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Scottish Air Quality Database

Annual Report 2020

Report for Scottish Government

Report for Scottish Government – ED11194

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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 (Apr 2007 – Apr 2010) to develop an Air Quality Database and Website for Scotland. This contract has been renewed in consecutive years, with the latest contract running from 2019-2022.

This report brings together all the Scottish Air Quality Database data for calendar year 2020 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 also includes a section on the effects of the Covid-19 pandemic on air quality in Scotland.

Legislation and Policy

In October 2020, the Scottish Government published the "Cleaner Air For Scotland 2 – Draft Air Quality Strategy Consultation[1]" report. In July 2021, accompanied by a Delivery Plan, and replacing "Cleaner Air for Scotland – The Road to a Healthier Future", Scottish Government published Scotland's second air quality strategy called "Cleaner Air for Scotland 2 – Towards a Better Place for Everyone" (CAFS2). CAFS 2 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 100 automatic monitoring sites throughout Scotland are available in the database for all or part of 2020. All automatic data maintained within the Scottish database are subject to the same QA/QC procedures as at the national network air quality monitoring stations within the UK Automatic Urban and Rural Network providing confidence and continuity in the data.

Analysis shows that data capture rates since 2008 have continued to improve, year on year, for both nitrogen dioxide (NO_2) and Particulate Matter (PM_{10}). A significant improvement in PM_{10} data capture since 2016 has been attributed to a change in analyser used within the network.

In 2020, no automatic monitoring sites exceeded the annual mean objective for NO_2. At the time of writing this report not all diffusion tube data for 2020 had been published. In 2019, 59 diffusion tube sites exceeded the NO_2 annual mean objective, 15 fewer than the previous year.

In 2020, no automatic monitoring sites measuring PM_{10} and $PM_{2.5}$ measured exceedances of the Scottish 24 h or annual mean objectives of either pollutant.

The pattern of measured concentrations in 2020 for both NO_2 and PM is not consistent with previous years. A significant decline in concentrations, especially NO_2, is attributed to the Covid-19 pandemic lockdown restrictions and the impact on road transport.

In 2020, the Air Quality Strategy (AQS) objective for ozone was not exceeded at any site. This is a significant change from the previous year when 7 sites exceed the objective.

[1] https://www.gov.scot/publications/cleaner-air-scotland-2-draft-air-quality-strategy-consultation/

In 2020, no exceedances of AQS objectives were observed for the pollutants SO_2, CO, benzene, 1,3-butadiene and benzo(a)pyrene.

Air Quality Mapping of Scotland

For NO_2, there were no modelled exceedances of the Scottish annual mean objective of 40 µg m^{-3} at background locations. Exceedances of the annual mean NO_2 objective were modelled at roadside locations in four of the six zones and agglomerations in Scotland. Exceedances of the annual mean NO_2 objective at roadside locations were modelled at 52 road links (102.7 km of road) in the Glasgow Urban Area and at 20 road links (45 km of road) in Central Scotland. In the Edinburgh Urban Area seven road links (11.0 km of road) exceedances were modelled and in the North East Scotland zone only four roads had an exceedance (8.5 km of road). No roadside exceedances of the annual mean NO_2 objective were modelled in the more rural zones and agglomerations of Scotland.

There were no modelled exceedances of the Scottish annual mean PM_{10} objective of 18 µg m^{-3} at background locations. Six road links (19.3 km of road) were however identified as exceeding in the Glasgow Urban Area and Central Scotland.

Air Quality Trends for Scotland

NO_2

Trend analysis of nitrogen dioxide concentrations at Scotland's five long-running urban non-roadside sites suggests that NO_2 concentrations are displaying highly significant decreasing trends. More recent years analysis (five years) show a less consistent trend across the country with one site showing increasing trends contradicting the perception that NO_2 concentrations are decreasing at all urban background sites

Nitrogen dioxide concentrations at Scotland's three long-running rural sites showed decreasing trends.

Scotland has a large number of urban traffic monitoring sites monitoring NO_2, of which 30 have now been operating for at least 10 years. This trend analysis therefore focused on eight of these sites. As with the previous report in this series, all eight sites show highly significant decreasing trends

Examination of trends at the same eight sites over the most recent five complete years (2016 to 2020) indicates that the patterns are very similar to the 10-year trends.

PM_{10}

PM_{10} at Scotland's eight long-running urban/Industrial background sites showed highly significant decreasing trends. PM_{10} at Scotland's eight long-running urban traffic sites showed statistically highly significant decreasing trends at all sites.

Examination of trends in PM_{10} at the same eight sites over the most recent five years indicates that, at some of these, the decreasing trends have continued but at others they have weakened or levelled off.

$PM_{2.5}$

By the end of 2020 there were four sites with 10 consecutive years of $PM_{2.5}$ data. Aberdeen Errol Place, Edinburgh St Leonards, and Grangemouth sites show slight but highly statistically significant decreasing trends for $PM_{2.5}$. Contrary to this, the rural site, Auchencorth Moss, showed no obvious trend over the past 10 years. At the end of 2020 there were nine sites with five years' worth of data. Four sites have decreasing trends with ranging levels of statistical significance. Another four sites, though decreasing, have no real identifiable statistically significant trend. South Lanarkshire Uddingston has an increasing trend though not statistically significant.

Ozone

Ozone has been measured at three rural sites in Scotland for 30 years. All three sites showed small increasing trends, highly statistically significant at two of the three sites. 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. Five of the sites showed increasing trends with varying levels of statistical significance. The remaining site showed no real trend.

10 year trend analysis of ozone concentrations showed increasing trends (at varying statistical significance) at all three Scottish urban background sites.

Additional Trend Analysis

Additional trend analysis was carried out at four sites located within the four major cities in Scotland. This analysis carried out using Openair compared 2020 data with data from the previous 10 years using a variety of analytical techniques.

Emissions of Pollution Species

Emissions of NOx in Scotland are estimated to have declined by 53% since 2005 and were estimated to be 85 kt in 2019, representing 10% of the UK total. Since 2008, emissions from passenger cars have further decreased. This has been mainly driven by improvements in catalyst repair rates resulting from the introduction of regulations controlling the sale and installation of replacement catalytic converters and particle filters for light duty vehicles. However, the increasing number of diesel cars partly offsets these emissions reductions, because diesel cars emit higher NOx relative to their petrol counterparts (88% of 2019 passenger car emissions is due to diesel cars).

Emissions of PM_{10} have declined by 30% since 2005 and in 2019 and were estimated to be 14 kt (8% of the UK total). Emissions from energy industries (and its movement away from coal use) and transport sources (the fleet increasing compliance with Euro emission standards) have had the most notable impact on the trend. Emissions levels since 2015 have plateaued and slightly increased

Emissions of $PM_{2.5}$ have declined by 33% since 2005 and in 2019 were estimated to be 9 kt (8% of the UK total). For $PM_{2.5}$, the residential, commercial and public sector combustion category accounts for 43% of 2019 emissions. The decline in emissions has significantly reduced over the past few years with no significant decrease since 2014. One of the reasons for this slowing has been attributed to the increase in emissions from the residential sector and in particular the combustion of wood. Emissions from the residential sector have increased by 50% since 2005.

Emissions of ammonia have declined by only 9% since 2005 and were estimated to be 31 kt (12% 0f the UK total) in 2019. Agriculture sources dominate throughout the time-series. The trend in NH_3 emissions has been largely driven by decreasing animal numbers and a decline in fertiliser use. After 2010, however, the decline was 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.

Emissions of Non-Methane Volatile Organic Compounds have declined 15% since 2005 and were estimated to be 148 kt in 2019 (18% of the UK total). This reduction is a result of reductions in fugitive and transport emissions which have declined 66% and 75% since 2005, respectively. There has been an increasing trend in NMVOCs since 2009. This has been attributed to the increase emissions from the food and drink sector specifically the storage and production of whisky (49% of emissions in 2019).

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

Cusum (or cumulative sum) analysis carried out indicates a decrease in NO_2 concentrations when compared to Business As Usual (BAU) modelled results, at the time lockdown started. For most of the monitoring sites the annual mean measured NO_2 was lower than predicted by the model. Glasgow Kerbside, Dumfries, and Edinburgh St John's Road observe the greatest decrease in NO_2, when compared to BAU. Overall, the average NO_2 concentrations across Scottish monitoring sites were lower by 20.5% on average when compared to BAU. When focused specifically on the lockdown period, the differences between measured and modelled concentrations were even greater, with reductions of 48.8% when compared to BAU. The greatest decreases in NO_2 during lockdown, on average, were at Urban Traffic sites. NOx diurnal analysis at two urban traffic sites shows that during lockdown the concentration profile is much lower overall, and the evening peaks normally seen all but disappeared. The observed change in the diurnal profile provides evidence that the reduction in NOx is consistent with a reduction in traffic emissions.

Compared to NOx it is less clear if changes in PM occurred when lockdown started, with large variation between sites.

Across all sites, the change in absolute PM when compared to BAU is very small over the lockdown period (Table 10.4), with an average decrease of 1.5 μgm^{-3} in PM_{10} and 0.59 μgm^{-3} in $PM_{2.5}$. These values are also more uncertain than for NOx, as the choice of the background site used for calculating the PM increment can have a large impact on the estimated PM increment.

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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.
- 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 2020 in the on-going project tasks and also highlights the new work undertaken during 2020 and into early 2021.

Section 2 of this report provides a breakdown of the legislation and policy that drives Local Air Quality Management 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 2020.

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 2020.

A statistical summary of all the available 2020 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.

In 2009, a pilot mapping exercise specific to Scotland was undertaken including future year projections for 2010, 2015 and 2020. This pilot exercise has been subject to further development in subsequent years and an improved methodology has been used to deliver pollution climate mapping of NO_x, NO_2 and PM_{10} including projections. As the number of monitoring sites in Scotland has significantly increased since 2006, it has become feasible to undertake pollution climate mapping of NO_x, 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 2020 is described in Section 7.

The SAQD has accumulated a substantial body of air quality data since its establishment which in turn allows for robust statistical trend analysis to be undertaken. 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).

In addition to the standard layout to the SAQD annual report series stated above, the 2020 report will include a section on the effects the 2020 Covid-19 pandemic had on air pollution concentrations in Scotland.

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 meeting limit and target values for a range of air pollutants and other legal obligations covered by the directives.

The Scottish Government has duly transposed these Directives into national law through the Air Quality Strategy and Air Quality Standards (Scotland) Regulations 2010, and the Pollution Prevention and Control (Scotland) Regulations 2012. 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.

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 the table below.

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
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	8 hourly running or hourly mean	31.12.2005

*not required to be monitored or assessed by local authorities under LAQM, however is a UK requirement under EU directive (Directives 2004/107/EC and 2008/50/EC)

2.2 Cleaner Air for Scotland-The Road to a Healthier Future

The "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.

CAFS considered the impact of air quality on health and looks at the estimated costs as well as the premature deaths associated with poor air quality.

Since the Cleaner Air for Scotland strategy was published in 2015, it 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 have been 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 Scottish Government this draft was published for consultation[2]. 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 NGOs 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.

2.3.1 CAFS2 – Overview

The 10 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

[2] https://www.gov.scot/publications/cleaner-air-scotland-2-draft-air-quality-strategy-consultation/

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 2019requires 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 2021will 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 in order 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.

2.4 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.

2.5 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 http://www.scottishairquality.scot/news/reports?view=technical. The framework provides a methodology for local authorities to undertake air quality assessment to inform decisions on transport related actions.

2.6 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. The first LEZ was introduced in Glasgow at the end of 2018. Due to the 2020 Covid-19 pandemic the deadlines for the implementation of LEZs for Edinburgh, Aberdeen and Dundee have been extended to 2022.

The Scottish Government will work in partnership with local authorities and Regional Transport Partnerships to introduce LEZs. Engagement with transport organisations, businesses and members of the public will help support the design of LEZs. Further information is available at http://www.scottishairquality.scot/lez/ and https://www.lowemissionzones.scot/.

2.6 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.

In 2016, the Scottish Government produced and updated Technical Guidance and Policy 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. Due to the on-going Covid-19 pandemic it was not possible to hold the seminar in the usual single venue as done in previous years. It was therefore decided to hold the event online and seperate the day long agenda into three two-hour webinars, over a three week period. Using the Teams Events platform, the event was held on the 10th, 17th and 24th March 2021 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; “Cleaner air for Scotland Strategy 2 (Andrew Taylor); Low Emission Zones Scotland (Vincent McInally); Particular Matter Intercomparison Study Scotland (Stephen Stratton); Shared transport and Mobility Hubs (Marian CoMo); Air Quality COVID-19 Analysis (Dr Louisa Kramer); COVID-19 Analysis a European Perspective (Dr Stuart Grange); Public Attitudes and Behavioural Change (Dr Jo Barnes); Air Quality within Rail Sector (Dr James Wright); Real World Emissions – Monitoring and Enforcement (Javier Buhigas); Edinburgh Councils Real World Emissions Study (Shauna Clark/Dr Jasmine Wareham).

In addition to the presenters stated, the Scottish Government and Ricardo were able to arrange for Dr Maria Neira from the World Health Organisation to be the seminars’ keynote speaker.

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 2021

SCOTTISH AIR QUALITY DATABASE AND WEBSITE ANNUAL SEMINAR

Wednesday 10th, 17th, and 24th March 2021

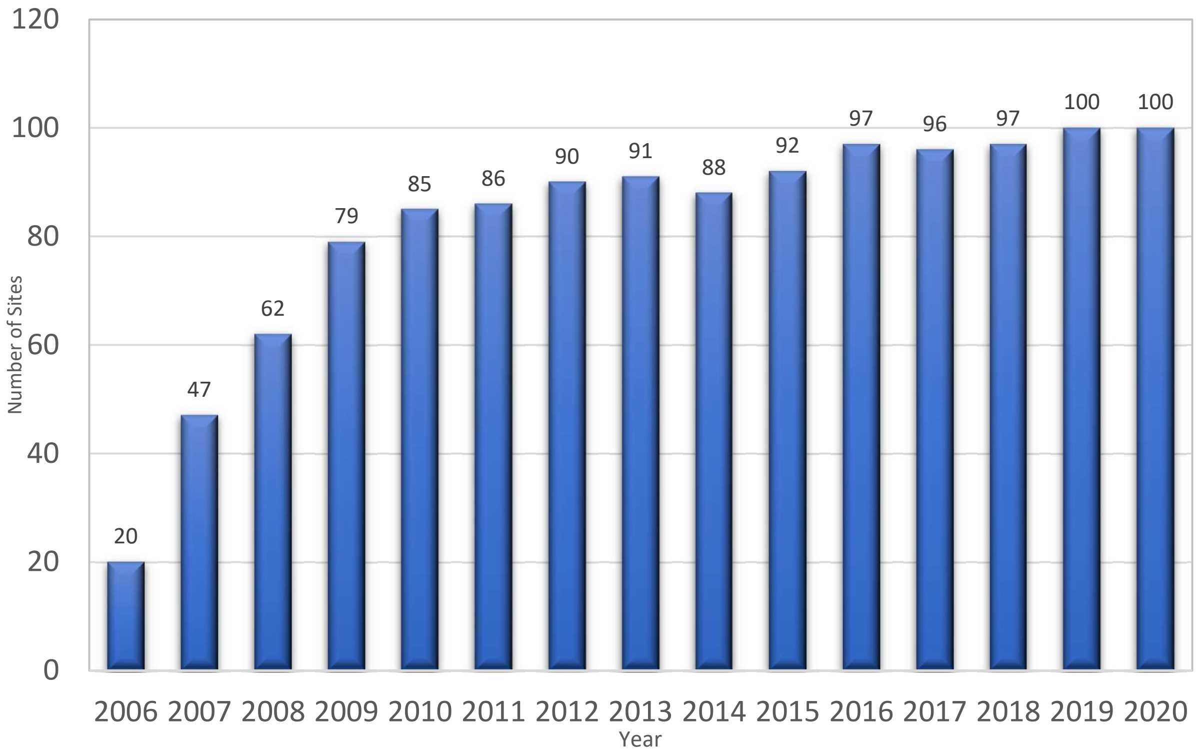
	Agenda	
	Webinar 1: Air Quality Scotland (10th March 2021)	
13:00	Welcome/Introduction	Ricardo Energy & Environment
13:10	Cleaner Air For Scotland 2	Andrew Taylor (Scottish Government)
13:30	SAQD Project Update and Developments	David Hector (Ricardo Energy & Environment)
14:00	Low Emission Zones Scotland	Vincent McInally (Transport Scotland)
14:20	Particulate Matter intercomparison Study Scotland	Stephen Stratton (Ricardo Energy & Environment)
14:50	Questions and Answer Session	
	Webinar 2: Air Quality Analysis and Health (17th March 2021)	
13:00	Welcome/Introduction	Ricardo Energy & Environment
13:10	Shared transport and mobility hubs – building better places and reducing car dependency	Marian Marsh (CoMo UK)
13:30	Air Quality Covid-19 Analysis	Dr Louisa Kramer (Ricardo Energy & Environment)
13:50	Covid-19 Analysis a European Perspective	Dr Stuart Grange (Swiss Federal Laboratories for Materials Science and Technology (Empa))
14:15	Public Attitudes & Behavioural Change	Dr Jo Barnes (University of the West of England)
14:45	Clean Air Day 2021	John Bynorth (EPS)
14:50	Questions and Answer Session	
	Webinar 3: Air Quality Research (24th March 2021)	
10:00	Welcome/Introduction	Ricardo Energy & Environment
10:10	Air Quality in Scotland a Global perspective	Dr Maria Neira (World Health Organisation)
10:40	Air Quality within the Rail Sector	Dr James Wright (RSSB)
11:00	Real World Emissions - Monitoring & Enforcement	Javier Buhigas (OPUS RSE)
11:25	City of Edinburgh Council's Real-World Emissions Study	Shauna Clark (City of Edinburgh Council) & Dr Jasmine Wareham (Ricardo Energy & Environment)
11:45	Questions and Answer Session	

4 Data Availability 2020

4.1 Hourly Data for Nitrogen Dioxide, Carbon Monoxide, Sulphur Dioxide, Ozone, PM_{10} and $PM_{2.5}$

At the end of 2020 the Scottish Air Quality Database contained data for 99 automatic monitoring sites. In total, one new monitoring site was added to the network: North Lanarkshire Motherwell Adele Street and one site was decommissioned and removed from the network during 2020: Falkirk Banknock. Figure 4.1 shows the growth of the SAQD from 20 sites in 2006 pilot study to 100 sites during 2019 and 2020.

Figure 4.1 Number of Monitoring Sites within the Scottish Air Quality Database Network 2006 – 2020



For the 22 UK Automatic Urban and Rural 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 2020, 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 are also provided for each site and the monitoring network the site is affiliated to; either the SAQD or the 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 on the 'Latest Data' page of the SAQD 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 available in the database for their period of operation.

Table 4.1 Scottish Air Quality Database Data Availability in 2020

Site Name	Type	East	North	Pollutants	Network	Start Year#	Data in 2020
Aberdeen Anderson Dr	RS	392506	804186	NO_2 PM_{10}	SAQD	2004	Jan – Dec
Aberdeen Errol Place	UB	394416	807408	NO_2 O_3 PM_{10} $PM_{2.5}$	AURN	1999	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	NO2, 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

Site Name	Type	East	North	Pollutants	Network	Start Year#	Data in 2020
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}	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	NO_2	SAQD	2005	Jan – Dec
Edinburgh Nicolson Street	RS	326145	673038	NO_2 PM_{10} $PM_{2.5}$	SAQD / AURN	2017	Jan – Dec
Edinburgh Queensferry Road	RS	318734	674931	NO_2 PM_{10}	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 O3	AURN	1986	Jan – Dec
Falkirk Banknock	RS	277247	679026	PM_{10} $PM_{2.5}$	SAQD	2013	Jan – Jun
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	SO_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

Site Name	Type	East	North	Pollutants	Network	Start Year#	Data in 2020
Glasgow Broomhill	RS	255030	667195	PM_{10} $PM_{2.5}$	SAQD	2007	Jan – Dec
Glasgow Burgher Street	RS	262548	664168	NO_2 PM_{10}	SAQD	2011	Jan – Jul
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} $PM_{2.6}$	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
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 Sunnyside Rd	RS	273054	665234	NO_2 PM_{10}	SAQD	2019	Jan – Dec
N Lanarkshire Coatbridge Whifflet	UB	273668	663938	NO_2 PM_{10} $PM_{2.5}$	SAQD	2007	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} $PM_{2.5}$	SAQD	2007	Jan – Dec
N Lanarkshire Motherwell Adele Street	RS	275642	656147	NO_2 PM_{10} $PM_{2.5}$	SAQD	2020	Aug - 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}	SAQD	2019	Jan – Dec
North Ayrshire Irvine High Street	KS	232142	638892	NO_2 PM_{10} $PM_{2.5}$	SAQD	2009	Jan – Dec

Site Name	Type	East	North	Pollutants	Network	Start Year#	Data in 2020
Paisley Gordon Street	RS	248316	663611	NO_2 PM_{10}	SAQD	2004	Jan – Dec
Peebles	S	324812	641083	NO_2 O_3	AURN	2009	Jan – Dec
Perth Atholl Street	RS	311582	723931	NO_2 PM_{10} $PM_{2.5}$	SAQD	2004	Jan – Dec
Perth Crieff	RS	286363	721614	NO_2 PM_{10} $PM_{2.5}$	SAQD	2010	Jan – Dec
Perth High Street	RS	311688	723625	NO_2 $PM_{2.5}$	SAQD	2003	Jan – Dec
Perth Muirton	UB	311688	723625	PM_{10} $PM_{2.5}$	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 $PM_{2.5}$	SAQD	2012	Jan – Dec
South Ayrshire Ayr High St	RS	233725	622120	NO_2 $PM_{2.5}$	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
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	KS	271065	658087	NO_2 PM_{10}, $PM_{2.6}$	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}	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 2020
* Sites changed monitoring
^Changes in number of measured pollutants or monitoring method during 2020
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.
~ At these sites, some pollutants are affiliated to the AURN network and some pollutants are affiliated the SAQD Network.
KS – Kerbside
R – Rural

RS – Roadside
S – Suburban
UB – Urban Background
UI – Urban Industrial

4.1.1 Summary of Changes to Monitoring Sites within the Database During 2020

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

Sites opened during 2020:

- N Lanarkshire Motherwell Adele Street NO_2 PM10 $PM_{2.5}$ on 07/08/2020

Sites closed during 2020:

- Falkirk Banknock PM_{10} $PM_{2.5}$ on 04/06/2020

Sites changes during 2020:

Monitoring of $PM_{2.5}$ in addition to PM_{10} using a FIDAS analyser at the following sites:

- East Dunbartonshire Milngavie on 14/05/2020
- Edinburgh Currie on 16/12/2020
- Edinburgh Glasgow Road on 16/012/2020
- Edinburgh Salamander Street on 16/02/2020
- Falkirk Hope Street on 15/12/2020
- Falkirk Main Street Bainsford on 15/12/2020
- Falkirk Grangemouth MC on 07/05/2020
- Falkirk Grangemouth Zetland Park on 15/12/2020
- Falkirk Grangemouth MC on 07/05/2020
- Falkirk Haggs on 23/07/2020
- N Lanarkshire Coatbridge Whifflet on 28/01/2020

4.2 NO_2 and PM_{10} Data Capture Rates

Figures 4.2 and 4.3 show the average data capture rates achieved between 2008 and 2020 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.

With the introduction of a harmonised QA/QC regime, the data capture rates for NO_2 and PM_{10} monitoring continue to improve. The sudden increase in PM_{10} data captures in 2017 has been attributed to the change in analyser type measuring PM at a significant number of local authority sites, coinciding with the requirement for local authorities to measure $PM_{2.5.}$ Likewise, a number of new PM sites were introduced, and analysers decommissioned half way through 2020 resulting in a decrease in the average data capture rate.

