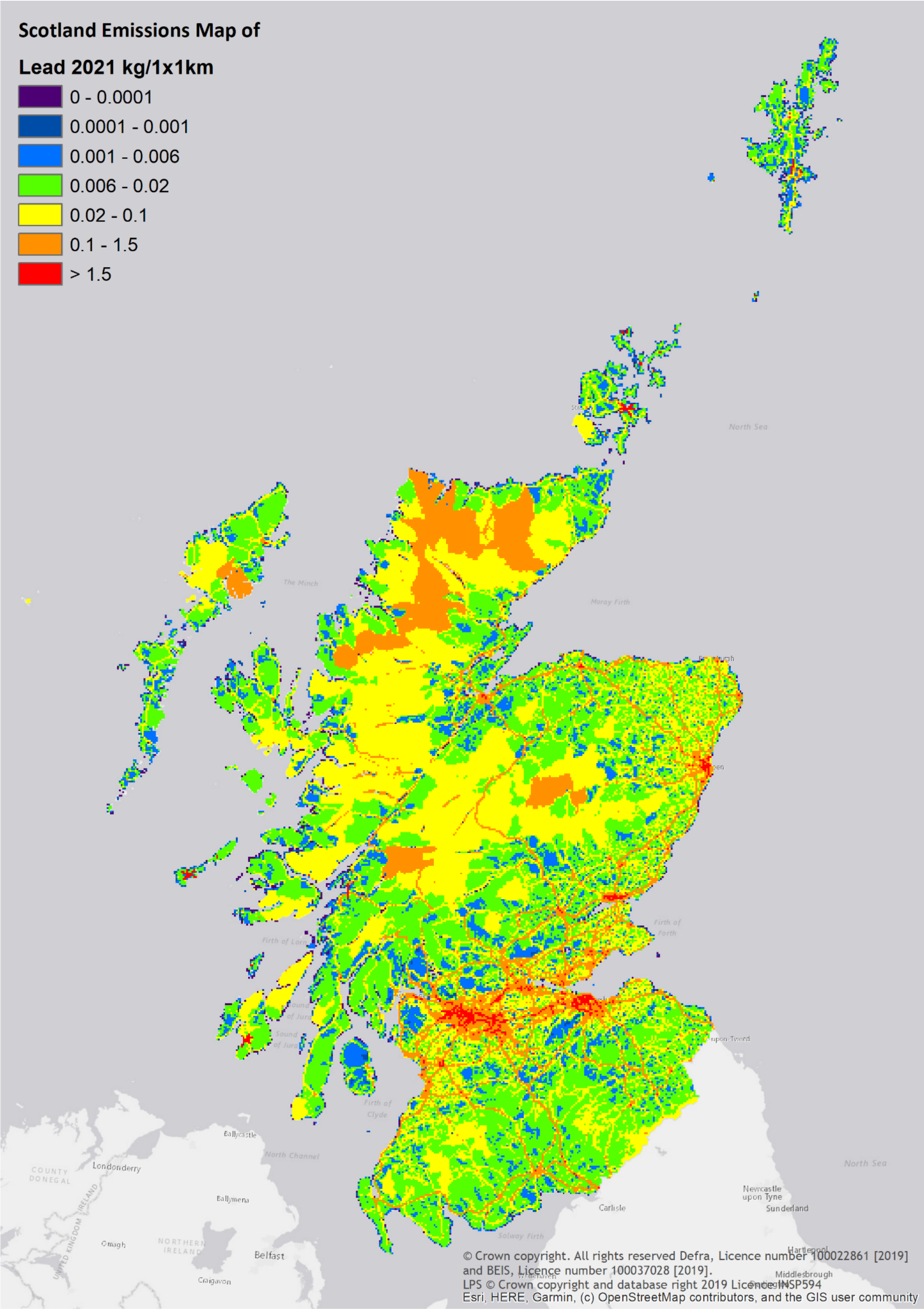


Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2021

Emissions of lead in Scotland were estimated to be 6.9 tonnes in 2021, representing 6% of the UK total in 2021 for lead. Emissions have declined by 47% since 2005 due to changes in energy sources, industrial combustion, and industrial processes. Emissions from power stations have decreased by 88% since the base year, due to the phase out of coal from the energy generation mix, with the closure of Longannet in 2016 marking the end of the use of coal in energy generation in Scotland. Unlike exhaust emissions which have been subject to the continued implementation of more stringent European regulation, non-exhaust emissions are not regulated and are strongly linked to the v-km driven on Scotland's roads. Non-exhaust emissions have decreased by 11% since the 2005 baseline. Industrial combustion accounts for 11% in 2021, and use of fireworks contributes a further 6%. Three of the seven sites in the UK which manufacture fibreboard, chipboard and oriented strand board are located in Scotland, and are key sites for lead emissions due to the burning of waste wood as fuel. Lead emissions have increased by 22% since 2020, primarily due to a 16% increase in emissions due to tyre and break wear in the transport sector. Due to the COVID-19 pandemic, travel restrictions resulted in a reduction in traffic volumes. The lifting of travel restrictions saw an associated increase in traffic volumes.