Figure 4.2 Network data capture rate for NO_2 monitoring, 2008 – 2020

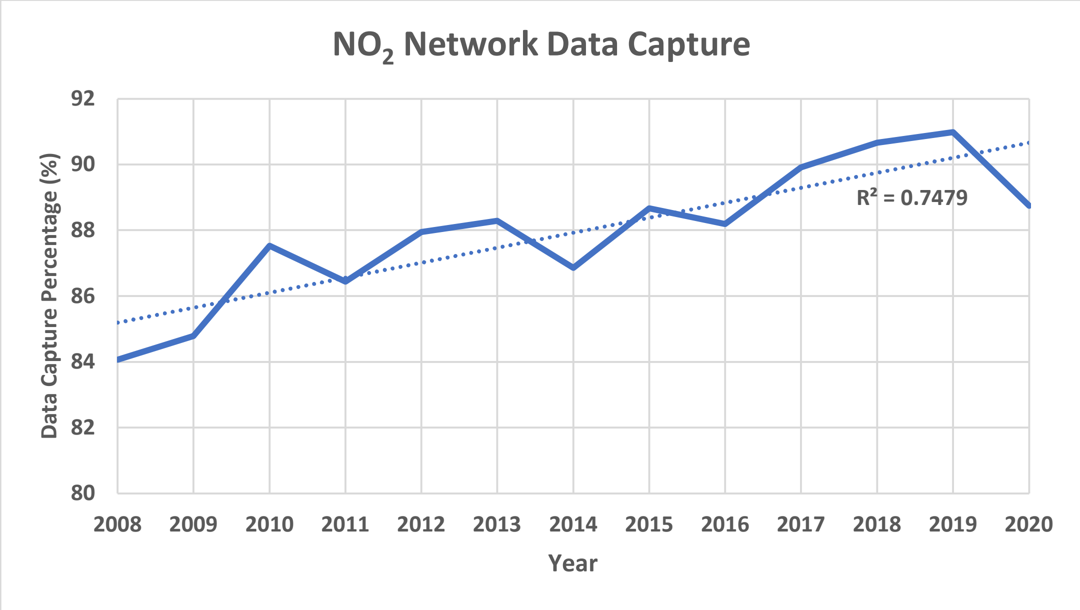
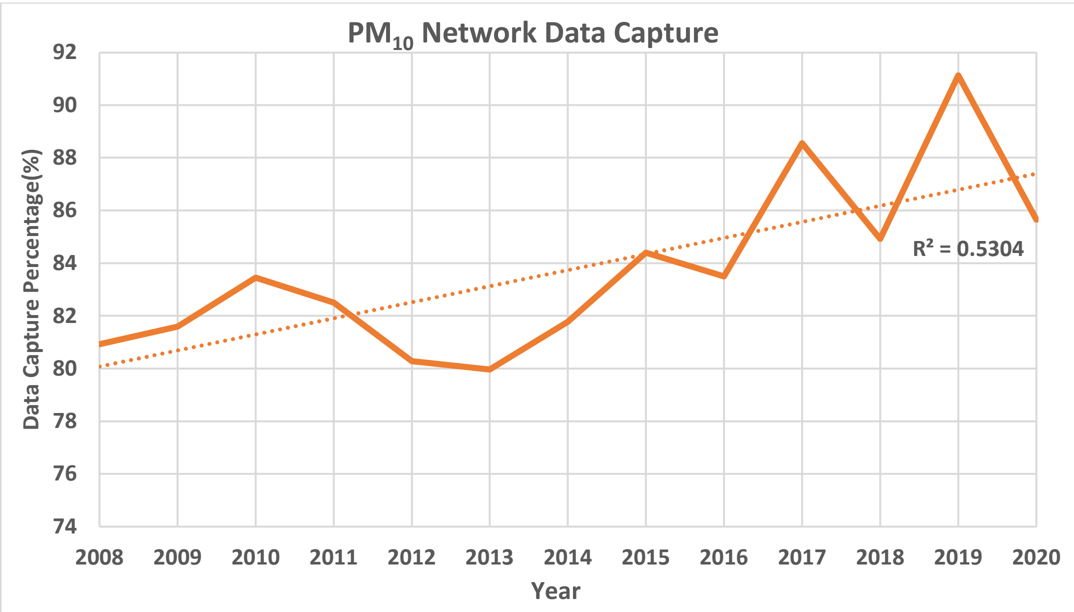


Figure 4.3 Network data capture rate for PM_{10} monitoring, 2008 – 2020



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 AURN are provided for all local authority sites within the database.

The main elements of the QA/QC programme are on-site analyser and calibration gas inter-calibrations every six months, 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.

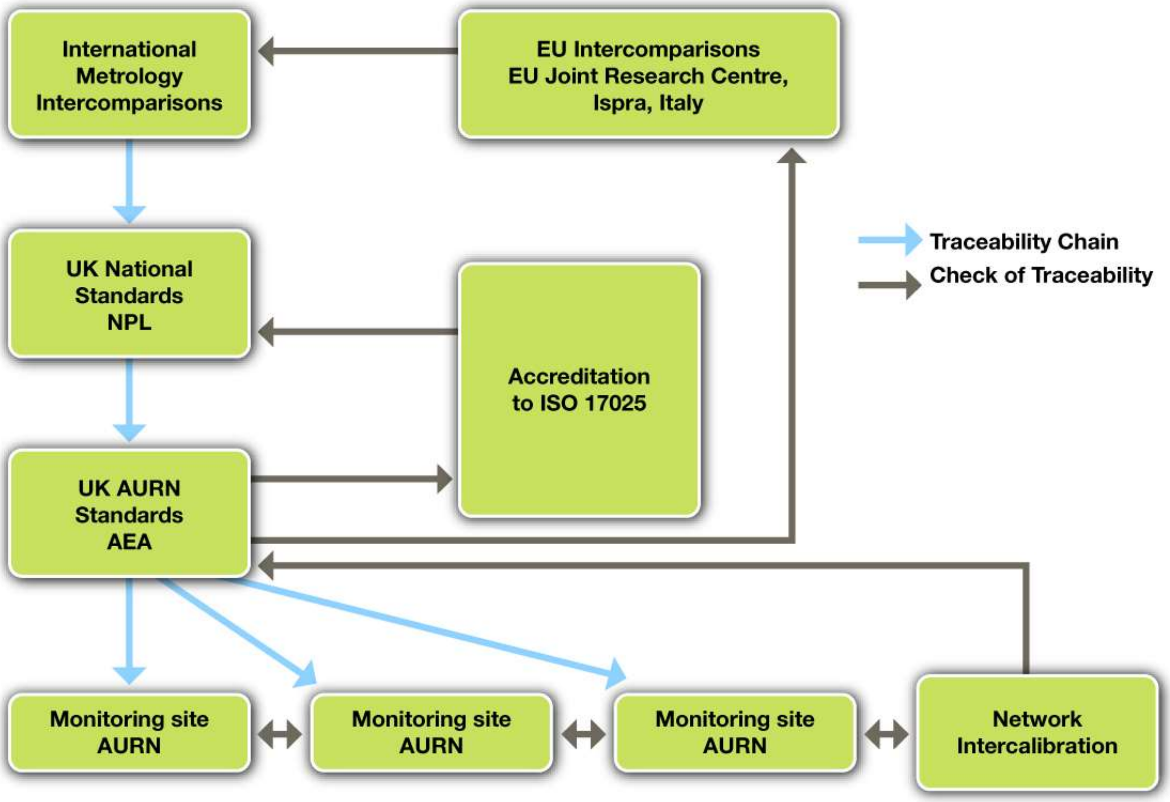
The assessment of the on-site calibration cylinder concentrations against accredited and traceable Ricardo Energy & Environment gas standard cylinders provides the essential final link in the measurement traceability chain (Fig 5.1). This process ensures that all monitoring stations in Scotland are traceable to reference gas standards held at Ricardo Energy & Environment. 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 Energy & Environment also participate in EU level inter-comparisons at the EU Joint Research Centre at Ispra, Italy. Hence, there is an unbroken traceability chain from each monitoring site in Scotland to internationally agreed gas calibration standards. This check also identifies any unstable 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 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 1.

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 Energy & Environment 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 SAQD as proviosional dara. These operations are carried out automatically by computer systems, with all output manually checked by data management experts.

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. 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 particular the automatic data summary bulletin, available by email from the website, and the plotting package incorporated into this, will be useful to authorities to rapidly evaluate their data against that from other stations.

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.

The policy on data rejection opted by Ricardo Energy & Environment 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 1.

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 well with the timetable for local authority reporting under the Review and Assessment process.

The ratified data are uploaded to the SAQD and overwrite the provisional data. Summary statistics of these ratified data are available from the website to assist local authorities complete their Air Quality Review and Assessment reports.

5.4 QA/QC During 2020

As discussed above, site inter-calibrations and audit visits are undertaken at six-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. Table 5.2 shows the full list of inter-calibrations and audits undertaken on air quality sites in the SAQD during 2020.

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 2020 audits

Site Faults Identified 2019	Number of Monitoring Sites Winter 2019/20	Number of Monitoring Sites Summer 2020
TEOM** and TEOM FDMS* k_0 out by > 2.5%	2	0
Particulate Analyser*** flow out by >10%	10	11
NO_x analyser converter <97% efficiency	11	9
NO cylinder out by >10%	7	3
SO_2 cylinder out by >10%	2	2
CO cylinder out by >10%	0	0
O3 Analyser out by >5%	5	2

* Filter Dynamics Measurement System
** Tapered Element Oscillating Microbalance
*** 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 2020 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. A summary of the site inter-calibrations and audits undertaken during 2020 is provided in Appendix 2.

5.4.1 Data Ratification

In 2013 with the renewal of the SAQD contract, data ratification was brought in line with the AURN schedule and is now undertaken at three-monthly intervals. Hence, as with the inter-calibrations and 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 2020 have now been uploaded to the Scottish Air Quality website A summary of all the data ratification undertaken during 2020 is provided in Appendix 2.

5.5 Volatile Correction Model

5.5.1 Background

The EU Directive on Ambient Air Quality[3] and the UK Air Quality Strategy[4] set target values and objectives respectively for PM_{10} concentrations in terms of gravimetric measurements referenced to the EU reference method of measurement (EN 12341). It has long been recognised that PM_{10} measurements made with many automatic PM_{10} monitors are not equivalent to the EU reference method. However, these analysers are widely used since they provide hourly resolved data and have many operational advantages over the manual reference method. Hence, correction factors, most noticeably the 1.3 correction factor for the TEOM analyser, have been widely used for many years. In setting the value of 1.3 as a correction factor, it was recognized that this was a conservative factor and that TEOMx1.3 data were likely to overestimate PM_{10} concentrations. In Scotland, a lower correction

[3] *Directive 2008/50/EC Of The European Parliament and of The Council of 21 May 2008 on ambient air quality and cleaner air for Europe http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:152:0001:0044:EN:PDF*

[4] *The Air Quality Strategy for England, Scotland, Wales and Northern Ireland. July 2007. CM 7169 http://www.scotland.gov.uk/Topics/Environment/Pollution/16215/6116*

factor of 1.14, which was based on intercomparison data obtained in Edinburgh, has also been widely used.

The results of the formal UK PM_{10} Equivalence Study[5] carried out in 2006, showed that data from the TEOM could not be considered as equivalent to the EU reference method, whether or not a correction factor was used. The reason for this is that the TEOM heats the filter used to collect PM_{10} to 50°C in order to eliminate the possible interference from water vapour – this heating also removes some of the more volatile components of the particulate matter.

In the new modification to the TEOM – the FDMS TEOM, the volatile fraction of PM_{10} is measured separately and used to correct the data in order to obtain results that are equivalent to the EU reference method. The equivalence of the FDMS TEOM analyser to the EU reference method was confirmed in the UK Equivalence study. Note that this study showed that a number of other PM_{10} analysers could also provide data equivalent to the EU reference method - Partisol 2025, FDMS Model B, Opsis SM200 Beta Attenuation Monitor (BAM), Opsis SM200 sampler (with slope and intercept correction) and the Met One BAM (with slope correction).

King's College London (KCL) developed a relationship utilising FDMS purge (volatile PM_{10}) measurements to correct data from nearby TEOM analysers. These corrected data were tested for equivalence with the EU reference method and shown to pass the appropriate criteria. Since then, as additional FDMS data have become available throughout the UK, the geographic range of the model has been extended and on-going tests have shown that any TEOM located within 130 km of an FDMS TEOM can be corrected with data from that analyser.

For additional information regarding this visit http://www.scottishairquality.co.uk/data.

5.5.2 Use of the VCM in Scotland

The VCM correction of Scottish PM_{10} data was first undertaken for the 2008 dataset. As the VCM method was relatively new and hourly meteorological data for pressure were not readily available, the corrections were undertaken on a daily, rather than hourly basis. These corrected data were provided to the local authorities and made available on the Scottish Air Quality website as a separate data spreadsheet.

However, additional refinement of the VCM model has been undertaken and hourly meteorological data for all parameters has been sourced. As a result, VCM correction of the 2009 to 2020 datasets has been undertaken on an hourly basis. This also brings into line the processing of the Scottish local authority data with that of the AURN.

The TEOM measurements are recorded with an inbuilt correction factors of 1.03x+3 (where x is the raw TEOM measurement) as mandated by the US Environmental Protection Agency. This is first removed and the data are then corrected to ambient pressure and temperature (as required by the EU Directive) using meteorological data from met monitoring sites within 260 km of the TEOM.

Data from FDMS analysers within 130 km of the TEOM are then used to provide an estimate of the volatile particle concentration at the TEOM location. This estimated volatile fraction is then added back onto the TEOM measurements to give Gravimetric Equivalent mass concentrations. The following data were used as inputs to the VCM:

- Hourly average temperatures (°C)
- Hourly average pressures (mbar)
- Hourly average TEOM concentrations ($\mu g\ m^{-3}$)
- Hourly average FDMS purge concentrations ($\mu g\ m^{-3}$)

[5] *UK Equivalence Programme for Monitoring of Particulate Matter. David Harrison Bureau Veritas UK Ltd. June 2006 (BV/AQ/AD202209/DH/2396)* *http://www.airquality.co.uk/archive/reports/cat05/0606130952_UKPMEquivalence.pdf*

For the 2020 corrections, temperature and pressure data from Edinburgh Airport meteorological monitoring stations were utilised. This site was selected as a good representation of weather conditions in the central belt of Scotland.

Hourly average purge measurements from all Scottish FDMS monitoring sites within the Scottish Government-run network (SAQD) and the UK national network (AURN) were used for the correction. A total of eight FDMS sites across Scotland were used for correcting hourly average TEOM data. A list of sites used for correction is provided in appendix 3 of this report. Table 5.4 provides the names of the sites where data was corrected using VCM.

Any outliers in the FDMS purge measurements were identified using Grubbs' Test[6] on daily average data. All hourly data within a day identified as an outlier were then removed from the data set and the average of each hourly purge measurement from the FDMS sites was calculated and used in the VCM calculations.

The corrected data for 2020 and calculated summary statistics have been provided to the local authorities. A flow chart showing the overall process employed for VCM correction of 2020 SAQD TEOM data is provide in Appendix 3. It should be noted that it is not possible to correct historical data with the VCM as measurements of volatile particle concentrations are not available prior to 2008.

Table 5.4 TEOM Sites data corrected using VCM in 2020

Site Name	Local Authority
Aberdeen Anderson Dr	Aberdeen City Council
Dundee Broughty Ferry Road	Dundee City Council
Edinburgh Currie	City of Edinburgh Council
Edinburgh Glasgow Road	City of Edinburgh Council
Edinburgh Salamander St	City of Edinburgh Council
Falkirk Bainsford	Falkirk Council
Falkirk Haggs	Falkirk Council
Falkirk Hope Street	Falkirk Council

[6] Grubbs' Test is a statistical method for identifying outliers within a dataset. For more information, visit the Engineering Statistics Handbook at:

http://www.itl.nist.gov/div898/handbook/eda/section3/eda35h.htm

6 Air Pollution in Scotland 2020

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 2020.

- Section 6.2 - Other pollutants covered by the Air Quality Strategy – PAH (benzo[a]pyrene), Benzene, 1,3-butadiene and lead - summary statistics for 2020 or 2020 depending on the availability of data.

- 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 Ozone

Tables 6.1.1 – 6.1.7 show the 2020 annual average data statistics for NO_2, PM_{10}, $PM_{2.5}$, CO, SO_2 and O_3 respectively, 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, 15 local authorities in Scotland have declared a total of 36 AQMAs (see http://www.scottishairquality.co.uk/laqm/aqma). Based on the data in the database, a summary of the air quality situation throughout Scotland, along the lines of that already provided in the Newsletter, is given under each table.

6.1.1 Nitrogen Dioxide

Table 6.1.1 shows nitrogen dioxide data for 89 sites utilising automatic monitoring during 2020. Although, data for 14 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 75 sites with 75% data capture or more, no 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, with a measured concentration of 36.0 µg m^{-3}. The greatest number of exceedances of the hourly mean objective was measured at Dumfries with three exceedances.

Table 6.1.1 Ratified data annual average concentration and data capture for NO_2 in 2020 for monitoring sites in the Scottish Air Quality Database

Site Name	Type	Annual Average NO_2 2020 (µg m^{-3})	No. hours >200 µg m^{-3}	Data capture NO_2 2020 (%)
Aberdeen Anderson Dr	RS	12.3	0	81.9
Aberdeen Errol Place	UB	13.5	0	94.5
Aberdeen King Street	RS	15.8	0	99.5
Aberdeen Market Street 2	RS	22.2	0	99.6
Aberdeen Union Street Roadside	RS	23.6	0	98.2
Aberdeen Wellington Road	RS	25.1	0	99.5
Alloa A907	RS	19	0	99.5
Bush Estate	R	3.7	0	96.2
Dumfries	RS	22.1	3	97.9
Dundee Broughty Ferry Road	RS	19.5	0	82.9
Dundee Lochee Road	RS	31.2	0	99.8
Dundee Mains Loan	UB	8.5	0	97.4
Dundee Meadowside	RS	23.8	0	32.0
Dundee Seagate	KS	28.5	0	99.8
Dundee Whitehall Street	KS	24	0	92.7
E Ayrshire Kilmarnock St Marnock St	RS	19	0	99.5
East Dunbartonshire Bearsden	RS	19.7	0	97.7
East Dunbartonshire Bishopbriggs	RS	19.7	0	81.6
East Dunbartonshire Kirkintilloch	RS	18.3	0	90.9
East Dunbartonshire Milngavie	RS	14.5	0	95.3
East Lothian Musselburgh N High St	RS	15	0	99.2
Edinburgh Currie	UB	4.9	0	33.7
Edinburgh Glasgow Road	RS	15.4	0	97.7
Edinburgh Gorgie Road	RS	18.4	0	92.4
Edinburgh Nicolson Street	RS	27.1	0	74.3
Edinburgh Queensferry Road	RS	25.8	0	99.2
Edinburgh Salamander St	RS	20.6	0	65.4
Edinburgh St John's Road	KS	25.6	0	99.4
Edinburgh St Leonards	UB	13.7	0	88.0
Eskdalemuir	R	1.7	0	84.6
Falkirk Grangemouth MC	UB	11.9	0	96.0
Falkirk Haggs	RS	18	0	89.8
Falkirk Hope St	RS	14.2	0	83.7

Site Name	Type	Annual Average NO_2 2020 (µg m^{-3})	No. hours >200 µg m^{-3}	Data capture NO_2 2020 (%)
Falkirk Main St Bainsford	RS	15.7	0	65.2
Falkirk West Bridge Street	RS	26.6	0	89.0
Fife Cupar	RS	20.9	0	90.8
Fife Dunfermline	RS	15.2	0	73.5
Fife Kirkcaldy	RS	12.2	0	99.5
Fife Rosyth	RS	15.4	0	99.6
Fort William	S	5.3	0	99.1
Glasgow Anderston	UB	19.5	0	98.4
Glasgow Burgher St.	RS	14.7	1	55.0
Glasgow Byres Road	RS	22.7	0	99.7
Glasgow Dumbarton Road	RS	25.2	0	99.7
Glasgow Great Western Road	RS	19.4	0	98.1
Glasgow High Street	RS	21.1	0	99.2
Glasgow Kerbside	KS	36.0	0	99.1
Glasgow Nithsdale Road	RS	28.7	0	7.0
Glasgow Townhead	UB	17.1	0	99.1
Glasgow Waulkmillglen Reservoir	R	5.3	0	89.9
Grangemouth	UI	11.1	0	98.2
Grangemouth Moray	UB	12.3	0	75.9
Inverclyde Greenock A8	RS	20.5	0	97.6
Inverness	RS	12.7	0	92.9
Inverness Academy Street	RS	28.2	0	88.0
Inverness Academy Street 1st Floor	RS	22.6	0	86.0
Lerwick	R	2.9	0	97.6
N Lanarkshire Airdrie Kenilworth Dr	RS	14.1	0	99.3
N Lanarkshire Chapelhall	RS	18.3	0	99.5
N Lanarkshire Coatbridge Sunnyside Rd	RS	15.7	0	99.4
N Lanarkshire Coatbridge Whifflet	UB	12.2	0	97.3
N Lanarkshire Croy	RS	12	0	76.4
N Lanarkshire Kirkshaws	RS	13.3	0	98.0
N Lanarkshire Motherwell	RS	13.8	0	75.0
N Lanarkshire Shawhead Coatbridge	RS	15.6	0	92.9
N Lanarkshire Uddingston New Edinburgh Rd	RS	17.1	0	99.6
North Ayrshire Irvine High St	RS	10.2	0	99.7
Paisley Gordon Street	RS	17.3	0	25.9
Peebles	S	3.8	0	99.1
Perth Atholl Street	RS	27.5	0	85.8
Perth Crieff	RS	13.1	0	93.7

Site Name	Type	Annual Average NO_2 2020 (µg m^{-3})	No. hours >200 µg m^{-3}	Data capture NO_2 2020 (%)
Perth High Street	RS	14.7	0	80.4
Renfrew Cockels Loan	RS	20.9	0	96.7
Renfrew Inchinnan Road	RS	19.9	0	97.3
South Ayrshire Ayr Harbour	RS	7.5	0	60.3
South Ayrshire Ayr High St	RS	10.1	0	95.7
South Lanarkshire Blantyre	RS	18.3	0	93.0
South Lanarkshire Cambuslang	RS	21.3	0	98.9
South Lanarkshire East Kilbride	RS	21.9	2	95.8
South Lanarkshire Hamilton	RS	19.2	0	85.6
South Lanarkshire Lanark	RS	13.1	0	84.1
South Lanarkshire Rutherglen	RS	-	-	0.0
South Lanarkshire Uddingston	RS	15.3	0	84.8
Stirling Craig's Roundabout	RS	14.2	0	99.6
West Dunbartonshire Clydebank	RS	21.2	0	11.9
West Dunbartonshire Glasgow Road	RS	12.6	0	99.7
West Lothian Broxburn	RS	19.1	0	90.9
West Lothian Linlithgow High Street 2	RS	14.6	0	71.4
West Lothian Newton	RS	13.7	0	48.4

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 NO2 Diffusion Tube data 2019

In October 2018 Scottish Government commissioned Ricardo to develop an NO_2 diffusion tube database and map similar to what is already provided for the automated site data. The map was 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 brings all the diffusion tube monitoring for each year together, enabling the user to identify the number of sites that exceeded the annual mean objective out of the more than 1100 monitoring sites across Scotland.

In 2020, seven diffusion tube sites exceeded the annual mean objective for NO_2. This is significantly down from previous years as illustrated in Figure 6.1.1.1. The seven sites that exceeded in 2020 are listed in table 6.1.1.1 below. The reason for the significant decrease in sites exceeding is attributed to the Covid-19 lockdown restrictions imposed at different levels throughout 2020, which in turn saw a decrease in vehicle usage, especially in urban areas.

For more information on the 2020 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). This diffusion tube data can also now be download via the data selector tool (http://www.scottishairquality.scot/data/data-selector).

Figure 6.1.1.1 Number of **NO_2 Diffusion Tube sites exceeding the Annual Mean Objective since 2013**

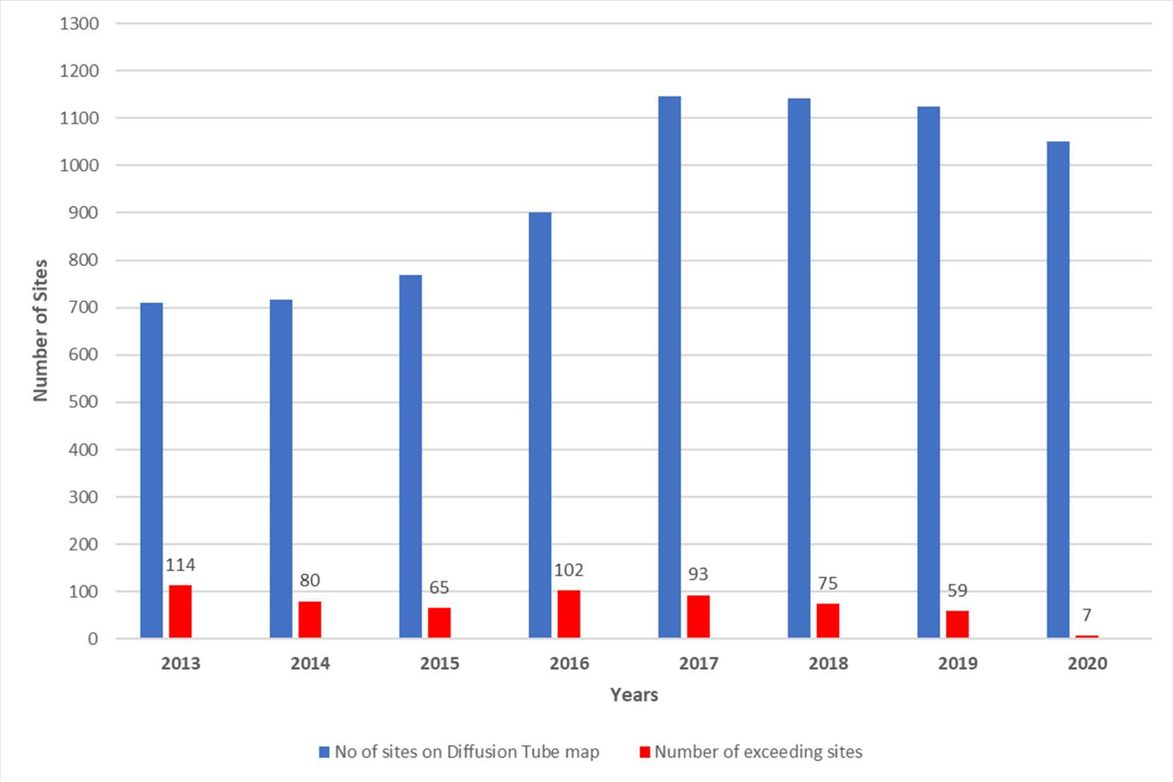


Table 6.1.1.1 NO_2 Diffusion Tube sites exceeding the Annual Mean Objective in 2020

Site Name	Annual Mean Concentration ($\mu g\ m^{-3}$)	Local Authority Name
39 Market Street	40	Aberdeen City Council
Dundee Logie St	40	Dundee City Council
Edinburgh London Road/East Norton Place	40	City of Edinburgh Council
Hope St 1	40	Glasgow City Council
Inchinnan Road	40	Renfrewshire Council
High St, Johnstone	40	Renfrewshire Council
233 Glasgow Road Blantyre	40	South Lanarkshire Council

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

6.1.2 Particulate Matter – PM_{10}

Table 6.1.2 shows the 2020 gravimetric equivalent PM_{10} data from 81 sites utilising automatic monitoring. Of these sites, 16 have less than 75% data capture. As discussed in Section 4.2.2, all TEOM data have been adjusted using the VCM.