Figure A4.2 shows a map of Scotland's Lead emissions in 2021.

Figure A4.2 Map of Lead Emissions in Scotland, 2021

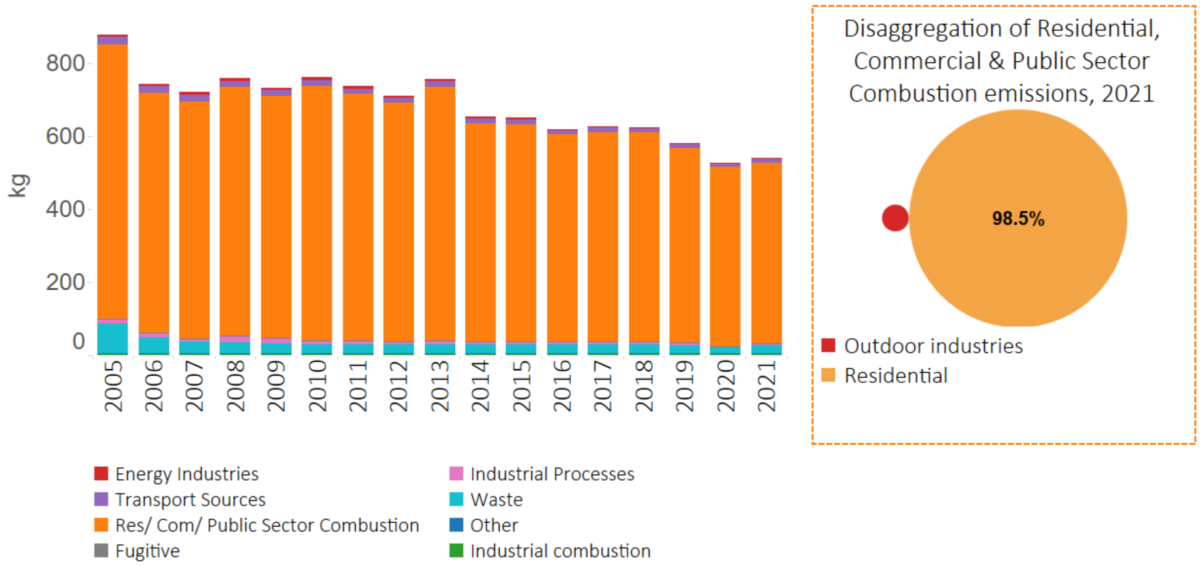


Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2021

Scotland benzene (a) Pyrene (B(a)P) Inventory by NFR Sector 2005 – 2021

Figure A4.3 provides a summary of Benzene (a) Pyrene (BaP) emission estimates for Scotland by category.

A4.3 Time Series of Scotland's B(a)P Emissions 2005-2021

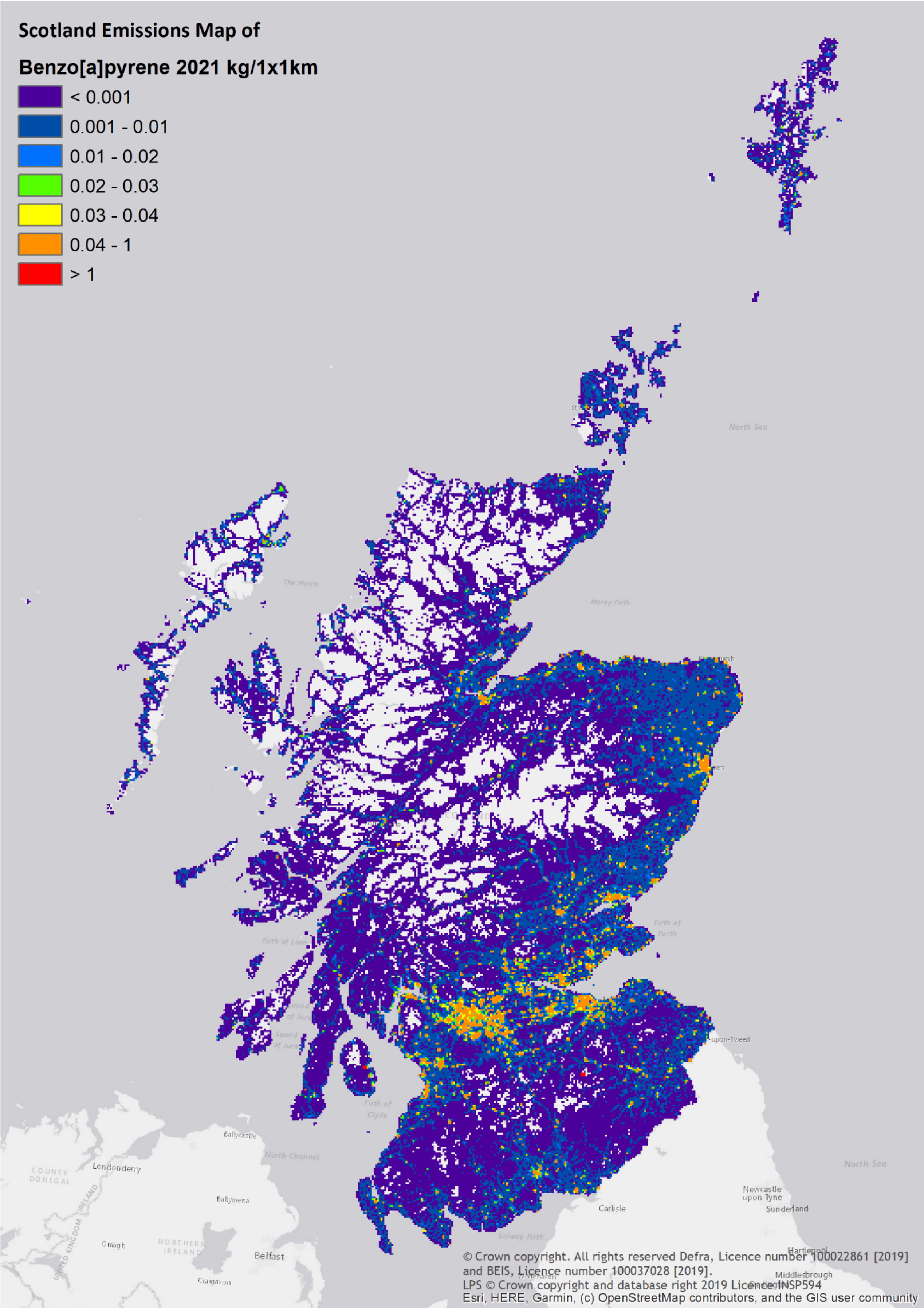


Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2021

Emissions of benzo(a)pyrene in Scotland were estimated to be 540 kg in 2021, representing 9% of the UK total for benzo(a)pyrene. Emissions have decreased 38% since 2005, primarily driven by a reduction in agricultural waste burning. Emissions from residential combustion account for 35% of the B[a]P emissions from Scotland in 2021, with domestic wood and coal combustion accounting for a significant proportion of the sector.

Figure A4.4 shows a map of Scotland's B(a)P emissions in 2021.