Of the 65 sites with 75% or greater data capture, no sites exceeded the annual average PM_{10} objective of 18 µg m^{-3}. The daily mean objective of 50 µg m^{-3} not to be exceeded more than 7 times in a year was also not exceeded at any site. The maximum PM_{10} annual mean concentration was measured at Edinburgh Salamander St with a measured annual mean concentration of 13.1 µg m^{-3}.

Table 6.1.2 Ratified data annual average concentration and data capture for PM_{10} in 2020 for monitoring sites in the Scottish Air Quality Database

Site Name	Type	PM_{10} Analyser Type*	Annual Average PM_{10} 2020 (µg m^{-3})	No. Days > 50 µg m^{-3}	Data Capture (%)
Aberdeen Anderson Dr	RS	VCM	9.3	0	94.5
Aberdeen Errol Place	UB	FIDAS	9.4	0	99.7
Aberdeen King Street	RS	FIDAS	10.7	0	99.6
Aberdeen Market Street 2	RS	FIDAS	10.4	0	99.6
Aberdeen Union Street Roadside	RS	FDMS	10.3	0	58.7
Aberdeen Wellington Road	RS	FIDAS	11.3	0	99.7
Alloa A907	RS	FIDAS	8.8	0	99.5
Angus Forfar Glamis Rd	RS	FDMS	9.8	0	77.3
Auchencorth Moss	R	FIDAS	5.5	0	99.9
Dundee Broughty Ferry Road	RS	TEOM/FIDAS	8.9	0	99.5
Dundee Lochee Road	KS	FIDAS	9.8	0	86.6
Dundee Mains Loan	UB	FIDAS	7.0	0	99.7
Dundee Meadowside	RS	FIDAS	9.1	0	99.0
Dundee Seagate	KS	FIDAS	9.6	0	99.7
Dundee Whitehall Street	KS	FIDAS	7.9	0	99.3
E Ayrshire Kilmarnock St Marnock St	RS	FIDAS	10.1	0	50.3
East Dunbartonshire Bearsden	RS	FIDAS	8.2	0	97.4
East Dunbartonshire Bishopbriggs	RS	FIDAS	9.5	0	77.7
East Dunbartonshire Kirkintilloch	RS	FIDAS	9.3	0	99.7
East Dunbartonshire Milngavie	RS	FDMS/FIDAS	9.7	0	94.4
East Lothian Musselburgh N High St	RS	BAM	9.9	0	82.1
Edinburgh Currie	UB	VCM/FIDAS	7.7	0	94.0
Edinburgh Glasgow Road	RS	VCM/FIDAS	11.1	0	73.1
Edinburgh Nicolson Street	RS	FIDAS	9.5	0	99.3
Edinburgh Queensferry Road	RS	FIDAS	11.2	0	99.7
Edinburgh Salamander St	UB	VCM/FIDAS	13.1	0	83.7
Edinburgh St John's Road	UB	FIDAS	9.9	0	99.5
Edinburgh St Leonards	RS	FIDAS	8.1	0	99.3
Edinburgh Tower Street	RS	FIDAS	8.6	0	96.9
Falkirk Banknock	RS	FIDAS	9.4	0	42.4
Falkirk Grangemouth MC	UB	FIDAS	7.7	0	64.0
Falkirk Haggs	RS	VCM/FIDAS	10.0	0	56.3
Falkirk Hope St	RS	VCM/FIDAS	9.0	0	87.4
Falkirk Main St Bainsford	RS	VCM/FIDAS	10.6	0	80.0
Falkirk West Bridge Street	RS	FIDAS	7.4	0	38.3
Fife Cupar	RS	FIDAS	11.3	0	96.6
Fife Dunfermline	RS	FIDAS	8.5	0	99.6
Fife Kirkcaldy	RS	FIDAS	9.0	0	99.8

Site Name	Type	PM_{10} Analyser Type*	Annual Average PM_{10} 2020 ($\mu g\ m^{-3}$)	No. Days > 50 $\mu g\ m^{-3}$	Data Capture (%)
Fife Rosyth	RS	FIDAS	9.1	0	99.7
Glasgow Anderston	UB	FIDAS	9.0	0	71.3
Glasgow Broomhill	RS	FIDAS	9.6	0	99.9
Glasgow Burgher St.	RS	FDMS	11.0	0	51.3
Glasgow Byres Road	RS	FIDAS	10.8	0	99.7
Glasgow Dumbarton Road	RS	FIDAS	10.2	0	99.7
Glasgow High Street	RS	FIDAS	9.3	0	99.2
Glasgow Kerbside	KS	FIDAS	11.4	0	95.9
Glasgow Nithsdale Road	RS	FIDAS	10.2	0	2.9
Glasgow Townhead	UB	FIDAS	8.8	0	99.4
Glasgow Waulkmillglen Reservoir	R	FIDAS	6.9	0	93.8
Grangemouth	UI	BAM (heated	8.5	0	97.0
Inverclyde Greenock A8	RS	FIDAS	9.5	0	99.9
Inverness	RS	FIDAS	7.8	0	96.1
N Lanarkshire Airdrie Kenilworth Dr	RS	BAM (un-	9.5	0	52.1
N Lanarkshire Chapelhall	RS	FIDAS	8.5	0	99.7
N Lanarkshire Coatbridge Sunnyside Rd	RS	BAM (un-	8.3	0	8.5
N Lanarkshire Coatbridge Whifflet	RS	VCM/FIDAS	7.7	0	94.7
N Lanarkshire Croy	RS	FIDAS	7.6	0	77.0
N Lanarkshire Kirkshaws	RS	FIDAS	8.8	0	96.7
N Lanarkshire Motherwell	RS	FIDAS	9.3	0	87.6
N Lanarkshire Motherwell Adele St.	RS	FIDAS	7.5	0	40.0
N Lanarkshire Shawhead Coatbridge	RS	FIDAS	8.2	0	99.9
N Lanarkshire Uddingston New Edinburgh	RS	BAM (un-	9.2	0	9.3
North Ayrshire Irvine High St	RS	FIDAS	11.3	0	98.9
Paisley Gordon Street	RS	FDMS	10.1	0	96.6
Perth Atholl Street	RS	FIDAS	10.2	0	87.0
Perth Crieff	RS	FIDAS	7.2	0	88.2
Perth Muirton	RS	FIDAS	6.2	0	97.7
Renfrewshire Johnstone	RS	FIDAS	10.2	0	92.3
South Lanarkshire Blantyre	RS	FIDAS	8.8	0	96.5
South Lanarkshire Cambuslang	RS	FIDAS	10.0	0	82.5
South Lanarkshire East Kilbride	RS	FIDAS	8.8	0	95.0
South Lanarkshire Hamilton	RS	FIDAS	9.2	0	99.7
South Lanarkshire Lanark	RS	FIDAS	8.3	0	99.8
South Lanarkshire Raith Interchange 2	RS	FIDAS	8.0	0	88.5
South Lanarkshire Rutherglen	RS	FIDAS	10.2	0	98.7
South Lanarkshire Uddingston	RS	FIDAS	9.6	0	94.0
Stirling Craig's Roundabout	RS	FIDAS	8.0	0	99.6
West Dunbartonshire Clydebank	RS	FIDAS	8.5	0	91.4
West Lothian Broxburn	RS	FIDAS	10.6	0	100.0
West Lothian Linlithgow High Street 2	RS	FIDAS	8.3	0	63.2
West Lothian Newton	RS	FIDAS	11.4	0	68.6

Shaded sites indicate data only available for part year and/or <75% data capture
Highlighted figures (in yellow) indicate exceedance of Scottish Air Quality Objectives
FIDAS and FDMS data are equivalent to gravimetric and hence are not adjusted

BAM (heated inlet) data are adjusted using gravimetric equivalent factor of 0.966
BAM (un-heated inlet) data are adjusted using gravimetric equivalent factor of 0.8333
VCM data are TEOM data corrected using the Volatile Correction Model

6.1.3 Particulate Matter – $PM_{2.5}$

Following the introduction of the new $PM_{2.5}$ annual mean objective of 10 µg m^{-3} in April 2016, local authorities continue to expand $PM_{2.5}$ monitoring, with the number of $PM_{2.5}$ sites increasing from 66 to 74 between 2019 and 2020. Data capture rates of less than 75% were measured at 16 sites. $PM_{2.5}$ concentrations in excess of the objective were not measured at any site. Figure 6.1.3 shows the 2020 annual average $PM_{2.5}$ and PM_{10} concentrations for all SAQD monitoring sites.

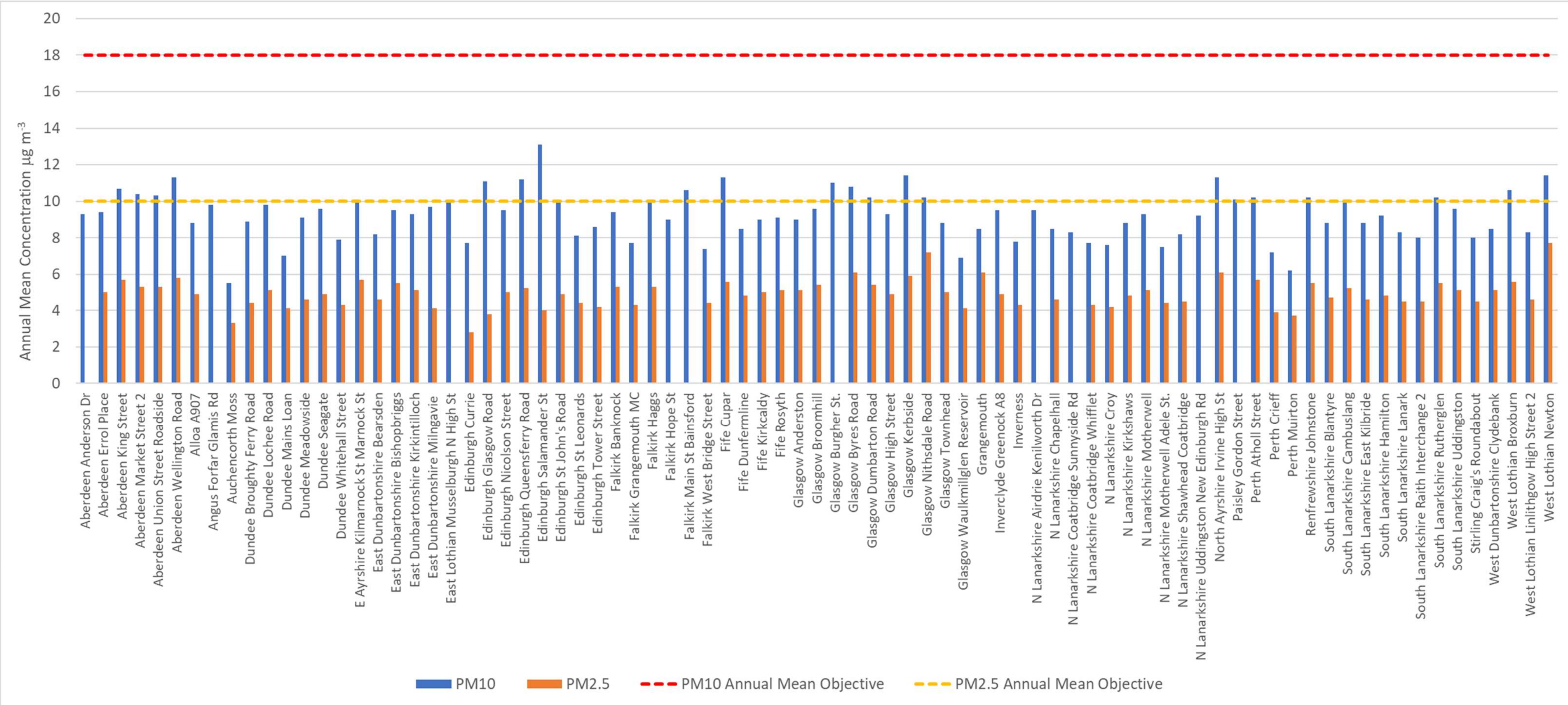
Table 6.1.3 Ratified data annual average concentration and data capture for $PM_{2.5}$ in 2020 for monitoring sites in the Scottish Air Quality Database

Site Name	Type	$PM_{2.5}$ Analyser Type	Annual Average $PM_{2.5}$ 2020 (µg m^{-3} gravimetric equivalent)	Data Capture (%)
Aberdeen Errol Place	UB	FIDAS	5.0	99.7
Aberdeen King Street	RS	FIDAS	5.7	99.6
Aberdeen Market Street 2	RS	FIDAS	5.3	99.6
Aberdeen Union Street Roadside	RS	TEOM FDMS	5.3	49.4
Aberdeen Wellington Road	RS	FIDAS	5.8	99.7
Alloa A907	RS	FIDAS	4.9	99.5
Auchencorth Moss	R	FIDAS	3.3	99.9
Dundee Broughty Ferry Road	RS	FIDAS	4.4	97.5
Dundee Lochee Road	KS	FIDAS	5.1	86.6
Dundee Mains Loan	UB	FIDAS	4.1	99.7
Dundee Meadowside	RS	FIDAS	4.6	99.0
Dundee Seagate	KS	FIDAS	4.9	99.7
Dundee Whitehall Street	KS	FIDAS	4.3	99.3
E Ayrshire Kilmarnock St Marnock St	RS	FIDAS	5.7	50.3
East Dunbartonshire Bearsden	RS	FIDAS	4.6	97.4
East Dunbartonshire Bishopbriggs	RS	FIDAS	5.5	77.7
East Dunbartonshire Kirkintilloch	RS	FIDAS	5.1	99.7
East Dunbartonshire Milngavie	RS	FIDAS	4.1	59.5
Edinburgh Currie	UB	FIDAS	2.8	4.2
Edinburgh Glasgow Road	RS	FIDAS	3.8	4.2
Edinburgh Nicolson Street	RS	FIDAS	5.0	99.3
Edinburgh Queensferry Road	RS	FIDAS	5.2	99.7
Edinburgh Salamander St	UB	FIDAS	4.0	4.2
Edinburgh St John's Road	UB	FIDAS	4.9	99.5
Edinburgh St Leonards	RS	FIDAS	4.4	99.3
Edinburgh Tower Street	RS	FIDAS	4.2	96.9
Falkirk Banknock	RS	FIDAS	5.3	42.4
Falkirk Grangemouth MC	UB	FIDAS	4.3	64.0
Falkirk Haggs	RS	FIDAS	5.3	29.8
Falkirk West Bridge Street	RS	FIDAS	4.4	38.1
Fife Cupar	RS	FIDAS	5.6	96.6
Fife Dunfermline	RS	FIDAS	4.8	99.6
Fife Kirkcaldy	RS	FIDAS	5.0	99.8

Site Name	Type	$PM_{2.5}$ Analyser Type	Annual Average $PM_{2.5}$ 2020 (µg m^{-3} gravimetric equivalent)	Data Capture (%)
Fife Rosyth	RS	FIDAS	5.1	99.7
Glasgow Anderston	UB	FIDAS	5.1	71.3
Glasgow Broomhill	RS	FIDAS	5.4	99.9
Glasgow Byres Road	RS	FIDAS	6.1	99.7
Glasgow Dumbarton Road	RS	FIDAS	5.4	99.7
Glasgow High Street	RS	FIDAS	4.9	99.2
Glasgow Kerbside	KS	FIDAS	5.9	95.9
Glasgow Nithsdale Road	RS	FIDAS	7.2	2.9
Glasgow Townhead	UB	FIDAS	5.0	99.4
Glasgow Waulkmillglen Reservoir	R	FIDAS	4.1	93.8
Grangemouth	UI	BAM	6.1	94.5
Inverclyde Greenock A8	RS	FIDAS	4.9	99.9
Inverness	RS	FIDAS	4.3	96.1
N Lanarkshire Chapelhall	RS	FIDAS	4.6	99.7
N Lanarkshire Coatbridge Whifflet	RS	FIDAS	4.3	87.1
N Lanarkshire Croy	RS	FIDAS	4.2	77.0
N Lanarkshire Kirkshaws	RS	FIDAS	4.8	96.7
N Lanarkshire Motherwell	RS	FIDAS	5.1	87.6
N Lanarkshire Motherwell Adele St.	RS	FIDAS	4.4	40.0
N Lanarkshire Shawhead Coatbridge	RS	FIDAS	4.5	99.9
North Ayrshire Irvine High St	RS	FIDAS	6.1	98.9
Perth Atholl Street	RS	FIDAS	5.7	87.1
Perth Crieff	RS	FIDAS	3.9	88.2
Perth High Street	RS	TEOM	5.8	85.7
Perth Muirton	RS	FIDAS	3.7	97.7
Renfrewshire Johnstone	RS	FIDAS	5.5	92.3
South Ayrshire Ayr Harbour	RS	TEOM FDMS	6.4	78.6
South Ayrshire Ayr High St	RS	TEOM FDMS	4.9	74.2
South Lanarkshire Blantyre	RS	FIDAS	4.7	96.5
South Lanarkshire Cambuslang	RS	FIDAS	5.2	82.5
South Lanarkshire East Kilbride	RS	FIDAS	4.6	95.0
South Lanarkshire Hamilton	RS	FIDAS	4.8	99.7
South Lanarkshire Lanark	RS	FIDAS	4.5	99.8
South Lanarkshire Raith Interchange 2	RS	FIDAS	4.5	88.5
South Lanarkshire Rutherglen	RS	FIDAS	5.5	98.7
South Lanarkshire Uddingston	RS	FIDAS	5.1	94.0
Stirling Craig's Roundabout	RS	FIDAS	4.5	99.6
West Dunbartonshire Clydebank	RS	FIDAS	5.1	91.4
West Lothian Broxburn	RS	FIDAS	5.6	100.0
West Lothian Linlithgow High Street 2	RS	FIDAS	4.6	63.2
West Lothian Newton	RS	FIDAS	7.7	68.6

Shaded sites indicate data only available for part year and/or <75% data capture
FIDAS data are adjusted using gravimetric equivalent factor of 0.943, all other data are not adjusted

Figure 6.1.3 Annual Average PM_{10} and $PM_{2.5}$ concentrations (μg m^{-3}) for all SAQD sites in 2020



6.1.4 Carbon Monoxide

Table 6.1. shows carbon monoxide was monitored using automatic techniques at one site during 2020. Edinburgh St Leonards achieved the Air Quality Strategy objective for this pollutant.

Table 6.1.4 Ratified data annual average concentration and data capture for CO in 2020 for monitoring sites in the Scottish Air Quality Database

Site Name	Type	Annual Average CO 2020 (mg m^{-3})	Max. Running 8hr Mean CO 2020 (mg m^{-3})	Data Capture (%)
Edinburgh St Leonards	UB	0.06	0	90.2

6.1.5 Sulphur Dioxide

Table 6.1.5 shows sulphur dioxide data from the eight sites utilising automatic monitoring for 2020 of which two did not achieve a data capture rate of greater than 75%. Of the remaining six sites, all met the requirements of the Air Quality Strategy for the 15-minute (no more than 35 times), 1-hour (no more than 24 times) and 24-hour (no more than 3 times) mean objectives SO_2 in 2020.

Table 6.1.5 Ratified data annual average concentration and data capture for SO_2 in 2020 for monitoring sites in the Scottish Air Quality Database

Site Name	Type	Annual Average SO_2 2020 (µg m^{-3})	No. 15 min SO_2 > 266µg m^{-3} 2020	No. 1 hr SO_2 > 350µg m^{-3} 2020	No. 24 hr SO_2 > 125µg m^{-3} 2020	Data Capture (%)
Edinburgh St Leonards	UB	1.2	0	0	0	70.6
Falkirk Bo'ness	UI	1.1	0	0	0	97.7
Falkirk Hope St	UB	1.3	0	0	0	94.0
Falkirk Grangemouth Zetland Park	UI	0.7	0	0	0	95.5
Falkirk Grangemouth MC	RS	1.2	0	0	0	96.6
Grangemouth Moray	UI	1.7	0	0	0	89.0
Grangemouth	UB	3.2	6	0	0	96.2
Lerwick	R	1.2	0	0	0	56.4

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

6.1.6 Ozone

Table 6.1.6 shows ozone data from 11 sites utilising automatic monitoring for 2020. 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 local authorities have little control over ozone levels in their area. In 2020, the Air Quality Strategy objective of not more than 10 days with a maximum 8-hour running mean greater than 100 µg m^{-3} was not exceeded at any site. This is a significant change from the previous year when seven sites exceed the objective.

Table 6.1.6 Ratified data annual average concentration and data capture for O_3 in 2020 for monitoring sites in the Scottish Air Quality Database

Site Name	Type	Annual Average O_3 2020 ($\mu g\ m^{-3}$)	No of days with running 8-hr mean >100 ug m^{-3}	Data capture O_3 2020 (%)
Aberdeen Errol Place	UB	45.5	3	61.0
Auchencorth Moss	R	58.9	4	99.2
Bush Estate	R	57.6	4	99.3
Edinburgh St Leonards	UB	54.5	5	98.5
Eskdalemuir	R	57.8	2	79.1
Fort William	S	55.4	4	99.4
Glasgow Townhead	UB	44.5	1	99.2
Glasgow Waulkmillglen Reservoir	R	56.3	2	75.1
Lerwick	R	70.4	5	96.6
Peebles	S	54.3	4	99.2
Strath Vaich	R	64.6	1	98.8

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

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. Hence, in some cases, the latest data available at the time of preparing this report is for 2019. Where other pollutants are also monitored in these networks, these pollutants are listed, but the data are not provided in this report.

6.2.1 PAH Monitoring Network[7]

The UK Monitoring and Analysis Network monitor some 39 Poly Aromatic Hydrocarbon (PAH) species at 33 sites. PAH monitoring of the compound benzo[a]pyrene is undertaken to provide data in compliance with the EU Air Quality Directive (Directive 2004/107/EC). An air quality objective for this compound 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 monthly summary results for all species monitored in the PAH network can be downloaded as spreadsheet summary data from http://uk-air.defra.gov.uk/interactive-map.

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 6.2.1. The sites at Edinburgh and Glasgow are co-located with the Edinburgh St Leonards and Glasgow Townhead AURN sites respectively. The

[7] 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]

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.

Table 6.2.1 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 2019 and 2020 are shown in Table 6.2.2. 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 2020.

Table 6.2.2 Annual Average Benzo(a)Pyrene Concentrations for 2019 - 2020 at Four Sites in Scotland

Site	2019 Annual Mean B(a)P Concentration (ng m^{-3})	2020 Annual Mean B(a)P Concentration (ng m^{-3})
Auchencorth Moss	0.014	0.010
Edinburgh St Leonards	0.061	0.0368
Glasgow Townhead	0.108	0.0577
Kinlochleven	0.277	0.240

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

6.2.2 Benzene

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 the EU Air Quality Directive and Scottish objective of 16.25 μg m^{-3} as an 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 2019 and 2020 are provided in Table 6.2.3.

Table 6.2.3 Annual Mean Benzene Concentrations in 2019 and 2020 at two sites in Scotland in the UK Non-Automatic Hydrocarbon Network

Site Name	Annual Mean benzene for 2019 (μg m^{-3})	Annual Mean benzene for 2020 (μg m^{-3})
Glasgow Kerbside	0.68	0.52
Grangemouth	0.78	0.58

6.2.3 Automatic Hydrocarbon Monitoring

Table 6.2.4 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 the EU Air Quality Directive (2008/50/EC). 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 www.scottishairquality.co.uk.

Table 6.2.4 Location of Automatic Hydrocarbon Monitoring Sites in Scotland

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

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

Table 6.2.5 Annual Average Benzene Concentration at Auchencorth Moss in the UK Automatic Hydrocarbon Network, for 2020

Site	2020 Benzene Annual mean concentration (µg m^{-3})	2020 Benzene Maximum running annual concentration (µg m^{-3})	2020 % Data Capture
Auchencorth Moss	0.19	0.20	68.0

Table 6.2.3 and 6.2.5 indicate 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 2020.

6.2.4 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 6.2.6 shows that 1,3-butadiene concentrations less than the Scottish Air Quality objective of 2.25 µg m^{-3} were measured during 2020, however, the data capture rate is less than 75% and so no conclusion can be made whether the objective is likely to have been exceeded or not . There is no EU Directive target for 1,3-butadiene.

Table 6.2.6. Annual Average 1,3-butadiene Concentration at Auchencorth Moss in the UK Automatic Hydrocarbon Network, for 2019 and 2020

Site	2018 1,3-butadiene Annual mean concentration (µg m^{-3})	2019 1,3-butadiene maximum running annual concentration (µg m^{-3})	2019 % Data capture
Auchencorth Moss	0.037	0.037	25.0

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

6.2.5 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 annual average spreadsheet summaries at www.uk-air.defra.gov.uk.

6.2.5.1 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 6.2.9 and data for the measurement of lead, nickel, arsenic and cadmium in 2020 are provided in Table 6.2.10.

Table 6.2.9 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 6.2.10 Annual Mean Metal Concentrations 2020 (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	0.22	0.024	0.22	0.90
Eskdalemuir	0.17	0.020	0.31	0.72

The results from these networks show that the EU limit value for lead, and the target values for nickel, arsenic and cadmium 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.

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 Results

There is no specific requirement for local authorities to provide their NO_2 diffusion tube data to a central storage facility. However, through the local authority Air Quality Support contract, a mechanism has been provided for authorities to provide these data. This data entry system is available from http://airquality.aeat.com/NO2admintools/NO2_logon.php. Where these data are provided by the authorities, they are then available for download from the Scottish air quality website (www.scottishairquality.co.uk). For the latest NO_2 diffusion tube data 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 the EU Directive (2008/50/EC). 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 Poly-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 2020; 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 heterogeneiety of the atmospheric pollutant concerned.

The Precipitation Network (Precip-Net)

There are 38 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 38 sites throughout the UK, of which, 13 are in Scotland (see Appendix 4). 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.

Rural NO_2 Network (NO_2-Net)

The nitrogen dioxide measurements are made at 24 of the 38 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 2020 with a data capture rate of 84.6%. Nitrogen dioxide is measured with diffusion tube samplers at nine sites in Scotland. The annual average concentrations measured in 2020 are provided in Table 6.3.2.

Table 6.3.2 NO_2 Annual Average Concentrations 2020 at Rural Monitoring Sites

Site	NO_2 (ug m^{-3})	Data Capture (%)
Allt a'Mharcaidh	1.1	38.4
Balquhidder 2	1.5	100
Eskdalemuir	1.7	100
Forsinard RSPB	1.3	84.6
Glensaugh	2.0	100
Loch Dee	1.5	69.2
Polloch	1.2	53.8
Strathvaich	1.3	53.8
Whiteadder	2.2	100

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 11 sites in this network located in Scotland are listed in Appendix 4.

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 NH3 and NH4+ (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 22 sites in this network located in Scotland are listed in Appendix 4.

7 Air Quality Mapping For Scotland

As part of the SAQD project, 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. Modelled roadside air pollutant concentrations are provided for road links in Scotland. The air pollution maps are derived from a combination of (1) measurements from Scotland's network of air quality monitoring stations, and (2) 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 UK.

The PCM methodology has been applied to provide pollution maps of Scotland for the Scottish Government for 2019 using measurements exclusively from Scottish air quality monitoring sites and Scottish meteorology. The maps provide spatial representation of the annual mean concentrations of:

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

The air pollution measurements used to prepare the maps presented here consists of appropriately scaled PM_{10} monitoring data (FDMS, Partisol, FIDAS and VCM-corrected TEOM data) and automatic monitoring measurements for NO_X and NO_2 from the model year. The model also uses Scottish meteorology observations (from RAF Leuchars) to create the Scotland-specific maps.

In 2009 Ricardo undertook a short study[8] on behalf of the Scottish Government which demonstrated that air pollutant source apportionment data and forward-projected concentrations of air pollutants were required for the Scottish pollution maps. These parameters were first calculated for 2009, using Scotland-specific data, for use by Scottish local authorities for their Local Air Quality Management Review and Assessment (LAQM) reports. Updates to these Scotland-specific air pollutant source apportionment data and forward-projected concentrations have been made for LAQM are available from a base year of 2018 at: http://www.scottishairquality.scot/maps.php?n_action=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 on emissions in 2020 and beyond.

7.1 Air Quality Maps for Scotland 2019

The details of the methodology and full results of the mapping study are provided in a separate report[9]. In this report, we summarise the main findings of this work.

7.1.1 NO_2 maps for 2019

The 2019 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.

[8] 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. http://www.scottishairquality.scot/assets/documents/reports2/258100203_LA_mapping_Report_Issue_1_FINAL.PDF

[9] Wareham, J., Goodhand, A. Stedman, J. and Morris, R. (2021). Scottish Air Quality Maps. Annual mean NO_X, NO_2, and PM_{10} modelling for 2019. http://www.scottishairquality.scot/assets/documents/Scottish_mapping_report_2019.html

Figure 7.1 Background NO_2 map for 2019, µg m^{-3} (Scotland-specific model)

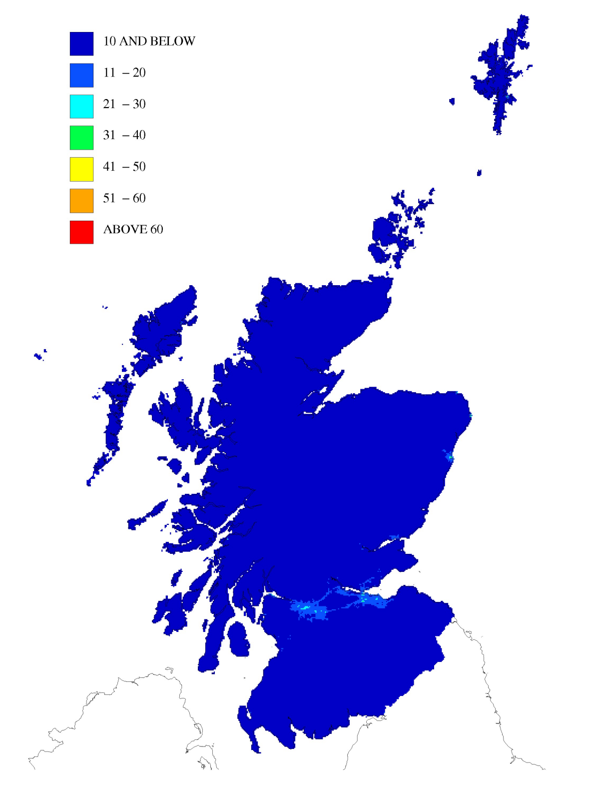


Figure 7.2 Roadside NO_2 map for 2019, µg m^{-3} (Scotland-specific model)

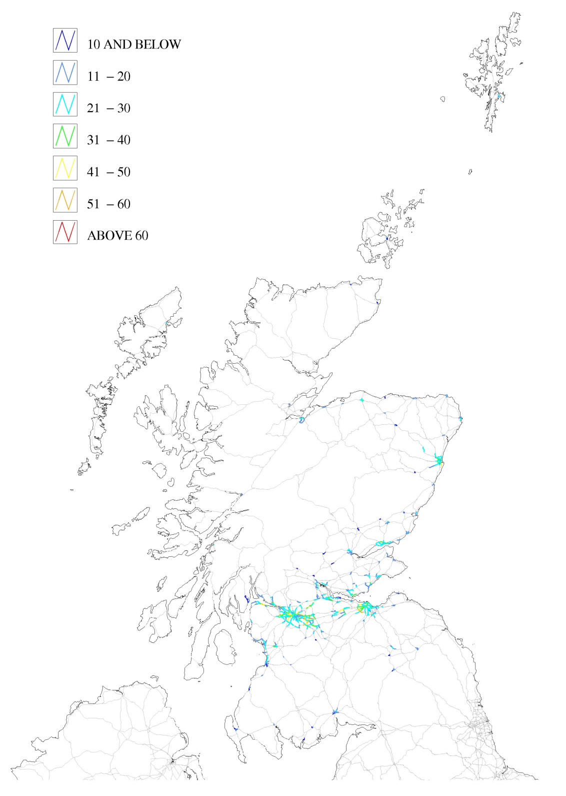


Table 7.1 shows that there were no modelled exceedances of the Scottish annual mean NO_2 objective of 40 µg m^{-3} at background locations. Overall exceedances of the Scottish annual mean NO_2 air quality objective were modelled at roadside locations in four of the six zones and agglomerations in Scotland. Exceedances of the annual mean NO_2 objective at roadside locations were modelled at 52 road links (102.5 km of road) in the Glasgow Urban Area and at 20 road links (45.0 km of road) in Central Scotland. In the Edinburgh Urban Area there were nine road links (11.0 km of road) where exceedances of the Scottish annual mean NO_2 air quality objective were modelled, and in the North East Scotland zone, four roads had an exceedance (8.5 km of road). No roadside exceedances of the Scottish annual mean NO_2 air quality objective were modelled in the more rural zones of Scotland, i.e., the Highlands and Scottish Borders. More detailed maps showing the roadside annual mean NO_2 concentrations can be found in the Scottish Air Quality Mapping report 2019.

Table 7.1 Annual mean exceedance statistics for background NO_2 in Scotland based on the Scotland-specific model, 2019.[1]

Zone or agglomeration	Total		>40 µg m^{-3}	
	Area (km^2)	Population	Area (km^2)	Population
Glasgow Urban Area	367	1,140,005	0	0
Edinburgh Urban Area	134	506,465	0	0
Central Scotland	10,064	1,986,164	0	0
North East Scotland	19,057	1,146,663	0	0
Highland	44,116	394,825	0	0
Scottish Borders	11,430	264,314	0	0

Total	**85,168**	**5,438,436**	**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, 2019.[2]

Zone or agglomeration	Total		>40 µg m^{-3}	
	Road links	Length (km)	Road links	Length (km)
Glasgow Urban Area	304	430.0	52	102.5
Edinburgh Urban Area	71	117.9	9	11.0
Central Scotland	328	506.1	20	45.0
North East Scotland	177	260.5	4	8.5
Highland	44	64.7	0	0.0
Scottish Borders	49	57.9	0	0.0
Total	**973**	**1,437.2**	**85**	**167.0**

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

7.1.2 PM_{10} maps for 2019

2019 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 appropriately scaled PM_{10} monitoring (FIDAS, FDMS, Partisol and VCM corrected TEOM) 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 (e.g., soot particles from biomass burning)
- sea salt aerosol, and
- iron and calcium-based dusts.

Maps of the modelled 2019 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 2019, µg m^{-3} (Scotland-specific model)

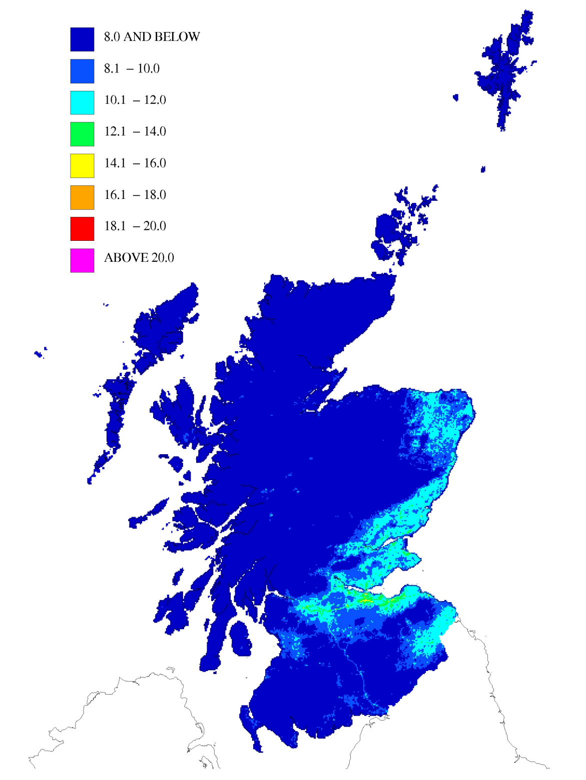


Figure 7.4 Roadside PM_{10} map for 2019, µg m^{-3} (Scotland-specific model)

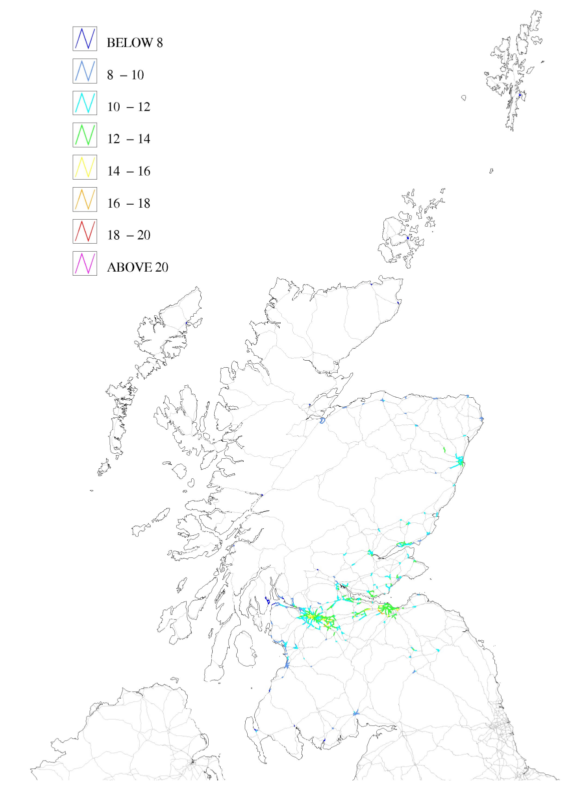


Table 7.3 shows that there were no modelled exceedances of the Scottish annual mean PM_{10} objective of 18 µg m^{-3} at background locations. Table 7.4 shows that there were no modelled exceedances of the Scottish annual mean PM_{10} objective of 18 µg m^{-3} at roadside locations.

Table 7.3 Annual mean exceedance statistics for background PM_{10} in Scotland based on the Scotland-specific model, 2019.[3]

Zone or agglomeration	Total		>18 µg m^{-3}	
	Area (km^2)	Population	Area (km^2)	Population
Glasgow Urban Area	367	1,140,005	0	0
Edinburgh Urban Area	134	506,465	0	0
Central Scotland	10,064	1,986,164	0	0
North East Scotland	19,057	1,146,663	0	0
Highland	44,116	394,825	0	0
Scottish Borders	11,430	264,314	0	0
Total	**85,168**	**5,438,436**	**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, 2019.[4]

Zone or agglomeration	Total		>18 µg m^{-3}	
	Road links	Length (km)	Road links	Length (km)
Glasgow Urban Area	304	430.0	0	0
Edinburgh Urban Area	71	117.9	0	0
Central Scotland	328	506.1	0	0
North East Scotland	177	260.5	0	0
Highland	44	64.7	0	0
Scottish Borders	49	57.9	0	0
Total	**973**	**1,437.2**	**0**	**0**

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

7.1.3 Forward projections from a base year of 2018

Forward projections of air pollutant concentrations to future years are not produced annually and were not carried out from a base year 2019. 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[10]. 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 on emissions in 2020 and beyond.

[10] http://www.scottishairquality.co.uk/data/mapping?view=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 for which not all monitoring stations (or sites) in Scotland currently meet the Air Quality Strategy Objectives. These pollutants are nitrogen dioxide and particulate matter. This section will also look at the pollutant ozone 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 January 2020). 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 (TG16). 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 are provided in the table 8.1.

AQD 2008 Directive	LAQM Description	Description
Urban Background	Urban Background and 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
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 Traffic	Roadside and Traffic	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 Industrial	Industrial	Site in an urban residential area downwind of specific industrial source
Suburban	Suburban Background	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

(Local Air Quality Management Technical Guidance (TG16), Feb 2018)

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 ten 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[11]. The Openair project is now maintained by Dr David Carslaw, of Ricardo Energy & Environment 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:

http://www.scottishairquality.scot/openair/openair.php

The trend analyses were done using the Openair "TheilSen" tool. 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, ** indicating significance at the 0.01 level and *** indicating significance at the 0.001 level. 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.

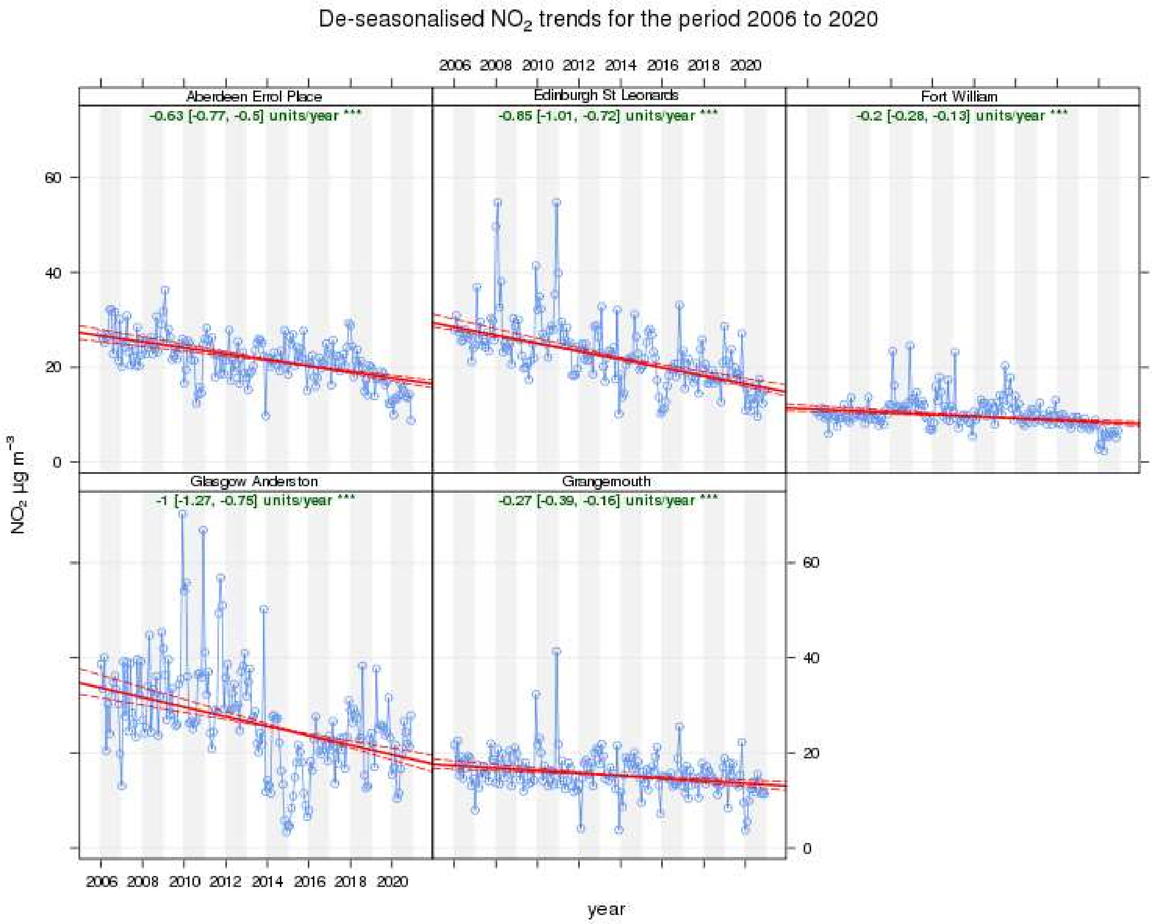
8.1.1 NO_2 at Urban Background Sites

There are relatively few long-running urban background monitoring stations in Scotland. Five urban non-roadside 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'.

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 2006-2019: 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.*

11 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 Concentration at Five Long-running Urban Non-Roadside Sites, 2006-2019

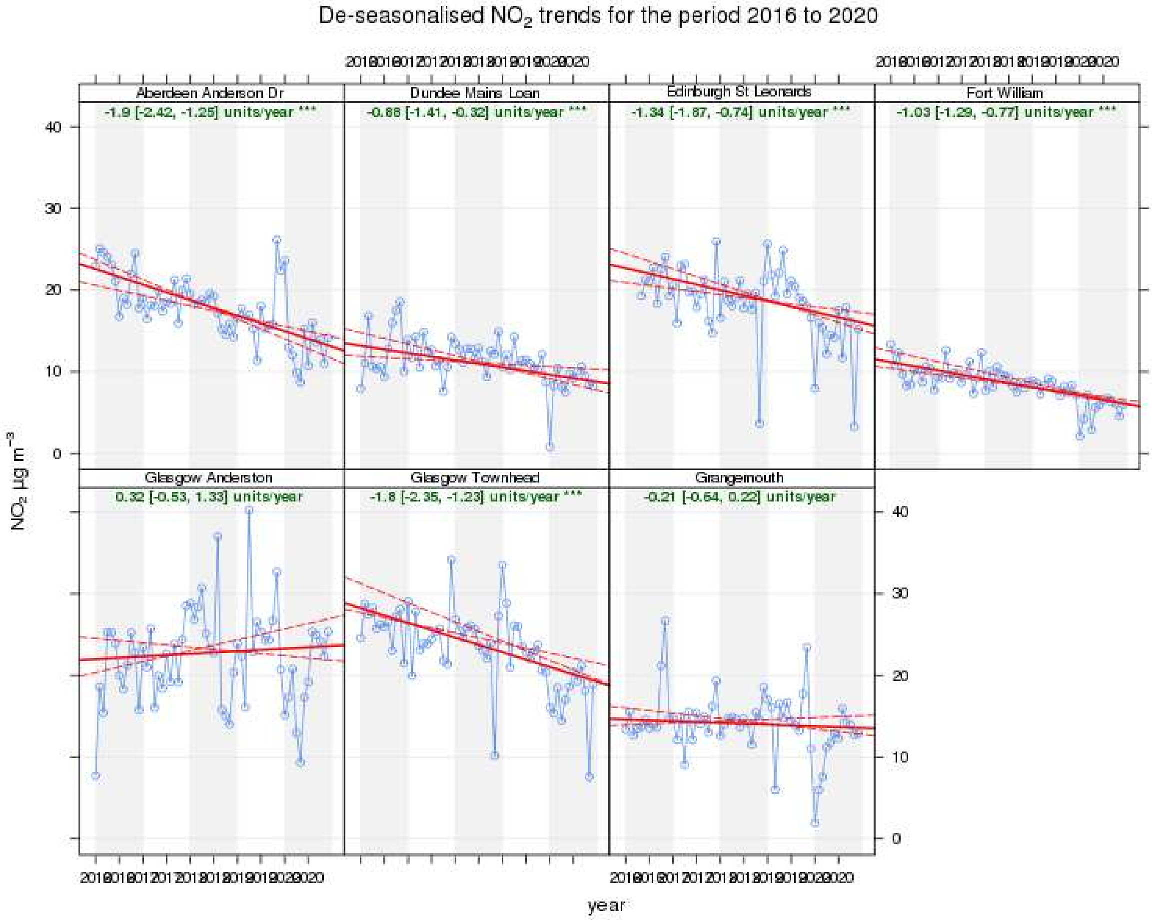


All sites shown in Figure 8-1 display highly significant negative trends (at the 0.001 level) over this time period. This analysis indicates that the decreasing trend in NO_2 concentrations is becoming more substantial over this time period.

Figure 8-2 takes into consideration analysis from all urban background site in Scotland over the past five years, which includes sites Dundee Mains Loan and Glasgow Townhead. As can be seen the decreasing trends seen in Figure 8-1 are not consistent across all sites looking at the past five years. Glasgow Anderston has switched from a decreasing to an increasing trend (though not statistically significant) contradicting the long term perception that NO_2 concentrations are decreasing at all urban background sites. The decreasing trend at Grangemouth is also no longer highly significant.

Looking at the influence the Covid-19 lockdown had on the data it is evident from this analysis that background levels though dipping in the first half of 2020 returned to what could be considered pre lockdown trends.

Figure 8-2 Trends in NO_2 Concentration at all Urban Non-Roadside Sites, 2016-2020

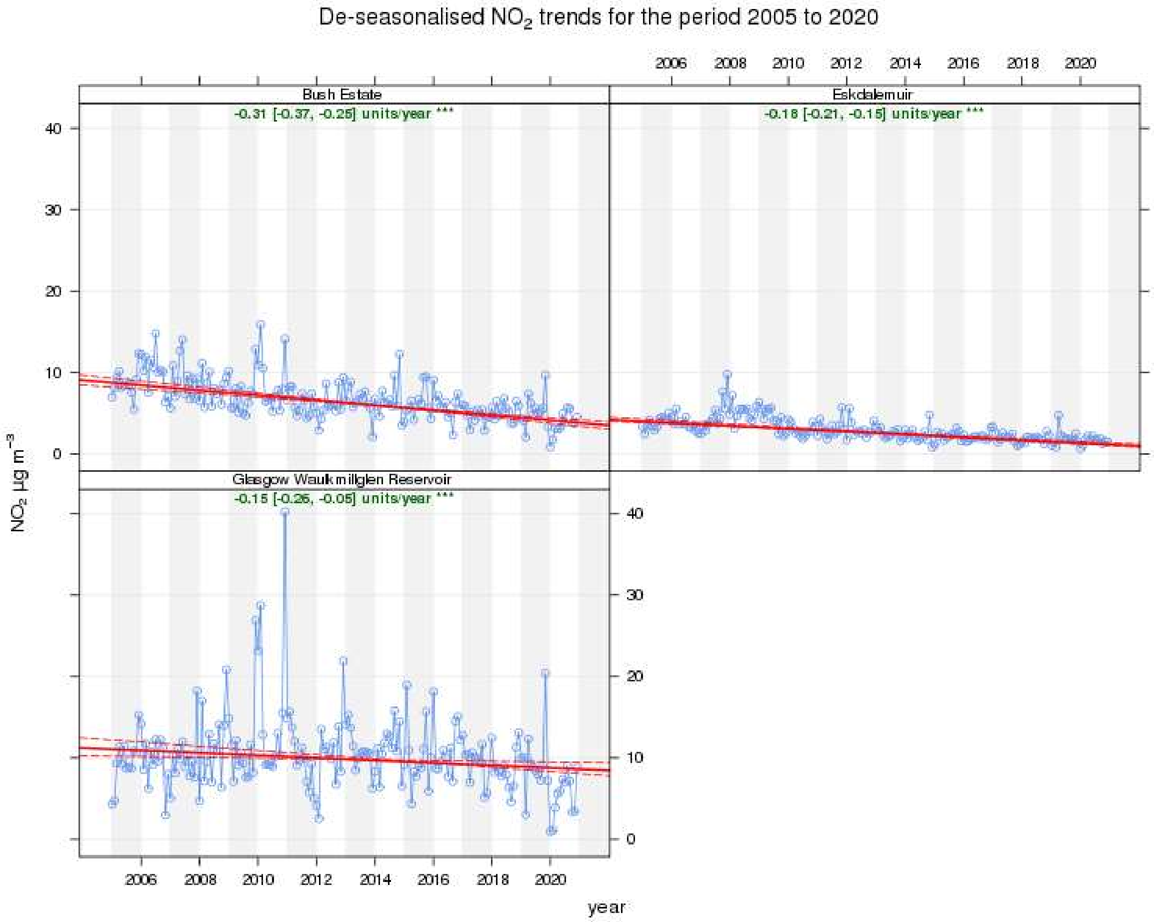


8.1.2 NO_2 at Rural Sites

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 Waukmillglen Reservoir. Figure 8-3 shows trends in NO_2 concentration at these sites.