Figure A4.4 Map of B(a)P Emissions in Scotland, 2021

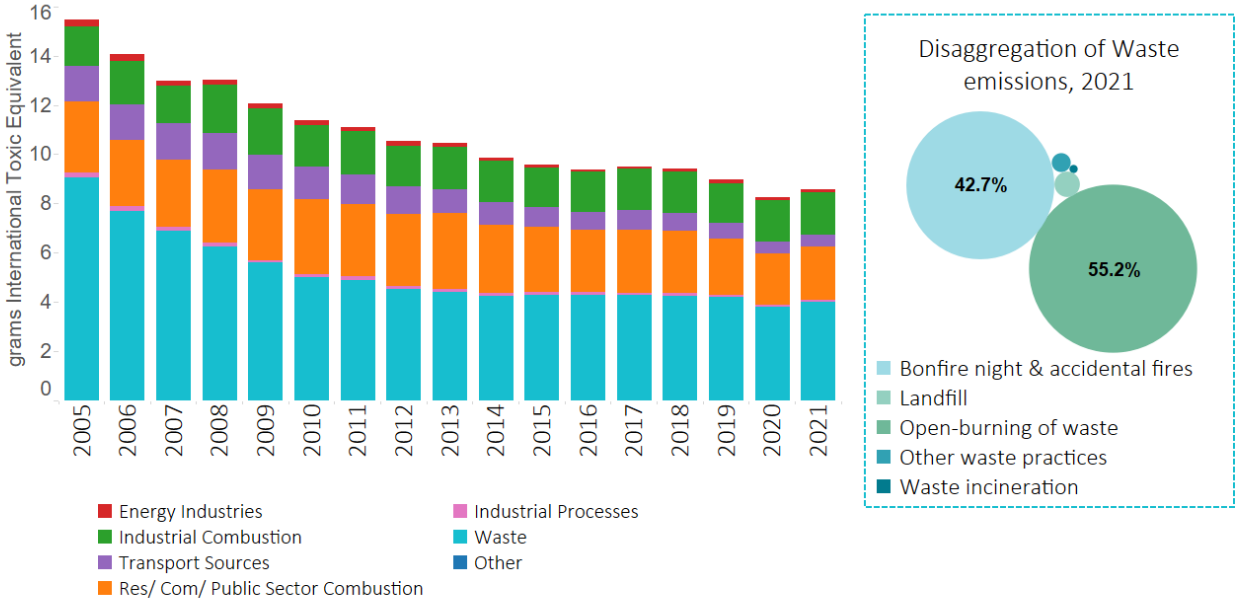


Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2021

Scotland Dioxins Inventory by NFR Sector 2005 – 2021

Figure A4.5 provides a summary of Dioxins emission estimates for Scotland by category.