All three sites show small but highly significant decreasing trends. This is a change from previous reports for Glasgow Waulkmillglen Reservoir. Where previously there was no significant trend there is now a highly significant decreasing trend. The drop in concentrations seen in 2020 due to the lockdown may have influenced this change.

Figure 8-3 Trends in NO_2 Concentration at Three Rural Sites, 2005 – 2020



8.1.3 NO_2 at Urban Traffic Sites

There are now over 40 roadside or kerbside monitoring stations that have been in operation for 10 years or more and are still in operation. These are as follows:

- Aberdeen Anderson Drive
- Aberdeen King Street
- Aberdeen Market Street
- Aberdeen Union Street
- Aberdeen Wellington Road
- Dumfries
- Dundee Lochee Road
- Dundee Seagate
- Dundee Whitehall Road
- East Dunbartonshire Bearsden
- East Dunbartonshire Bishopbriggs
- East Dunbartonshire Kirkintilloch
- Edinburgh Gorgie Road
- Edinburgh Salamander Street
- Edinburgh St John's Road
- Falkirk Haggs
- Falkirk Hope Street
- Falkirk Park Street
- Falkirk West Bridge Street
- Fife Cupar
- Fife Dunfermline
- Fife Rosyth
- Glasgow Byres Road
- Glasgow Kerbside (Hope Street)
- Inverness
- North Lanarkshire Chapelhall
- North Lanarkshire Shawhead Coatbridge
- North Lanarkshire Croy
- North Ayrshire Irvine High Street
- Paisley Gordon Street
- Perth Atholl Street
- Perth High Street
- South Ayrshire Ayr High St

- South Lanarkshire East Kilbride
- Stirling Craig's Roundabout
- West Dunbartonshire Clydebank
-
- West Dunbartonshire Glasgow Road
- West Lothian Broxburn
- West Linlithgow High Street

This is a large number of sites, so for the purposes of this report we have selected eight of the above long-running sites which have measured exceedances of the Air Quality Strategy Objective for annual mean NO_2 (40 µg m^{-3}) in recent years (though not necessarily 2020). 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, Perth Atholl.

Figure 8-4 shows the trend plot. As with the previous report in this series (the 2018 edition), all eight sites show highly significant decreasing trends (at the 0.001 level).

Trends over the most recent five complete years, 2016 – 2020, have also been examined for these sites. These are shown in Figure 8-5. Comparing the ten-year and five-year trends, the patterns are similar in that they all have decreasing trends but of varying significance. At all sites, the decreasing trend has become greater in magnitude over the past five years compared to the past 10.

The influence of the lockdown in 2020 is far more evident at the urban traffic sites which has resulted in the significant increase in the decreasing trends when looking at the past five years' data. It also shows the difference the lockdown has had between urban and background/rural sites. Where at background sites the drop is only really seen in the first half of 2020, at urban sites the step change is seen across the whole year.

Figure 8-4 Trends in NO_2 Concentration at Eight Long-running Urban Traffic Sites with Exceedances, 2010 – 2020

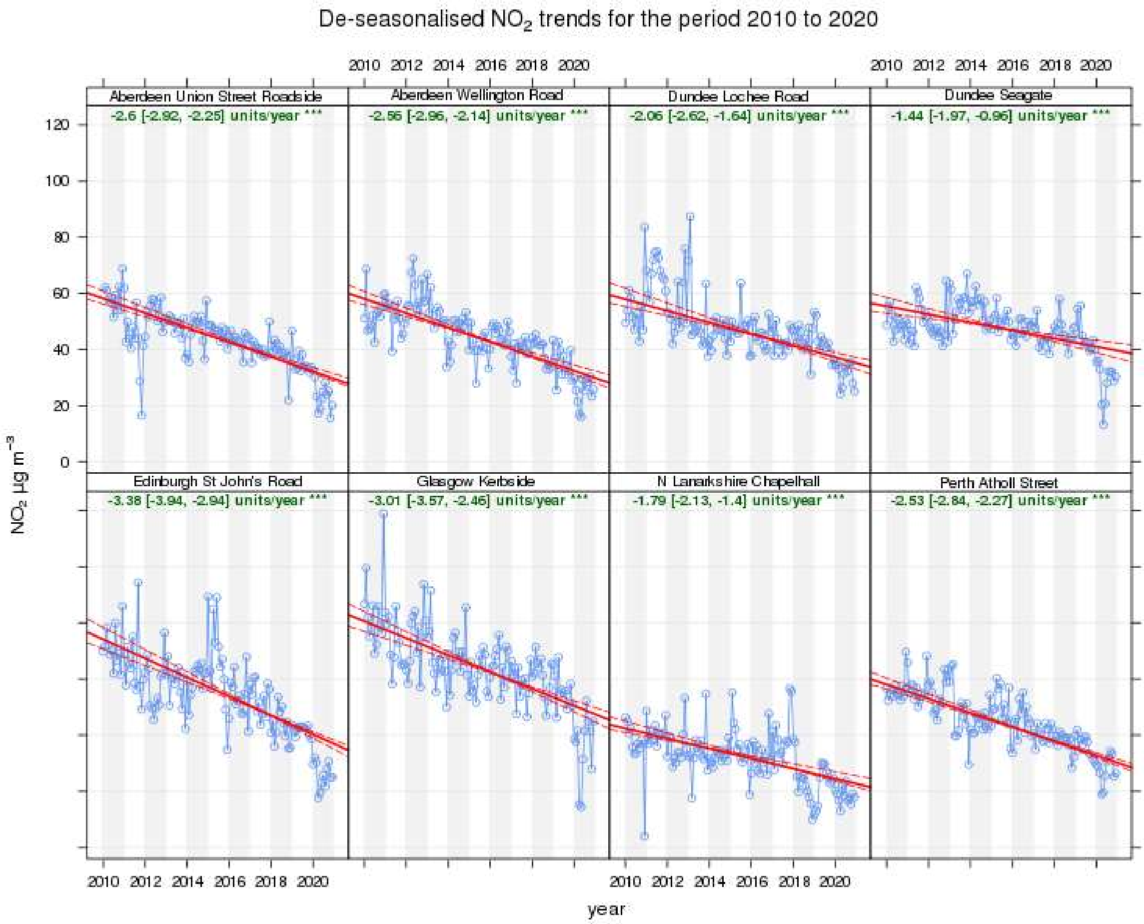
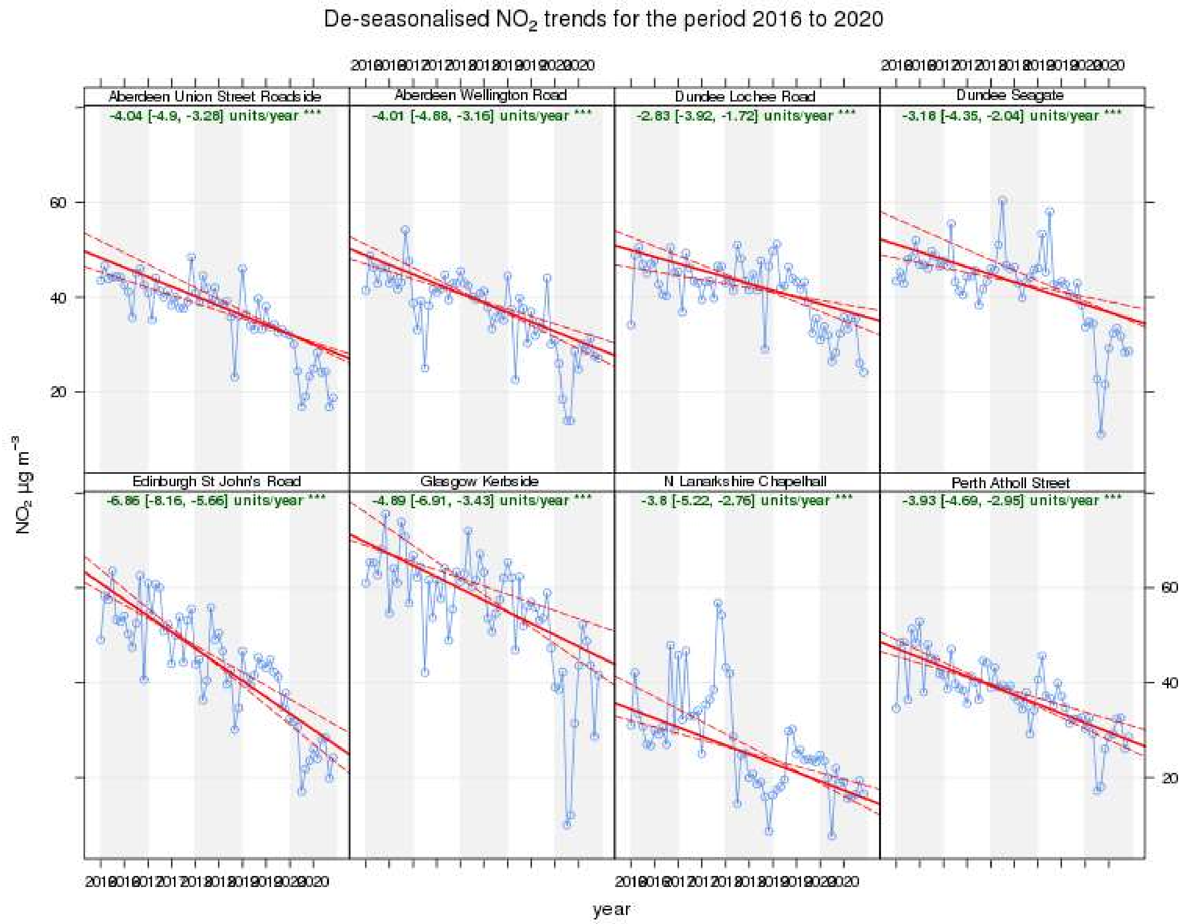


Figure 8-5 Recent Trends in NO_2 Concentration at Eight Long-running Urban Traffic Sites with Exceedances, 2016-2020



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.

During the period covered by this trend analysis, many of Scotland's monitoring sites have used the Tapered Element Oscillating Microbalance (TEOM) to monitor PM_{10}. For the reasons discussed in Section 5 it is necessary to correct TEOM data for possible evaporation of the volatile component (due to the high operating temperature of the TEOM, necessary to prevent condensation on the filter). For years up to and including 2008 the conventional way of doing this was to apply a factor of 1.3 to the data, and the data presented here for those years have been adjusted in this way. However, in 2009 a better correction method became available: the King's College Volatile Correction Model (VCM), which can be found at http://www.volatile-correction-model.info/ . This model uses measurements from nearby FDMS-TEOM instruments (which measure both the volatile and non-volatile fraction) to calculate and apply a correction to the daily or hourly dataset. This is now the recommended method and has been used for the data presented here for years 2009 onwards, from sites where the TEOM are still being used. Over the past four years the number of TEOM and FDMS-TEOM used to measure particulate matter has significantly reduced.

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 ten years or longer. These are: Aberdeen Errol Place (TEOM, converted to FDMS in 2009, and then to FIDAS in November 2019), Dundee Broughty Ferry Road (TEOM, data VCM corrected, converted to FIDAS in January 2020), Dundee Mains Loan (TEOM, data VCM corrected, converted to Fidas in October 2017), Edinburgh St Leonards (FDMS, converted to a FIDAS in July 2019), Glasgow Anderston (FDMS since 2011, converted to Fidas in November 2018), Grangemouth (FDMS since 2009, changed to BAMs June 2018), Falkirk Grangemouth MC (TEOM, converted to FIDAS in May 2020), and North Lanarkshire Coatbridge Whifflet (TEOM, converted to FIDAS in January 2020). Dundee Broughty Ferry Road and Grangemouth are urban industrial; the rest are urban background.

Figure 8-6 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 are examined in Figure 8-7. Its show that though the decreasing trend is still evident at all sites it is no longer highly significant at all sites.

Figure 8-6 Trends in PM_{10} Concentration at Six Long-Running Urban Background and Urban Industrial Sites, 2007 – 2020

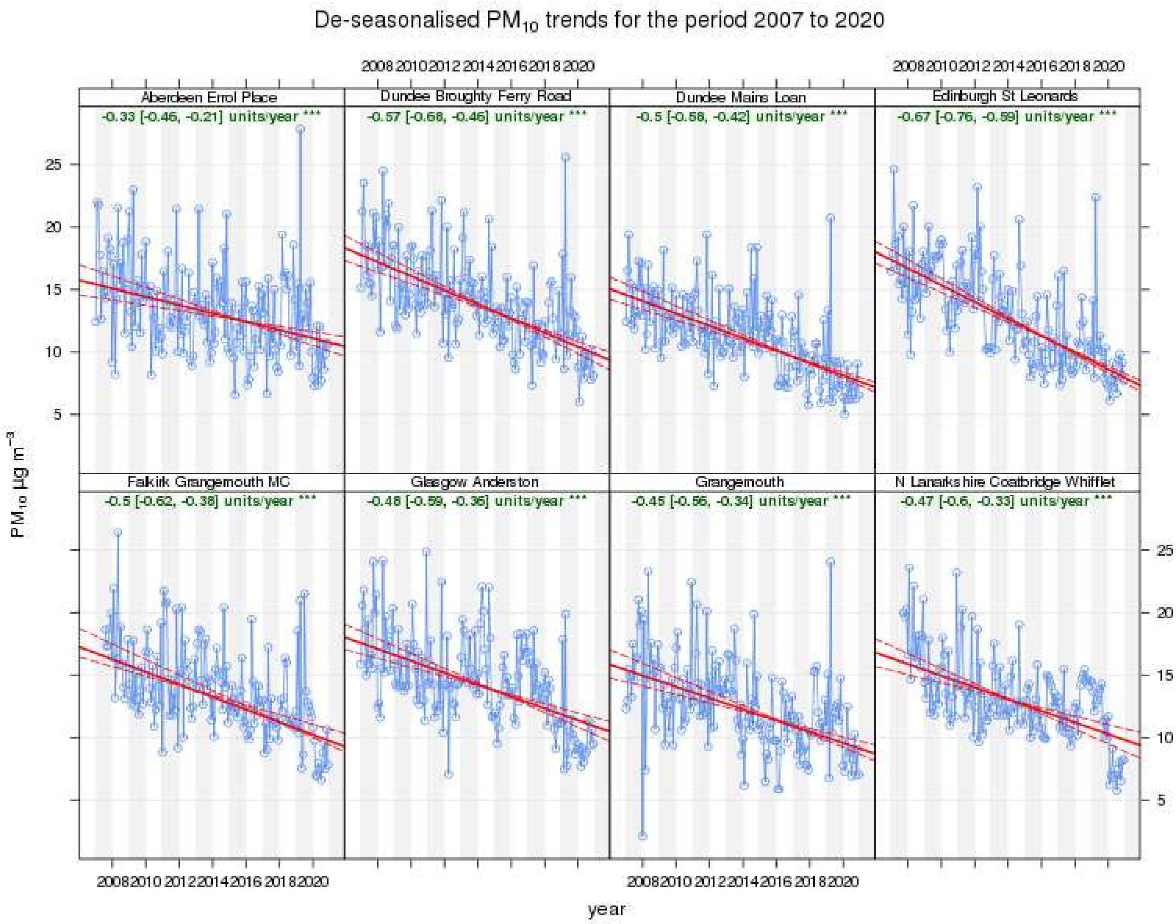
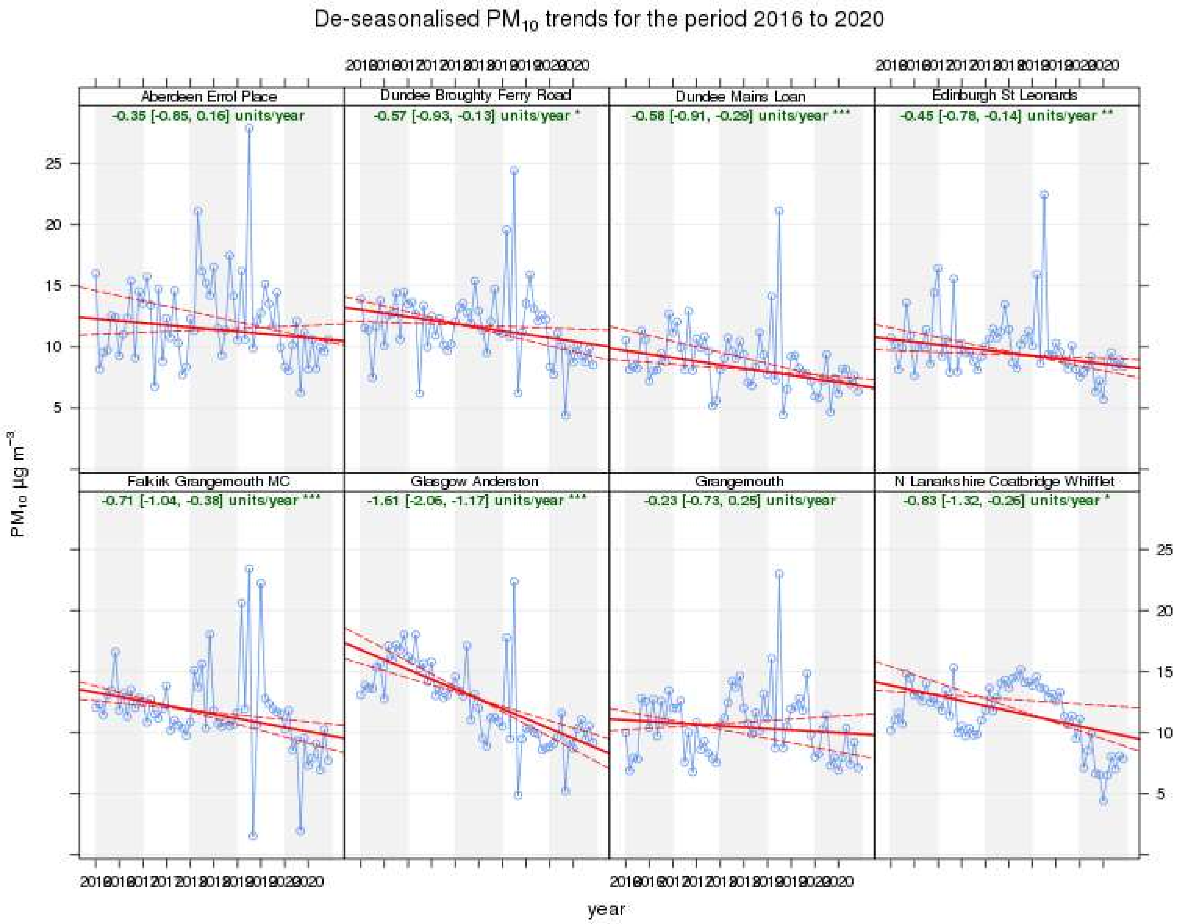


Figure 8-7 Trends in PM10 Concentration at Six Long-Running Urban Background and Urban Industrial Sites, 2016 – 2020



8.2.2 PM10 at Urban Traffic Sites

There are 34 PM10 monitoring sites in Scotland that have been monitoring for over 10 years. These are as follows:

- Angus Forfar
- Aberdeen King Street
- Aberdeen Union Street Roadside
- Aberdeen Wellington Road
- Alloa
- East Dunbartonshire Bearsden
- East Dunbartonshire Bishopbriggs
- East Dunbartonshire Kirkintilloch
- East Lothian Musselburgh N High St
- Edinburgh Salamander St
- Falkirk Hope St
- Falkirk Park St
- Falkirk West Bridge Street
- Fife Cupar
- Fife Rosyth
- Glasgow Abercromby Street
- Glasgow Anderston
- Glasgow Broomhill
- Glasgow Byres Road
- Glasgow Nithsdale Road
- Glasgow Waulkmillglen Reservoir
- Grangemouth Moray
- N Lanarkshire Coatbridge Whifflet
- N Lanarkshire Shawhead Coatbridge
- North Ayrshire Irvine High St
- Paisley Gordon Street
- Perth Atholl Street
- Perth Crieff
- Perth High Street
- South Ayrshire Ayr High St
- South Lanarkshire East Kilbride
- Stirling Craig's Roundabout

- West Dunbartonshire Clydebank
- West Lothian Broxburn
- West Lothian Whitburn

Trends in de-seasonalised monthly mean PM_{10} concentrations for eight traffic-related sites in operation since 2009 or earlier are shown in Figure 8-8. The sites selected for this analysis are Aberdeen Wellington Road (FDMS, Converted to FIDAS in September 2016), East Dunbartonshire Bearsden (Aberline, converted to FIDAS in January 2019), Edinburgh Salamander (TEOM, Converted to December 2020), Fife Cupar (FDMS, converted to FIDAS in December 2016) , Glasgow Anderston (FDMS, converted to FIDAS in November 2018), Glasgow Byres Road (FDMS, converted to FIDAS in December 2017), Perth Crieff (BAM, converted to FIDAS in December 2017) and West Lothian Broxburn (FDMS, Converted to FIDAS in September 2017). These sites were chosen to be analysed because of the length of time they have been monitoring (10 years or more), present or historical exceedances of the annual mean objective and geographical coverage.

All sites showed highly statistically significant decreasing trends (at the 0.001 level). The trends indicate that PM_{10} over the past 10 years is decreasing year on year at these roadside sites.

Trends in de-seasonalised monthly mean PM_{10} concentrations for the same eight sites (plus Edinburgh Queensferry Road), for the most recent five complete years 2016 – 2020, are shown in Figure 8-9. Figure 8-9 shows that PM_{10} concentrations over the past five years also show a highly significant decreasing trend with the exception of Edinburgh Queensferry Street and Glasgow Byres Road sites. Here the trend is still decreasing however not statistically significant, indicating a leveling off.