A4.5 Time Series of Scotland's Dioxins Emissions 2005-2021

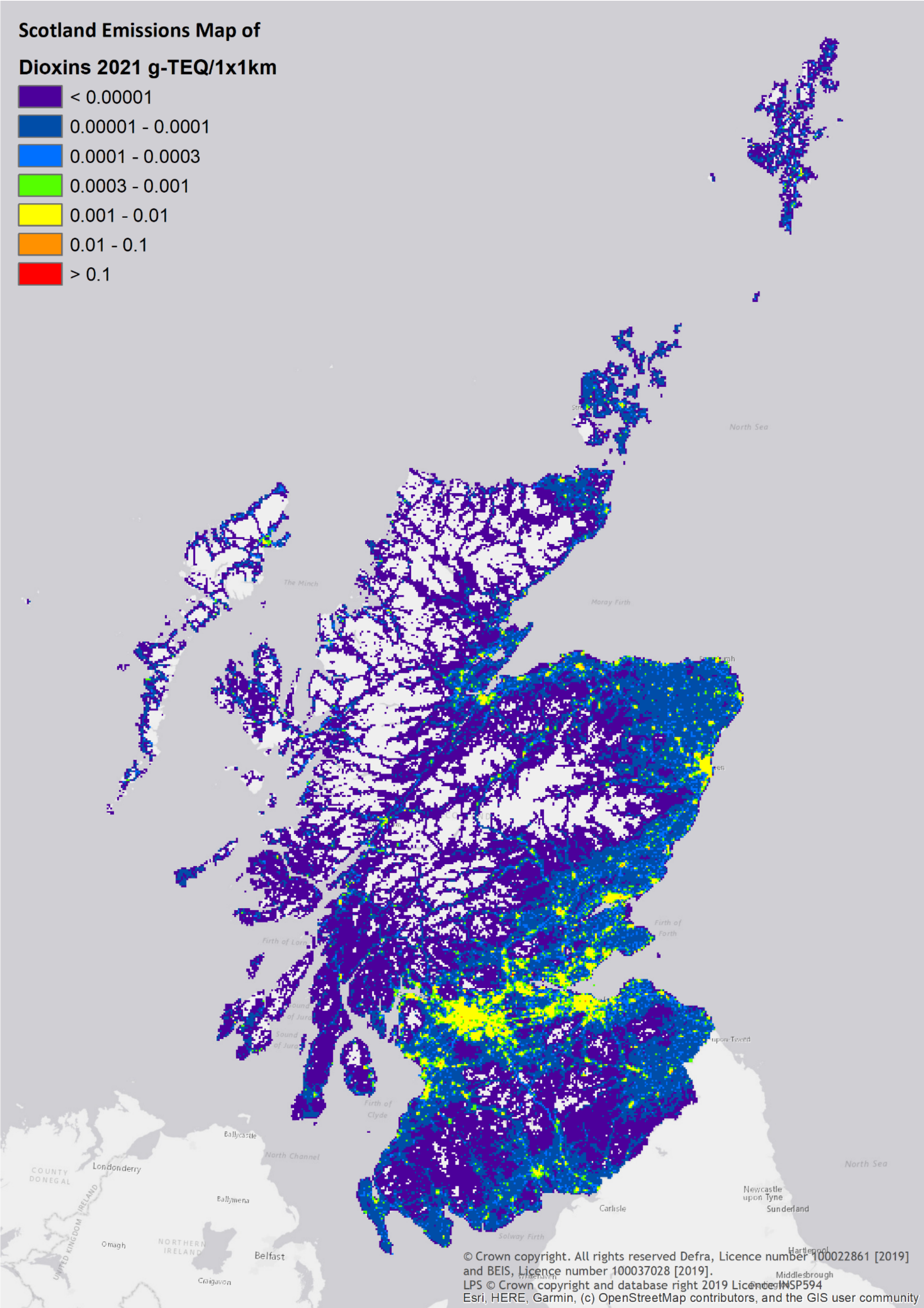


Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2021

Emissions of dioxins in Scotland were estimated to be 8.6g international toxic equivalents (I-TEQ) in Scotland in 2021, representing 7% of the UK total for dioxins. Emissions have declined by 45% since 2005, mainly driven by a reduction in emissions from the waste sector. The decline in dioxin emissions since 2005 tracks the trend of a reduction in coal use in power stations, and the introduction of more stringent regulatory controls and the promotion of alternative waste disposal and recycling streams to reduce small-scale open waste burning of household and garden waste.

Figure A4.6 shows a map of Scotland's Dioxin emissions in 2021.

Figure A4.6 Map of Dioxin Emissions in Scotland, 2021

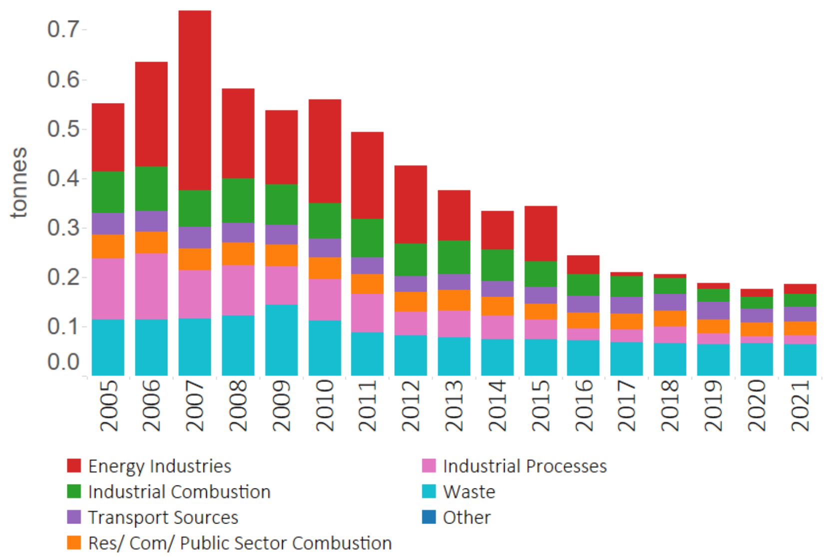


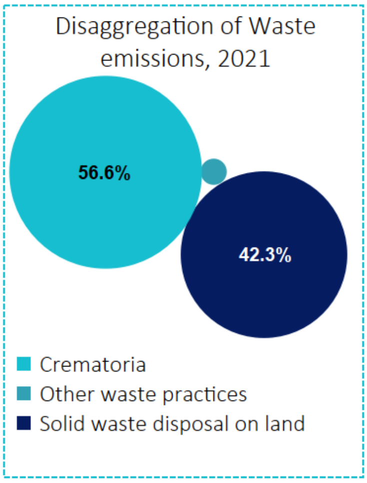
Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2021

Scotland Mercury (hg) Inventory by NFR Sector 2005 – 2021

Figure A4.7 provides a summary of Mercury (Hg) emission estimates for Scotland by category.

A4.7 Time Series of Scotland's Mercury Emissions 2005-2021



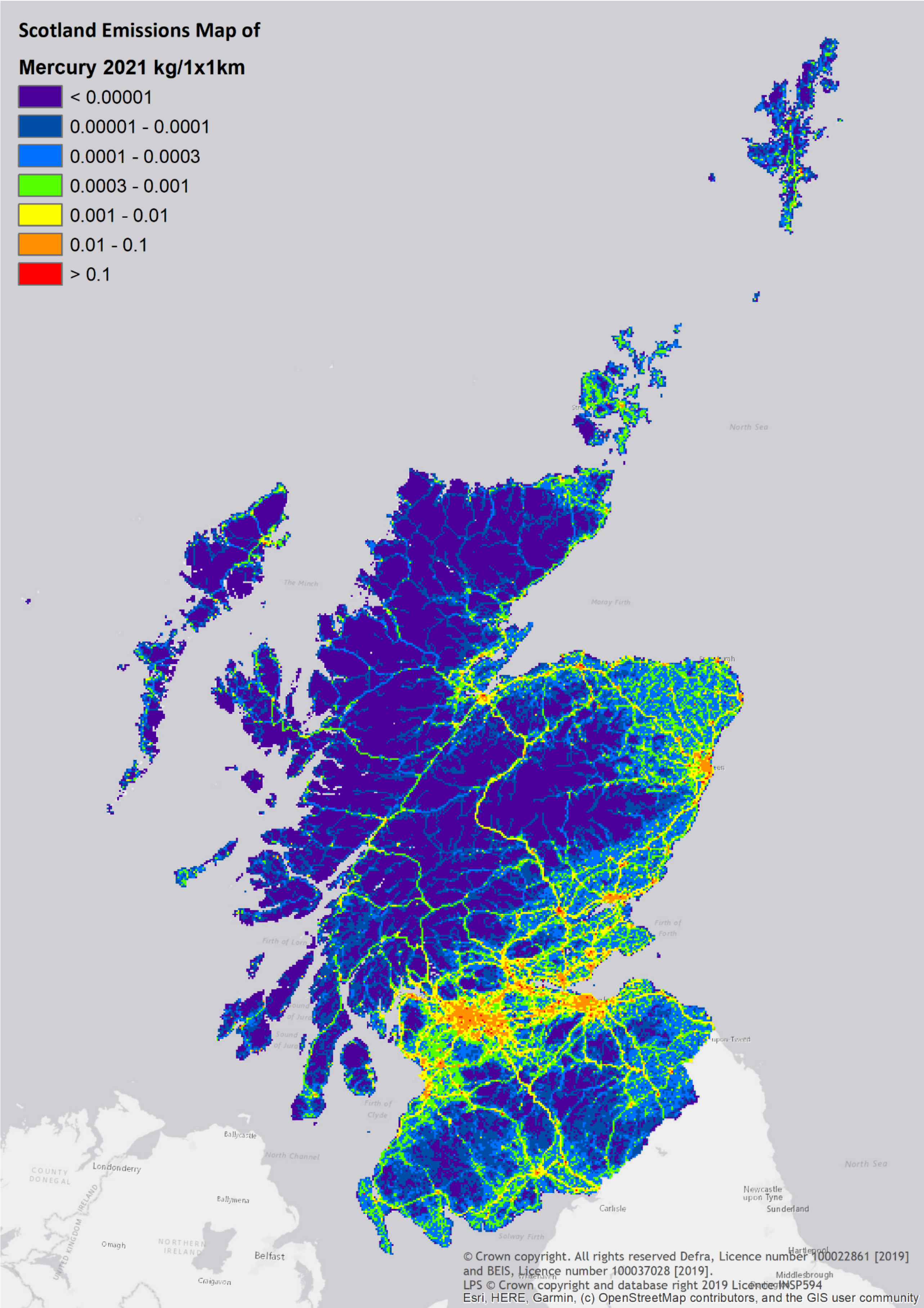


Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2021

Emissions of Hg in Scotland were estimated to be 0.19 t in 2021 and have declined by 66% since 2005. Emissions in Scotland account for 5% of the UK total in 2021 for Hg. This decline in emissions stems from changes to combustion in power and heat generation and chloralkali process emissions, with a 32% and 25% contribution to the overall trend, respectively. The decline in emissions from power and heat generation is driven by the reduction in combustion of coal. As observed above, the emissions from energy industries have been negligible since 2017 since the cessation of coal used for energy generating purposes in Scotland. Since 2016, emissions from crematoria have been the largest source of emissions, representing 19% of the Scotland total Hg emissions in 2021.

Figure A4.8 shows a map of Scotland's Hg emissions in 2021.

Figure A4.8 Map of Mercury Emissions in Scotland, 2021



Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2021

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