Figure 8-8 Trends in PM_{10} Concentration at Eight Long-Running Urban Traffic Sites, 2010 – 2020

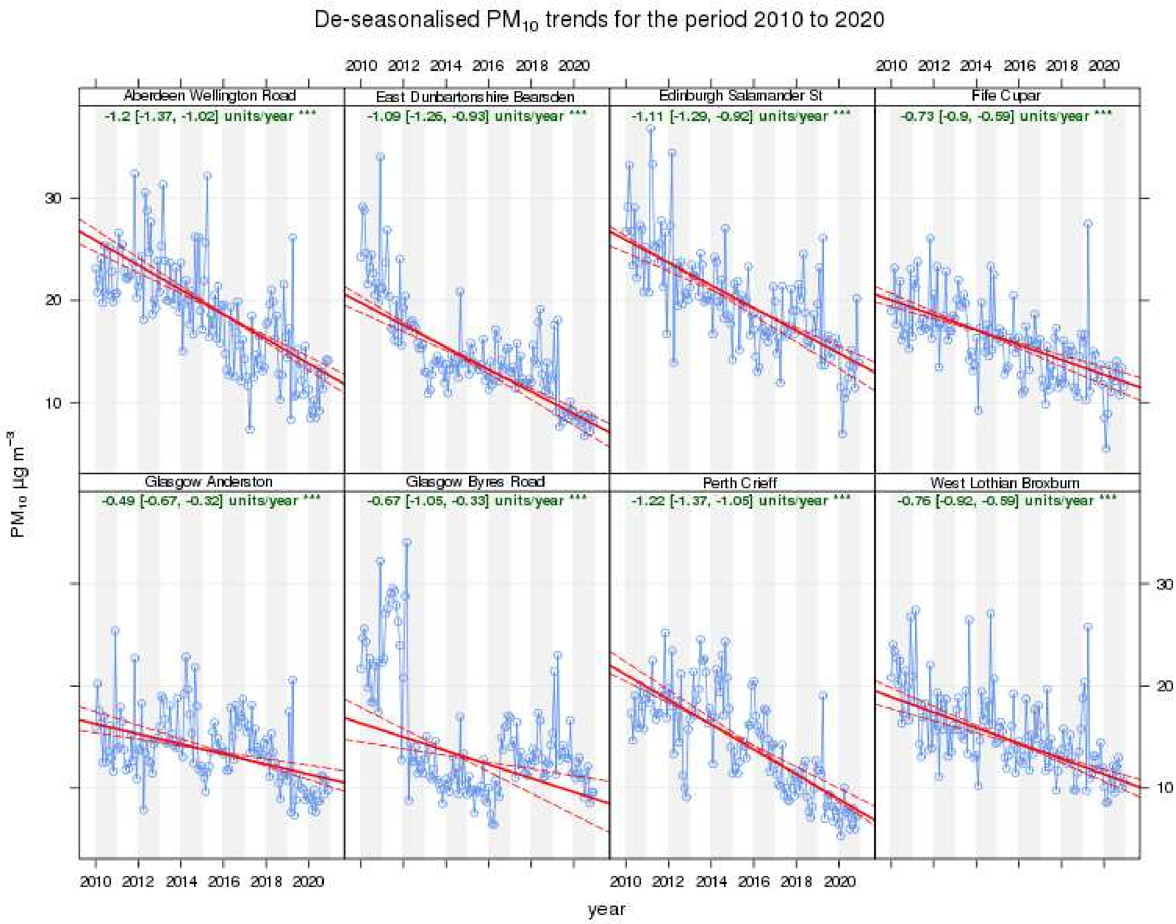
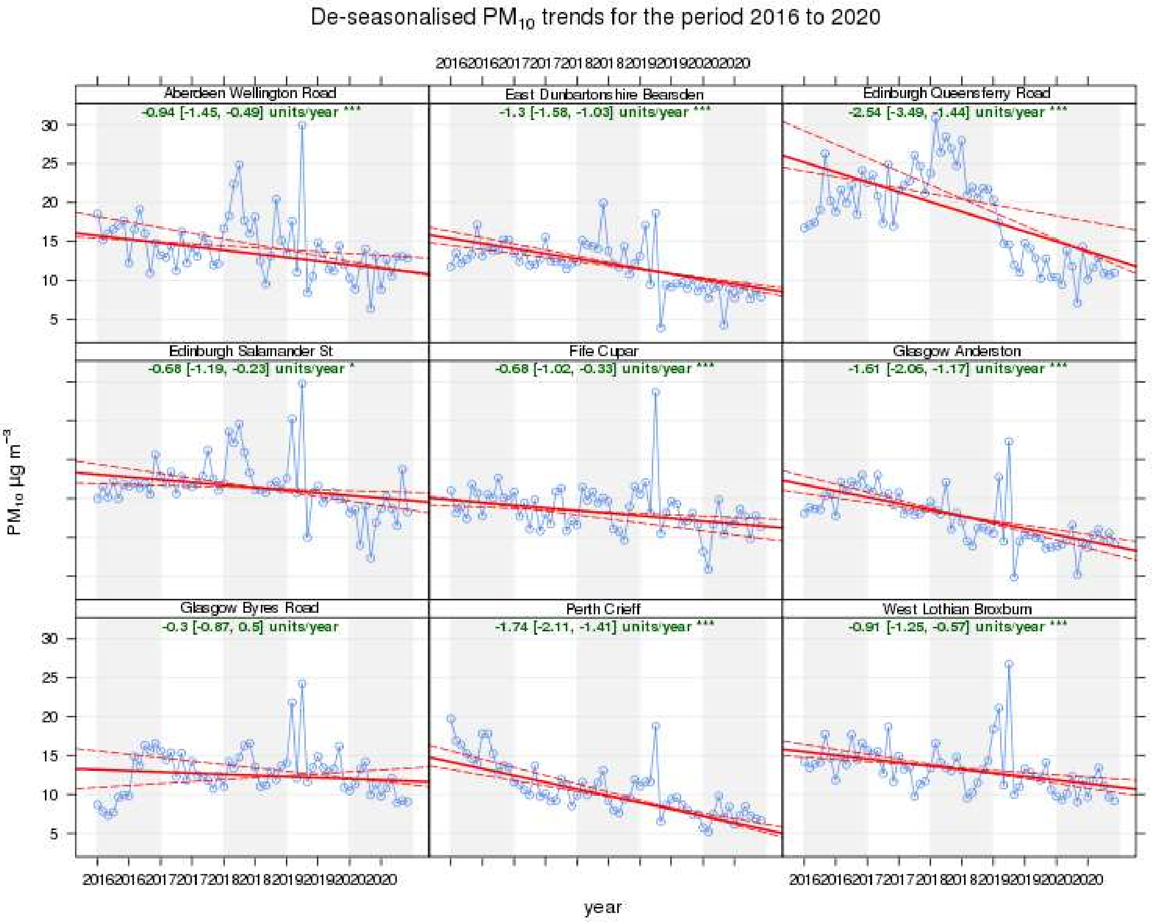


Figure 8-9 Trends in PM_{10} Concentration at Eight Long-Running Urban Traffic Sites, 2016 – 2020



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, absorbed on their surfaces, into the lungs.

At the time of writing this report there are 76 sites monitoring $PM_{2.5}$ in Scotland. However, the vast majority of these sites started monitoring in the last five years with the introduction of the $PM_{2.5}$ objective and the requirement for local authorities to measure the pollutant. By the end of 2020 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 8-10.

Aberdeen Errol Place, Edinburgh St Leonards, and Grangemouth sites show slight but highly statistically significant (at the 0.001 level) decreasing trends for $PM_{2.5}$. Contrary to this, the rural site Auchencorth Moss shows no trend indicating no real change in concentrations over the past 10 years.

As of the end of 2020, there were an additional nine sites with five years' worth of data, the minimum required for trend analysis. The site are Glasgow Townhead, Aberdeen Union Street, Aberdeen Market Street (UT) Glasgow High Street, West Dunbartonshire Clydebank, South Lanarkshire Lanark, South Lanarkshire Uddingston, North Ayrshire Irvine High Street, and Fife Rosyth. All sites are Urban traffic sites with the exception of Glasgow Townhead which is Urban Background. Figure 8-11 illustrates the trend for these 9 $PM_{2.5}$ sites. As can be seen, there are four sites which have decreasing trends with ranging levels of statistical significance. The other five sites, though downward, have no real identifiable statistically significant trend. South Lanarkshire Uddingston has an increasing trend though not statistically significant.

Figure 8-10 Trends in $PM_{2.5}$ Concentration at Four Long-Running Monitoring Sites, 2010 – 2020

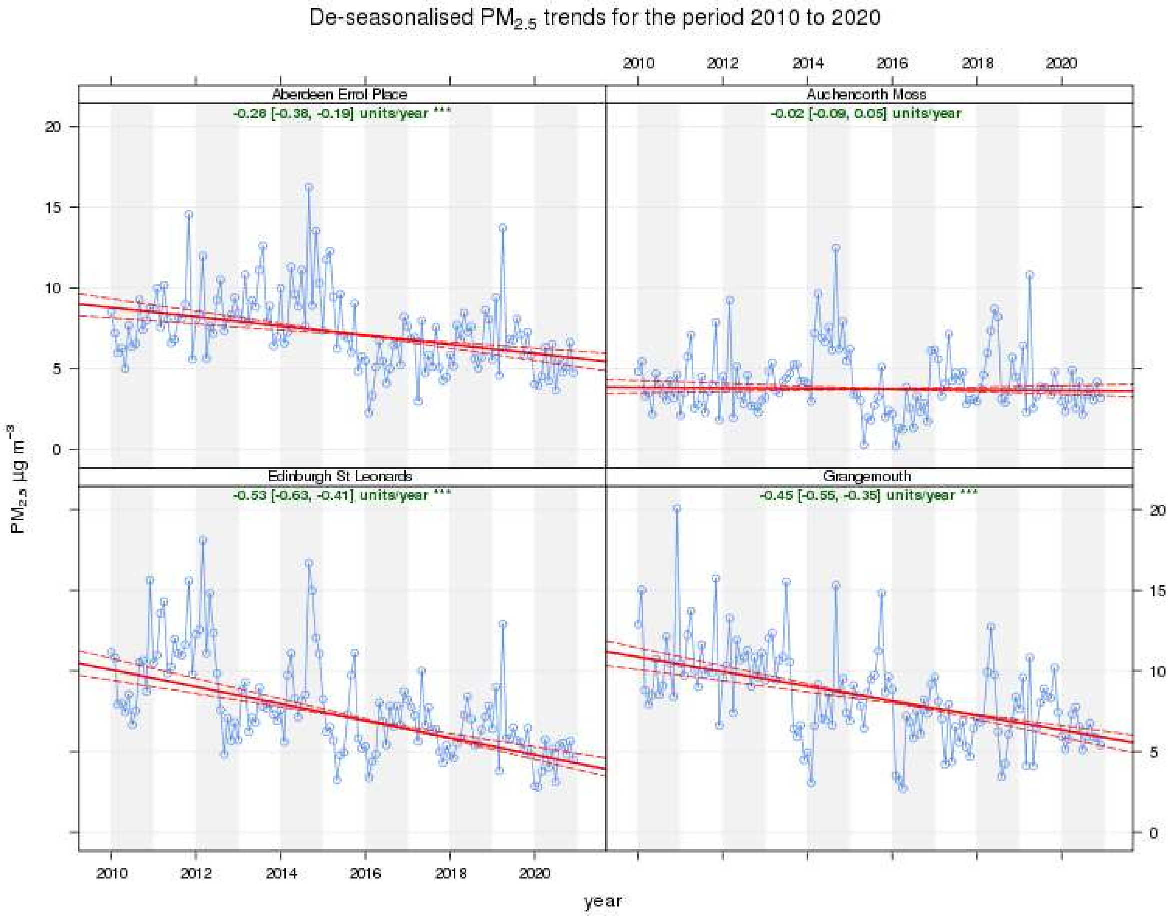
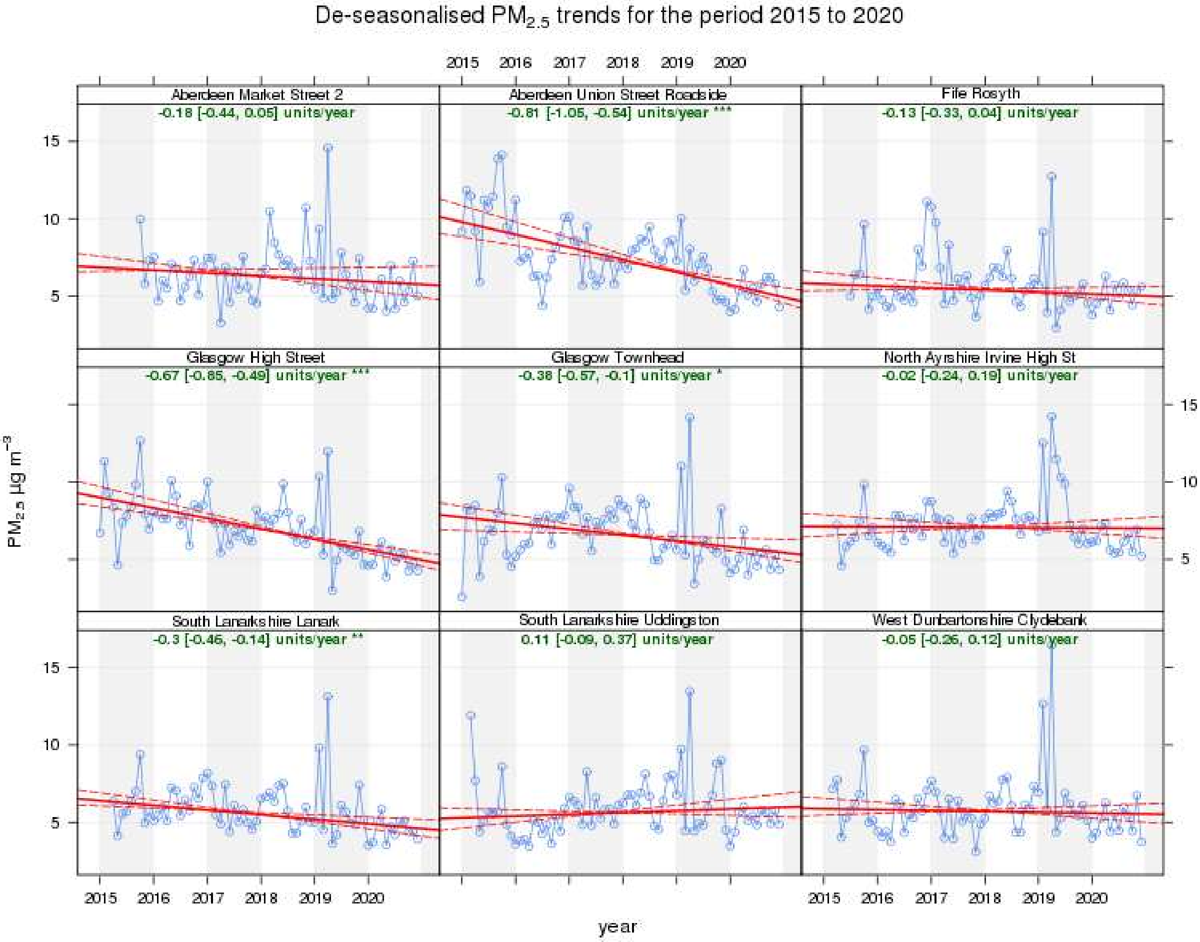


Figure 8-11 Trends in $PM_{2.5}$ Concentration at Four Long-Running Monitoring Sites, 2010 – 2020



8.4 Ozone

8.4.1 Rural Ozone

Three of Scotland's rural air quality monitoring stations have been monitoring ozone for 31 years, 1986 – 2020. These are Bush Estate, Eskdalemuir and Strath Vaich. Figure 8-12 shows long-term trends in de-seasonalised monthly mean ozone (O_3) concentrations at these three exceptionally long-running rural monitoring sites. All three sites showed a small increasing trend in monthly mean rural ozone concentrations over this period. For Bush Estate and Eskdalemuir this trend was highly statistically significant. For Strath Vaich the trend was minimal and not statistically significant. The charts also show considerable 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.[12]

Six sites have been in operation for over 10 years. These are the above three sites, plus Auchencorth Moss, Glasgow Waukmillglen Reservoir and Lerwick. Trends in ozone concentration at these six sites are shown in Figure 8-11. In contrast to the 30-year trends, the ten-year trends were less consistent. Five of the sites showed increasing trends with varying levels of statistical significance. The remaining site, Glasgow Waulkmillglen showed a not statistically significant decreasing trend.

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

Figure 8-12 Trends in O_3 Concentrations at Long-Running Rural Sites, 1986 – 2020

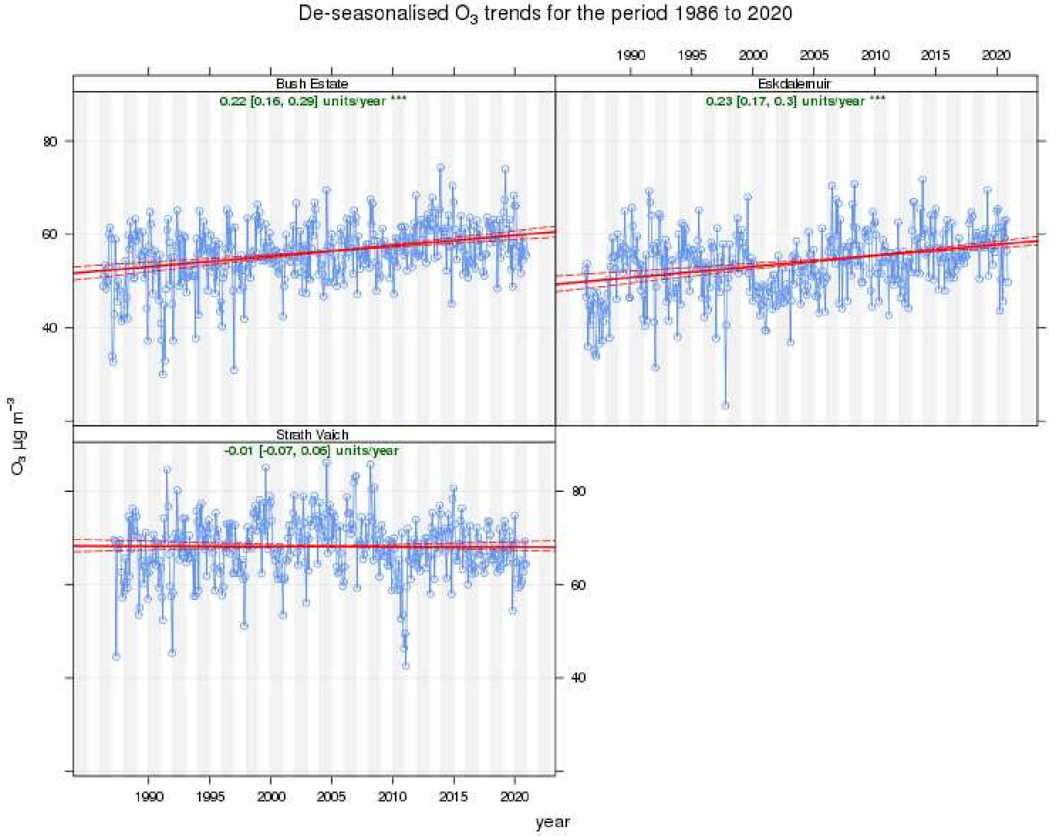
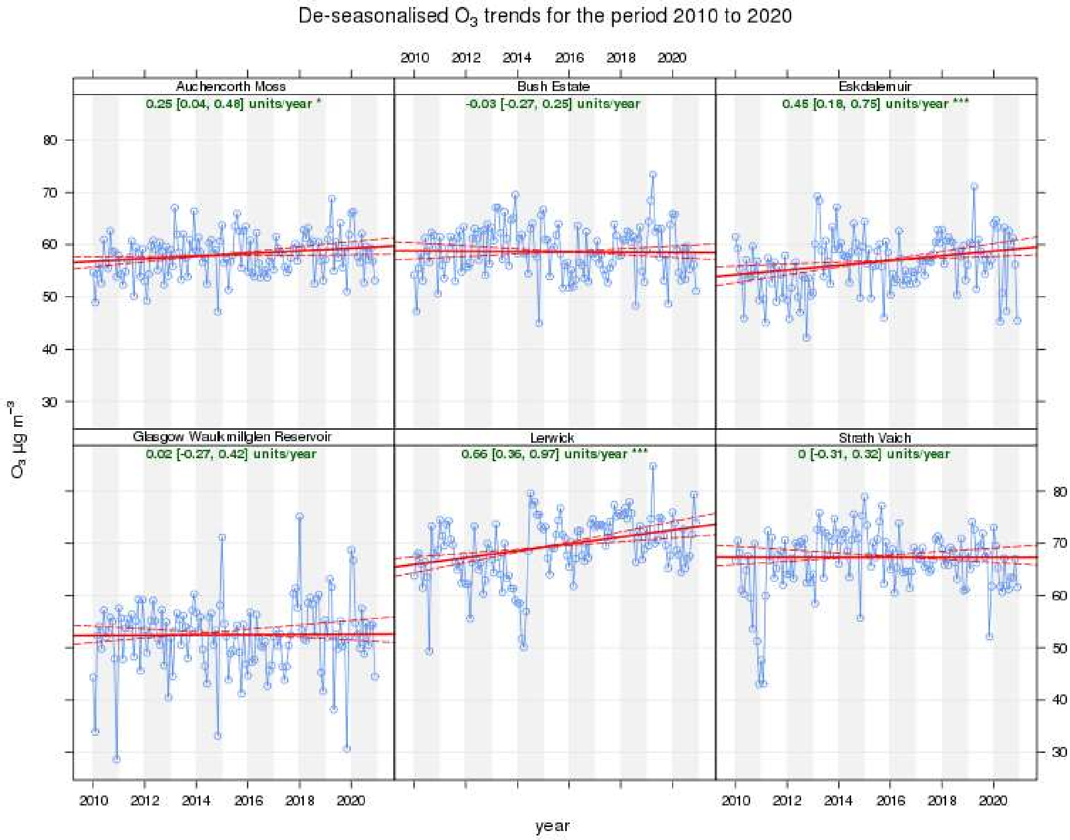


Figure 8-13 Trends in O_3 Concentrations at Six Long-Running Rural Sites, 2010 – 2020



8.4.2 Urban Background Ozone

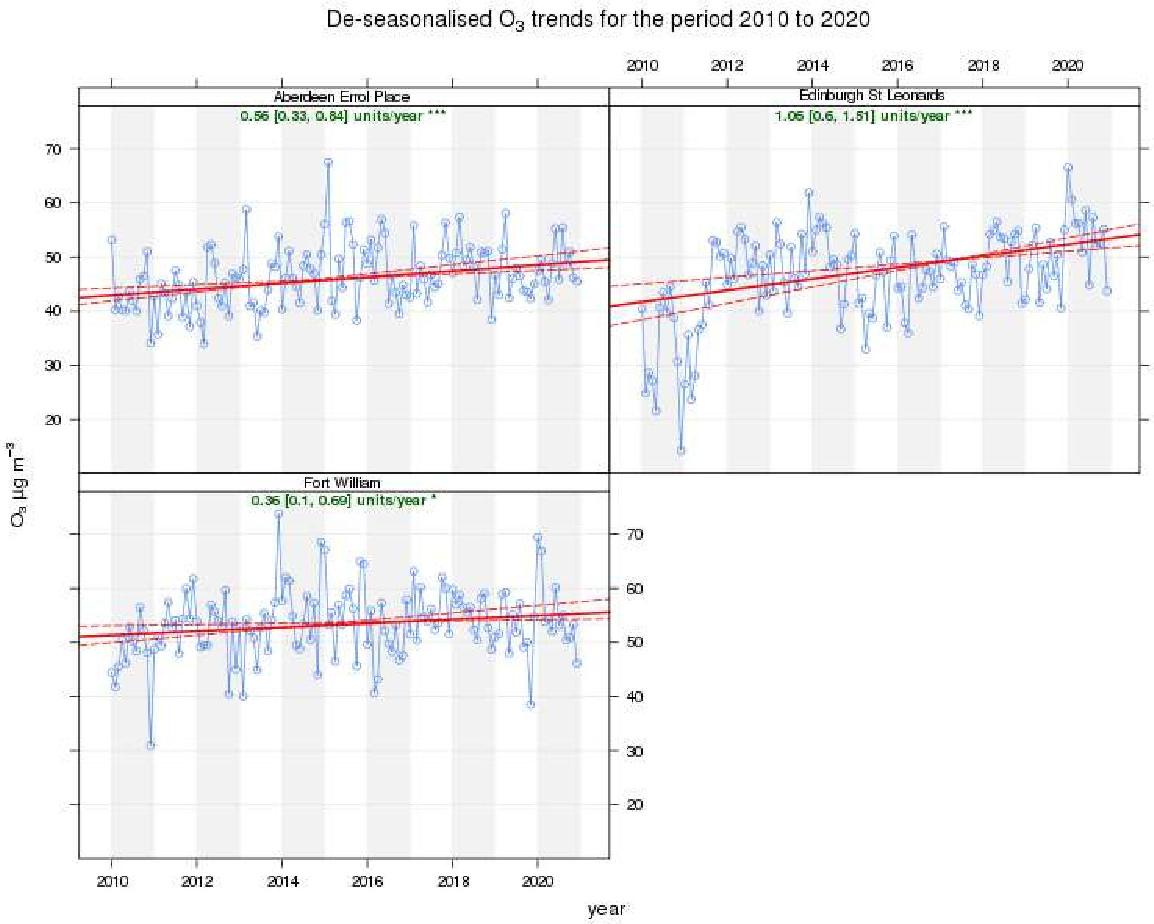
Figure 8-14 shows trends in de-seasonalised monthly mean ozone concentrations at the three Scottish urban background monitoring sites which have been monitoring ozone for the past 10 years, 2010-2019: Aberdeen Errol Place, Edinburgh St Leonards and Fort William.

There is again an increasing trend at all three sites, highly significant at Aberdeen Errol Place and St Leonards.

At Edinburgh St Leonards there was a noticeable dip in measured ozone concentrations throughout 2010 and into 2011. The reason for this is unknown and an investigation of these low data has confirmed that the analyser was operating within its usual parameters throughout 2010 – 2011. Since no reason could be found to discard the data, they must be assumed to be genuine.

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

Figure 8-12 Trends in O_3 Concentration at Two Long-Running Urban Background Sites, 2010 – 2020



8.5 Additional Trend Analysis

Additional Analysis can be carried out on the SAQD monitoring data using analysis tools suggest 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
http://www.scottishairquality.scot/news/reports?view=laqm. 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 arrange of additional analysis techniques are 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 2020 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 2020 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 8-13 to 8-16 illustrate this analysis for the 4 sites mention.

Figure 8-13 Openair Analysis – Aberdeen Wellington Road

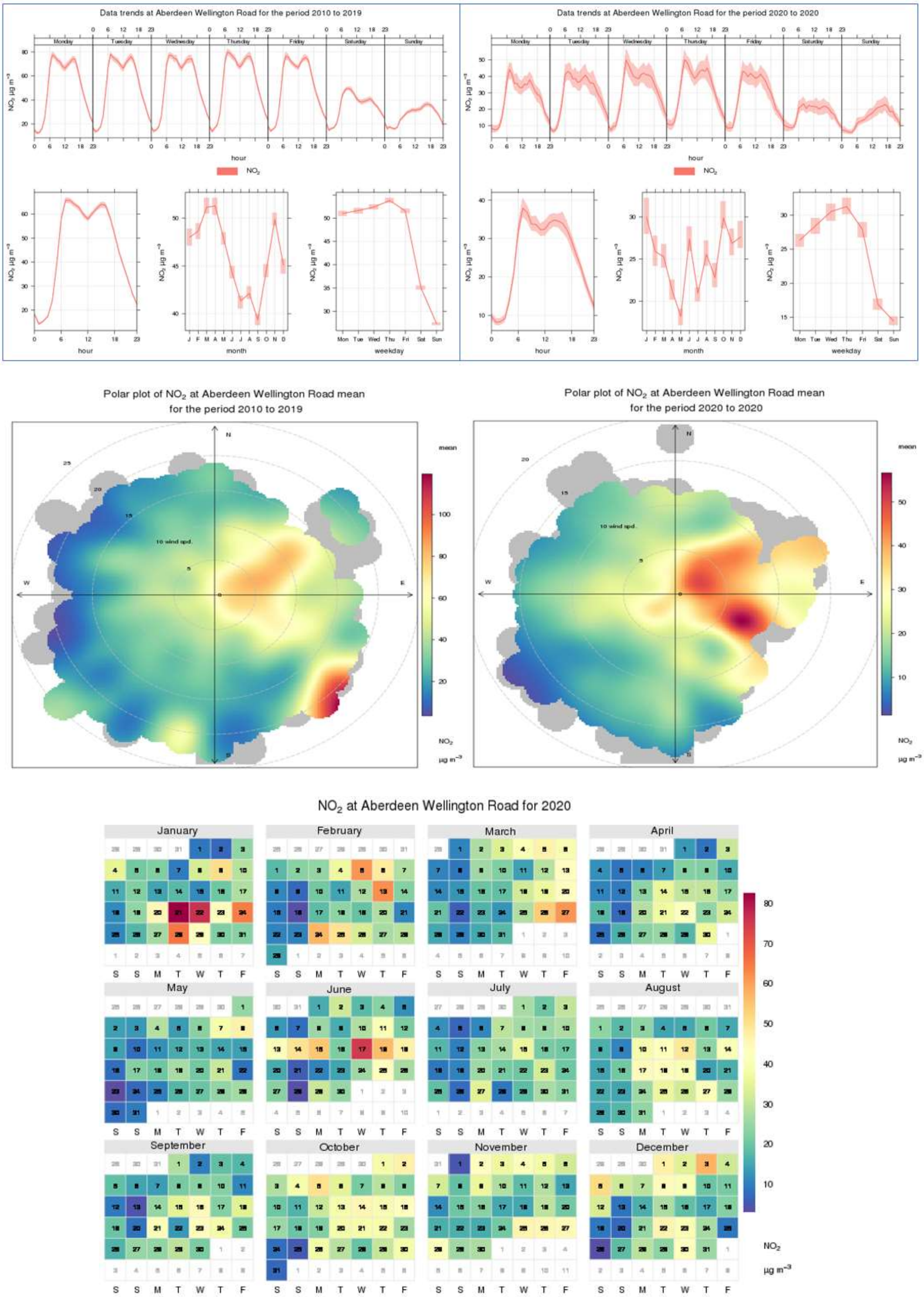


Figure 8-14 Openair Analysis – Dundee Lochee Road

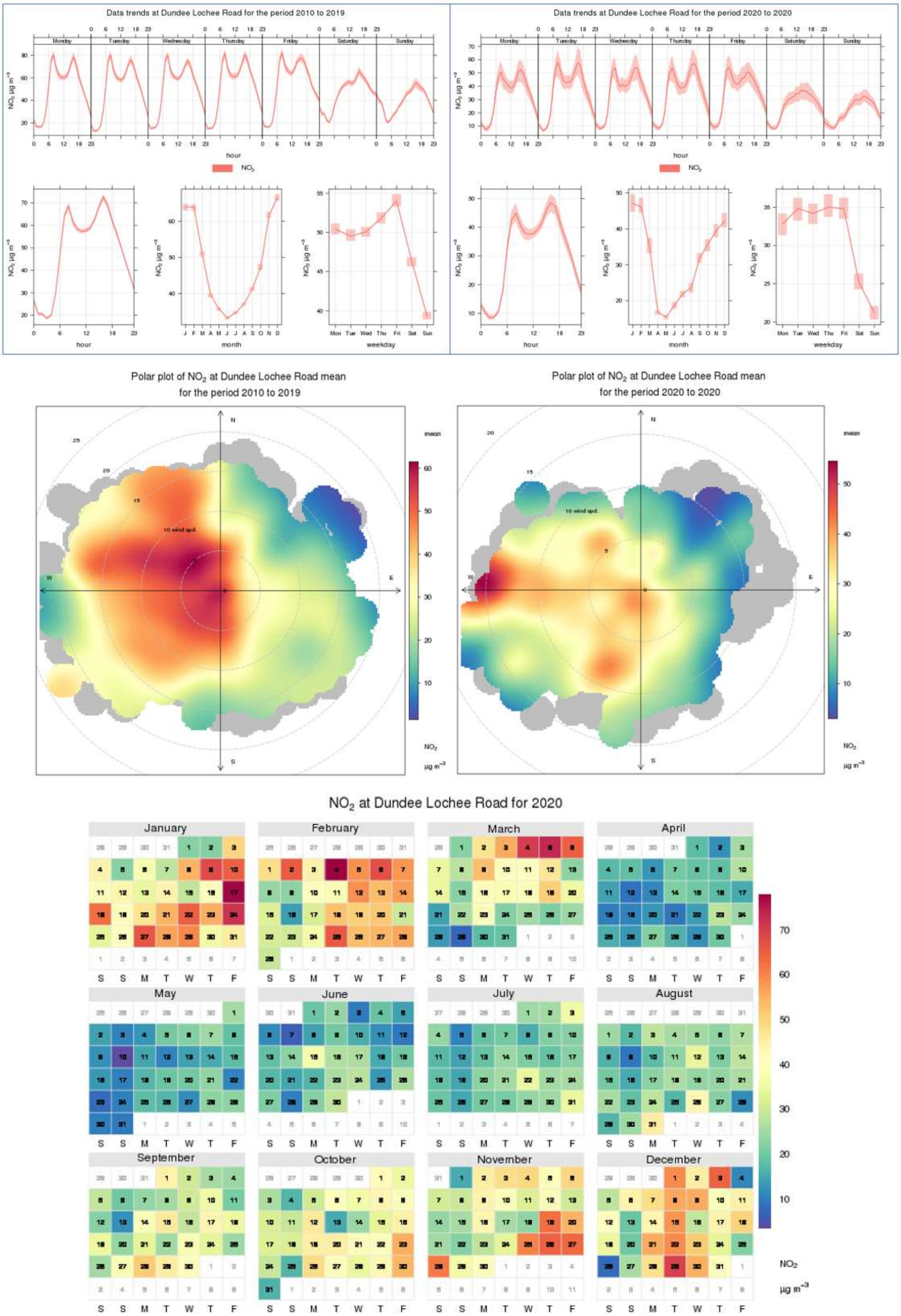
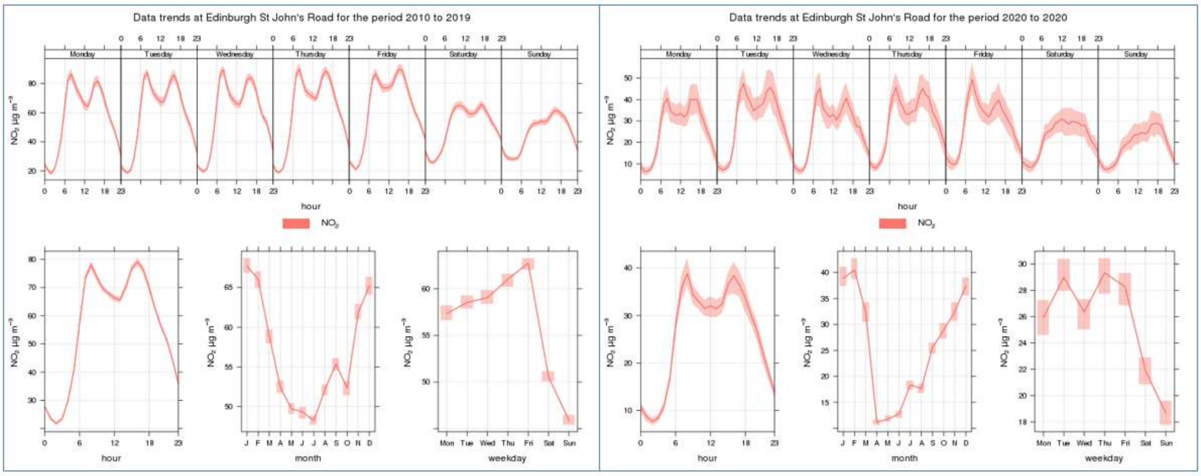
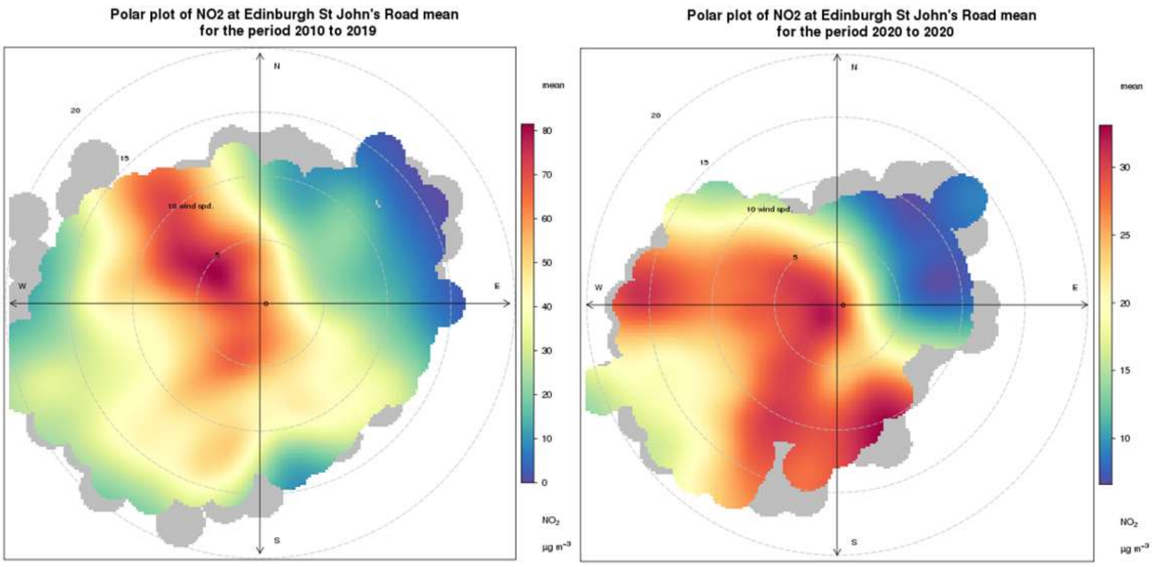


Figure 8-15 Openair Analysis – Edinburgh St Johns Road





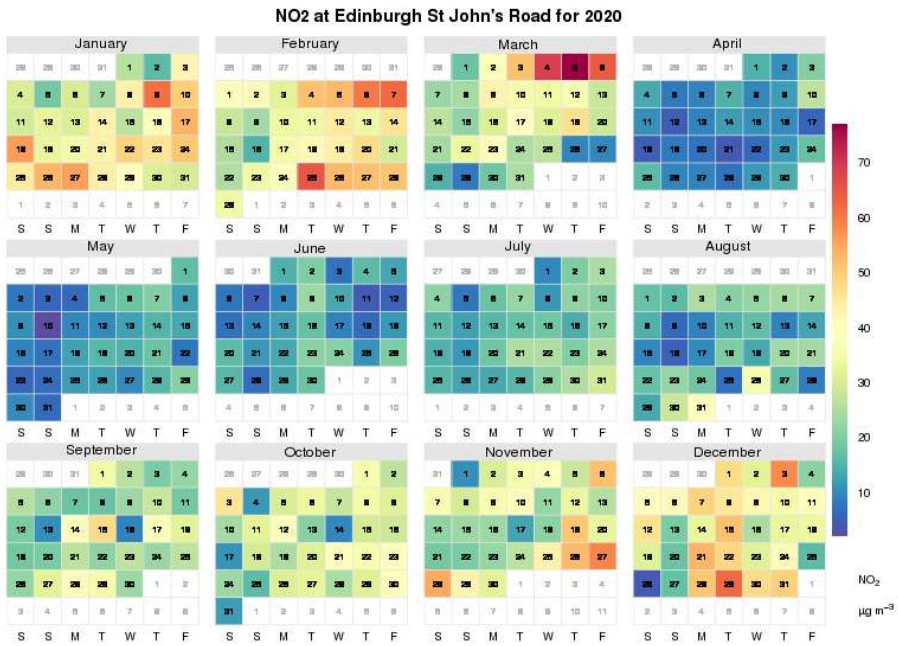
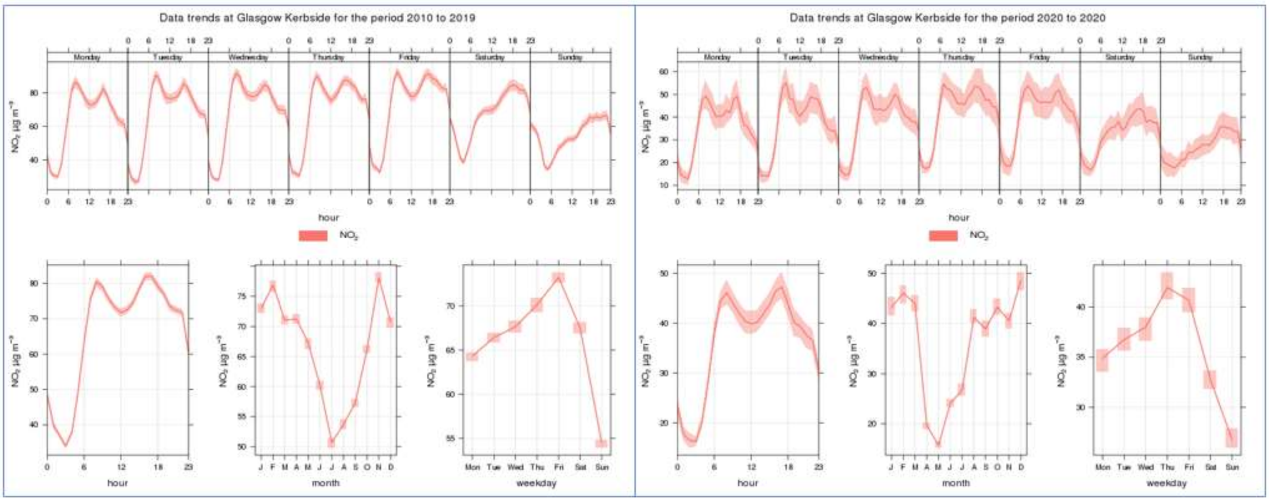
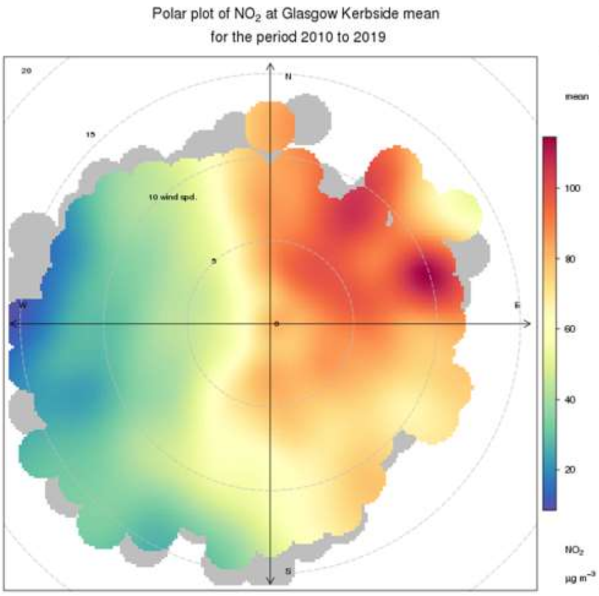
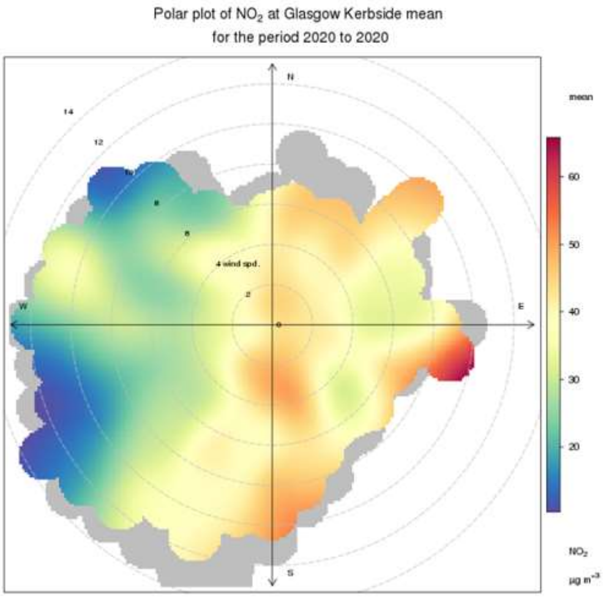
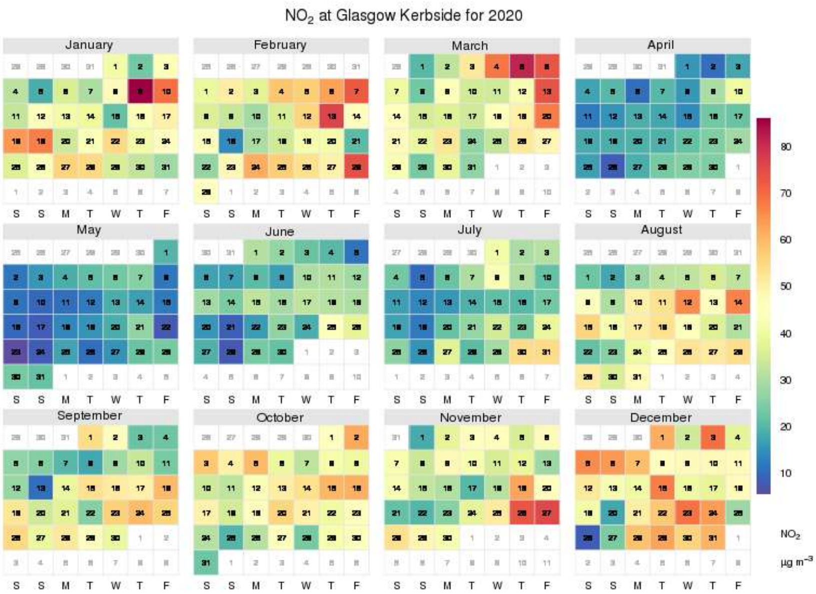


Figure 8-16 Openair Analysis – Glasgow Kerbside









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[13]. The inventory covers a wide range of pollutants, but in this report will mainly focus on NO_x, Particulate Matter (PM_{10}, and $PM_{2.5}$), Ammonia, and VOC. This is mainly due to the current low levels of CO, SO_2 and Pb in Scotland. 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 have been compiled from the information presented on SEPA's SPRI database, with permission from SEPA. The data provided is up to 2019, 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 all of the 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 upon 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 (www.scottishairquality.scot/news/reports?view=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 note 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 – 2019".

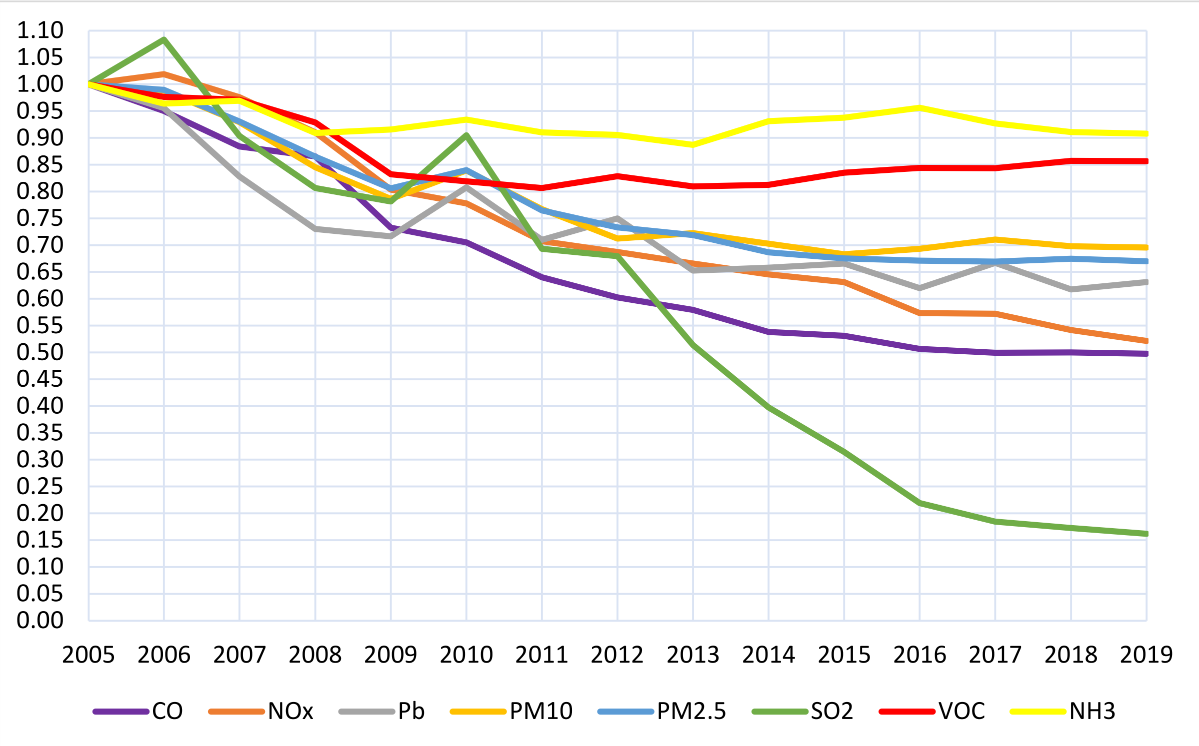
[13] Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2019 https://naei.beis.gov.uk/reports/reports?report_id=1030

When comparing previously reported emissions with the most recent data, you may see 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 began to increase. In fact, VOCs emission levels 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.

Figure 9.1 Scotland normalised trends for all monitored pollutants



9.2 Scotland NOx Inventory by NFR Sector 1990 – 2019

Table 9-2 and 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.

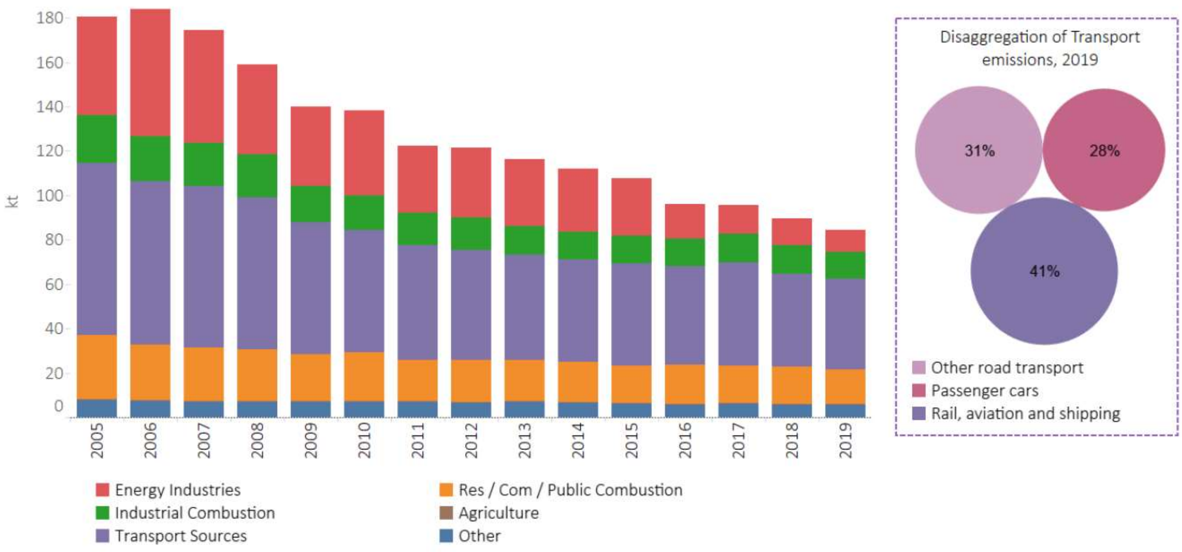
Table 9-1 Summary of NO_x emission estimates for Scotland (2005 – 2019)

Category	2005	2006	2007	2008	2009	2010	2011
Energy Industries	44.6	57.0	50.8	40.6	36.0	38.4	30.2
Industrial Combustion	21.6	20.3	19.6	19.5	16.1	15.6	14.9
Transport Sources	92.7	89.6	88.9	87.5	76.7	69.1	67.0
Other	8.7	8.4	8.3	7.8	7.9	8.1	8.6
Residential & other combustion	29.0	25.1	24.2	23.5	21.2	21.7	18.3
Total:	196.6	200.3	191.9	178.9	157.9	152.9	139.0

Category	2012	2013	2014	2015	2016	2017	2018	2019
Energy Industries	31.2	30.0	28.4	25.8	15.8	13.2	12.3	10.2
Industrial Combustion	14.6	13.0	12.5	12.5	12.1	12.8	12.8	12.1
Transport Sources	63.1	61.1	60.6	61.4	60.3	62.5	57.1	56.7
Other	7.5	8.4	7.4	7.4	6.7	7.0	7.3	8.4
Residential & other combustion	18.7	18.5	18.1	17.0	17.6	16.9	17.1	15.2
Total:	135.1	130.9	126.9	124.0	112.7	112.4	106.5	102.6

Units: kilotonnes (kt)
Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2019

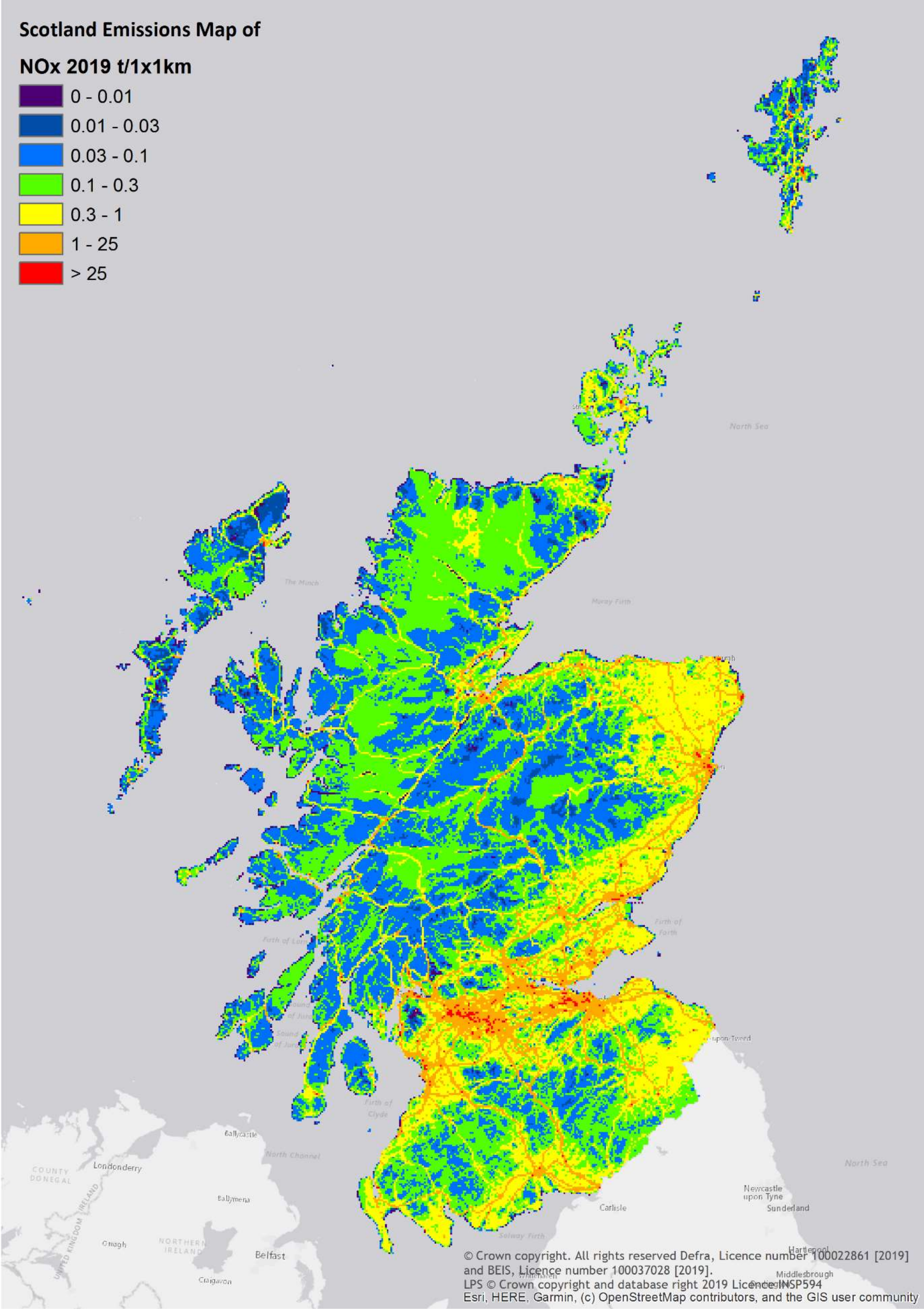
Figure 9.2 Time series of Scotland NO_x emissions 2005-2019



Emissions of **nitrogen oxides** in Scotland were estimated to be 85kt in 2019, representing 10% of the UK total. Emissions have declined by 53% 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 NOX relative to their petrol counterparts (88% of 2019 passenger car emissions were due to diesel cars). The peak in NO_X emissions in 2006 is due to the increased use of coal at power stations that year. 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, Longannet Power Station, 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.

Figure 9.3 shows a map of Scotland's NOx emissions in 2019.

Figure 9.3 Map of NO_x Emissions in Scotland, 2019



Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2019

9.3 Scotland PM_{10} Inventory by NFR Sector 2005 – 2019

The table 9-2 and Figure 9.4 give a summary of the Summary of PM_{10} emission estimates for Scotland by category. The detailed data are available in report and website cited in the introduction to this Chapter.

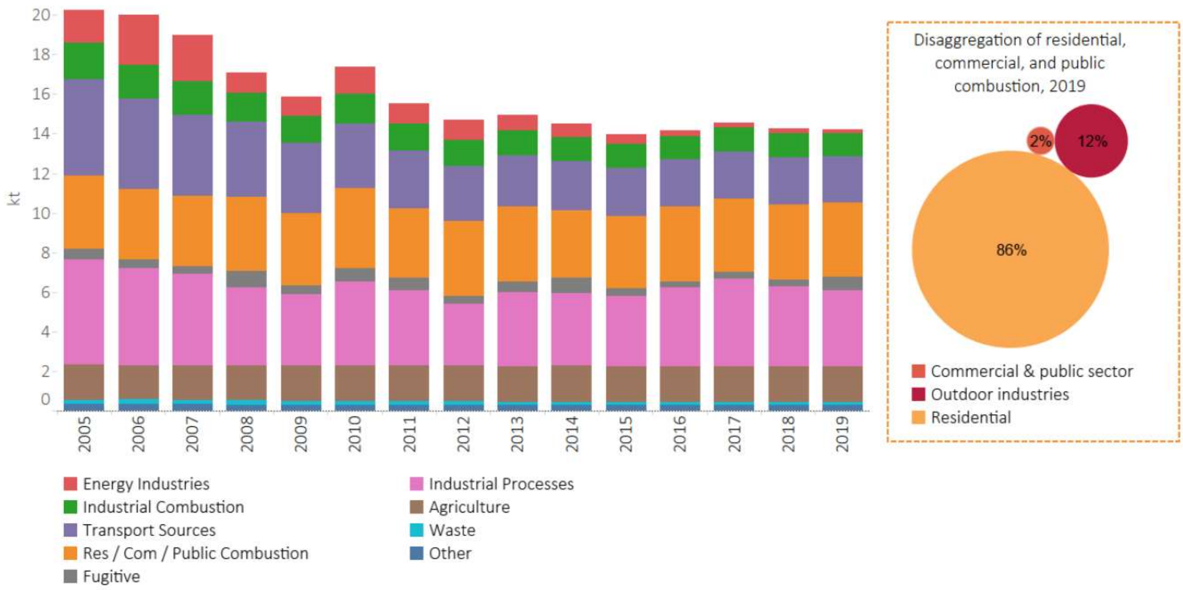
Table 9-2 Summary of PM_{10} emission estimates for Scotland (2005 – 2019)

Category	2005	2006	2007	2008	2009	2010	2011
Agriculture	2.0	1.8	1.7	1.6	1.6	1.5	1.4
Energy Industry	1.7	2.5	2.4	1.0	1.0	1.4	1.0
Industrial Combustion	1.8	1.7	1.7	1.5	1.4	1.5	1.3
Transport	5.6	5.3	4.6	4.4	4.0	3.6	3.2
Industrial Processes	5.3	4.9	4.6	3.9	3.6	4.3	3.8
Solvent Processes	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Residential & Other Combustion	6.5	6.3	6.2	6.8	6.3	6.9	6.6
Other	22.9	22.6	21.3	19.4	18.0	19.2	17.6
Total:	2.0	1.8	1.7	1.6	1.6	1.5	1.4

Category	2012	2013	2014	2015	2016	2017	2018	2019
Agriculture	1.4	1.3	1.3	1.3	1.4	1.3	1.3	1.3
Energy Industry	1.0	0.8	0.7	0.5	0.3	0.2	0.3	0.2
Industrial Combustion	1.3	1.2	1.2	1.2	1.1	1.2	1.2	1.2
Transport	3.0	2.9	2.7	2.7	2.6	2.7	2.6	2.6
Industrial Processes	3.1	3.7	3.7	3.6	4.0	4.4	4.0	3.8
Solvent Processes	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Residential & Other Combustion	6.3	6.6	6.4	6.2	6.4	6.4	6.5	6.7
Other	16.3	16.5	16.1	15.7	15.9	16.3	16.0	15.9
Total:	1.4	1.3	1.3	1.3	1.4	1.3	1.3	1.3

Units: kilotonnes (kt)
Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2019

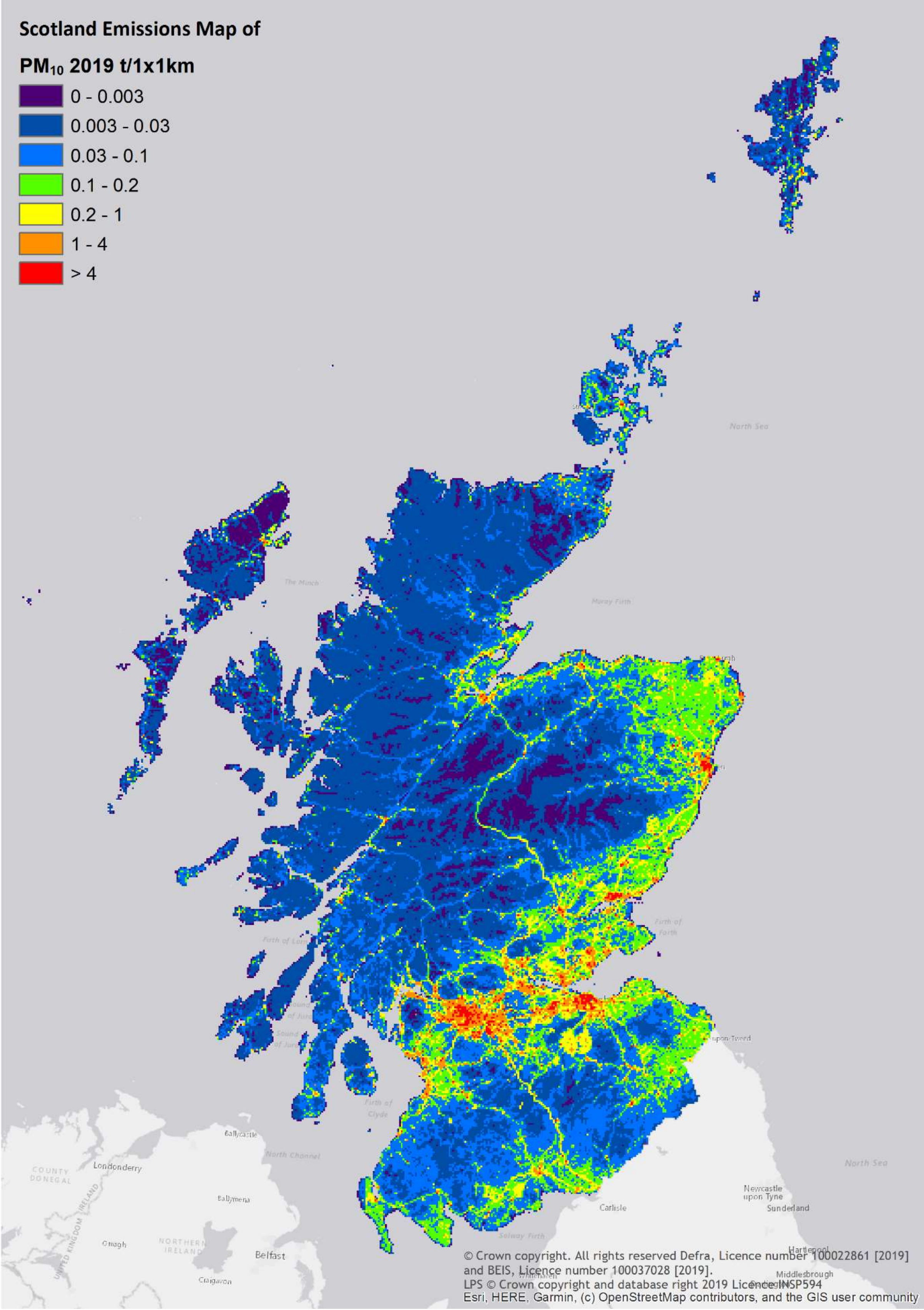
Figure 9.4 Time Series of Scotland's PM_{10} Emissions 2005-2019



Emissions of **PM_{10}** in Scotland were estimated to be 14kt in 2019, declining by 30% since 2005. These emissions account for 8% of the UK total. Unlike most other pollutants, the emissions profile of PM_{10} is diverse: transport sources, residential and industrial processes each accounted for over 16% of total emissions in 2019. 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 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 stringer 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 2019, 79% 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. Emissions levels since 2015 have plateau and slightly increased

Figure 9.5 shows a map of PM_{10} emission in Scotland for 2019.

Figure 9.5 Map of PM_{10} Emissions in Scotland, 2019



Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2019

9.4 Scotland $PM_{2.5}$ Inventory by NFR Sector 2005 – 2019

Table 9-3 and 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.

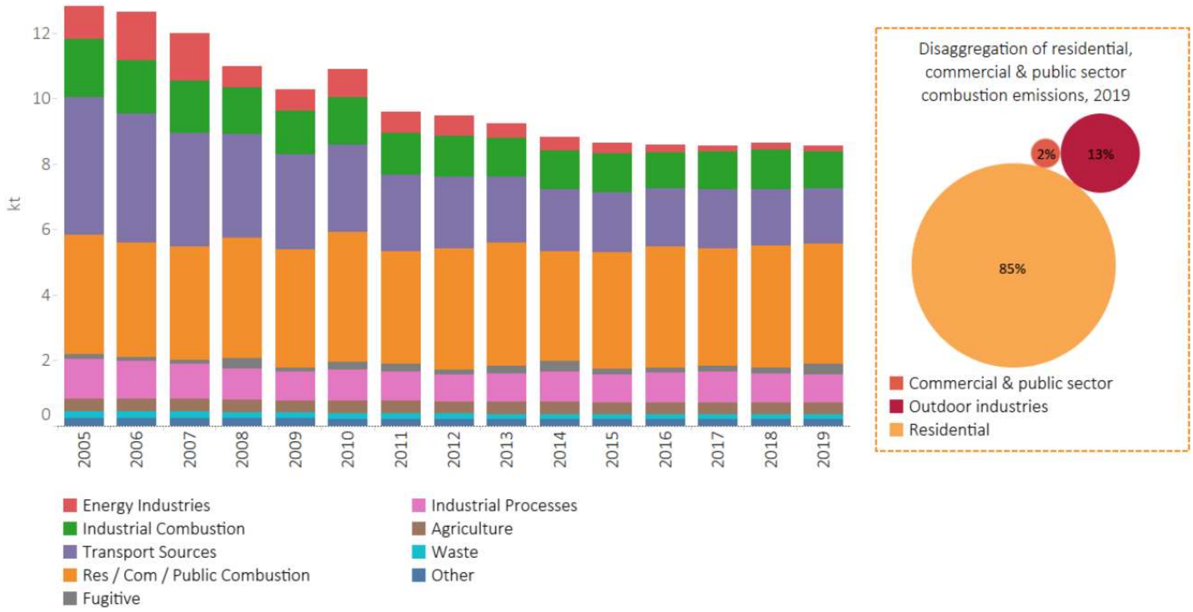
Table 9-3 Summary of $PM_{2.5}$ emission estimates for Scotland (2005 – 2019)

Category	2005	2006	2007	2008	2009	2010	2011
Agriculture	0.39	0.38	0.38	0.38	0.37	0.38	0.38
Energy Industry	1.03	1.47	1.45	0.65	0.64	0.86	0.66
Industrial Combustion	1.76	1.62	1.60	1.43	1.33	1.44	1.28
Transport	4.87	4.62	3.98	3.76	3.40	2.99	2.66
Industrial Processes	1.21	1.14	1.07	0.96	0.87	0.94	0.89
Solvent Processes	0.03	0.03	0.03	0.03	0.03	0.02	0.03
Residential & Other Combustion	4.75	4.61	4.54	4.93	4.66	5.16	4.83
Other	14.0	13.9	13.1	12.1	11.3	11.8	10.7
Total:	0.39	0.38	0.38	0.38	0.37	0.38	0.38

Category	2012	2013	2014	2015	2016	2017	2018	2019
Agriculture	0.38	0.37	0.37	0.37	0.37	0.37	0.36	0.36
Energy Industry	0.62	0.47	0.41	0.33	0.24	0.19	0.20	0.18
Industrial Combustion	1.27	1.18	1.18	1.18	1.10	1.17	1.20	1.13
Transport	2.46	2.27	2.16	2.08	2.03	2.02	1.95	1.93
Industrial Processes	0.82	0.88	0.91	0.85	0.90	0.94	0.90	0.87
Solvent Processes	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Residential & Other Combustion	4.71	4.88	4.56	4.63	4.75	4.69	4.82	4.90
Other	10.3	10.1	9.6	9.5	9.4	9.4	9.5	9.4
Total:	0.38	0.37	0.37	0.37	0.37	0.37	0.36	0.36

Units: kilotonnes (kt)
Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2019

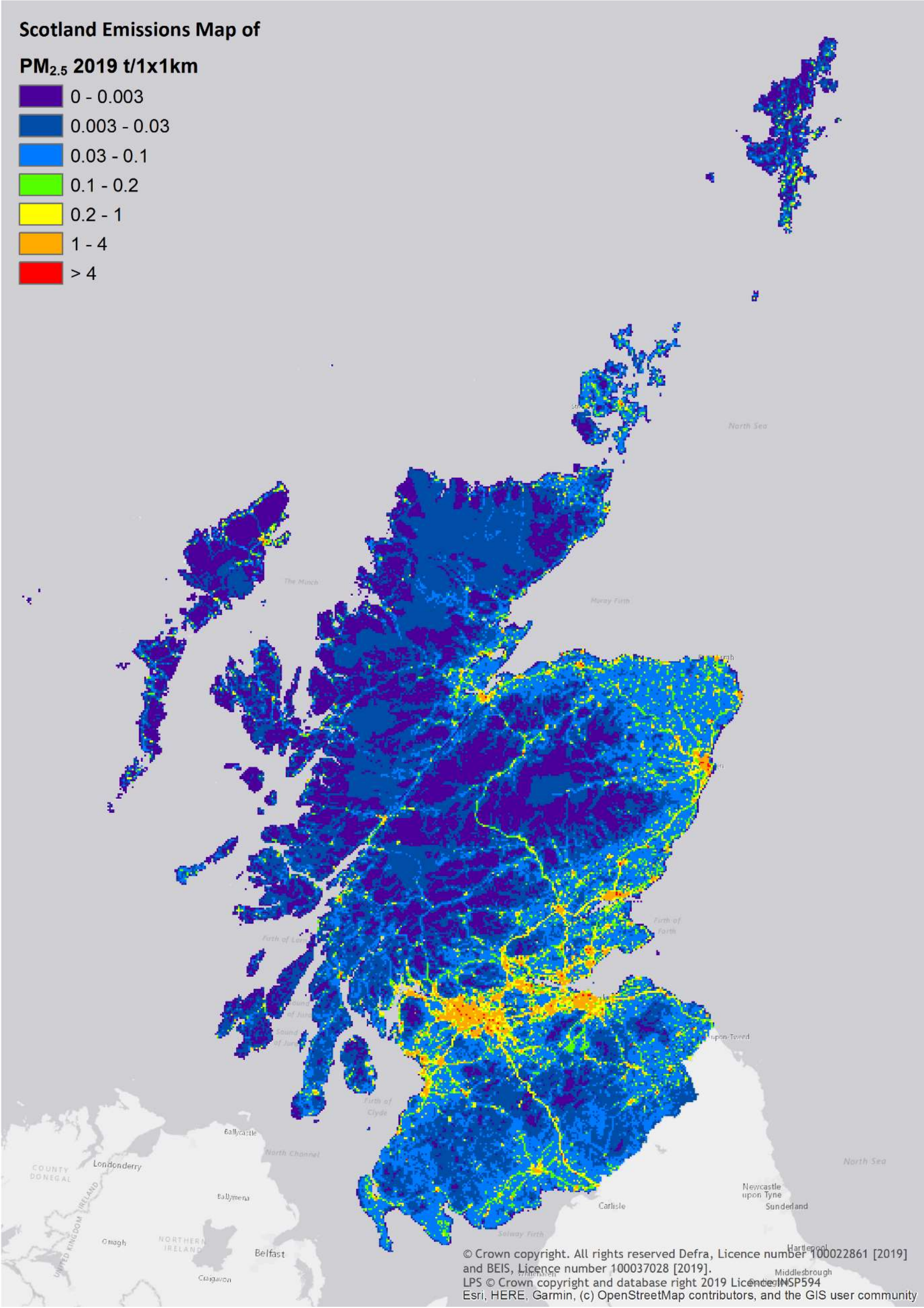
Figure 9.6 Time Series of Scotland's $PM_{2.5}$ Emissions 2005-2019



Emissions of **$PM_{2.5}$** in Scotland were estimated to be 9kt in 2019, declining by 33% since 2005. These emissions account for 8% of the UK total in 2019. 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) accounts for 43% of 2019 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. However, these declines in emissions have been offset by increases in emissions from the residential sector, and in particular, the combustion of wood. Emissions from the residential sector have increased by 50% since 2005.

Figure 9.7 shows a map of $PM_{2.5}$ emissions in Scotland for 2019.

Figure 9.7 Map of $PM_{2.5}$ Emissions in Scotland, 2019



Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2019

9.5 Scotland Ammonia (NH_3) Inventory by NFR Sector 2005 – 2019

Table 9-4 and 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.

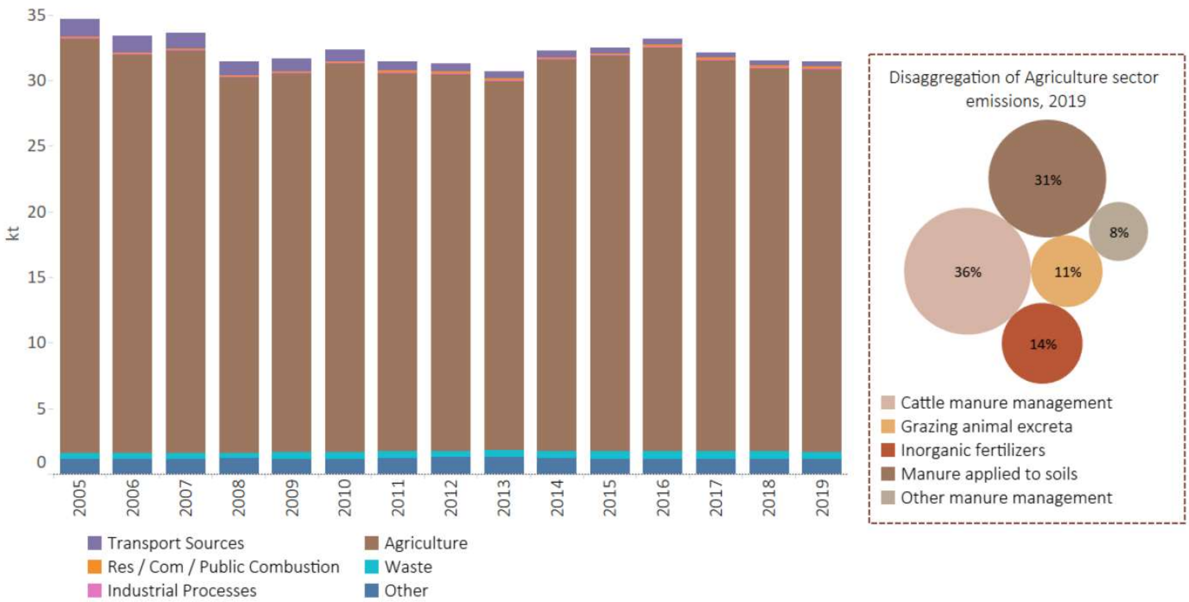
Table 9-4 Summary of Ammonia emission estimates for Scotland (2005 – 2019)

Category	2005	2006	2007	2008	2009	2010	2011
Agriculture	31.60	30.44	30.73	28.68	28.92	29.65	28.84
Industrial Processes	0.08	0.07	0.07	0.06	0.06	0.07	0.07
Transport	1.36	1.28	1.17	1.04	0.99	0.87	0.75
Waste	0.42	0.42	0.43	0.40	0.47	0.48	0.49
Other	1.94	1.92	1.92	1.98	1.97	1.99	2.06
Total:	35.40	34.12	34.31	32.17	32.41	33.06	32.21

Category	2012	2013	2014	2015	2016	2017	2018	2019
Agriculture	28.74	28.17	29.83	30.18	30.81	29.77	29.21	29.15
Industrial Processes	0.07	0.05	0.05	0.05	0.05	0.05	0.06	0.05
Transport	0.65	0.56	0.49	0.44	0.42	0.39	0.38	0.38
Waste	0.49	0.51	0.57	0.57	0.58	0.60	0.56	0.52
Other	2.11	2.11	2.02	1.96	2.00	2.02	2.03	2.04
Total:	32.06	31.40	32.96	33.19	33.85	32.82	32.24	32.14

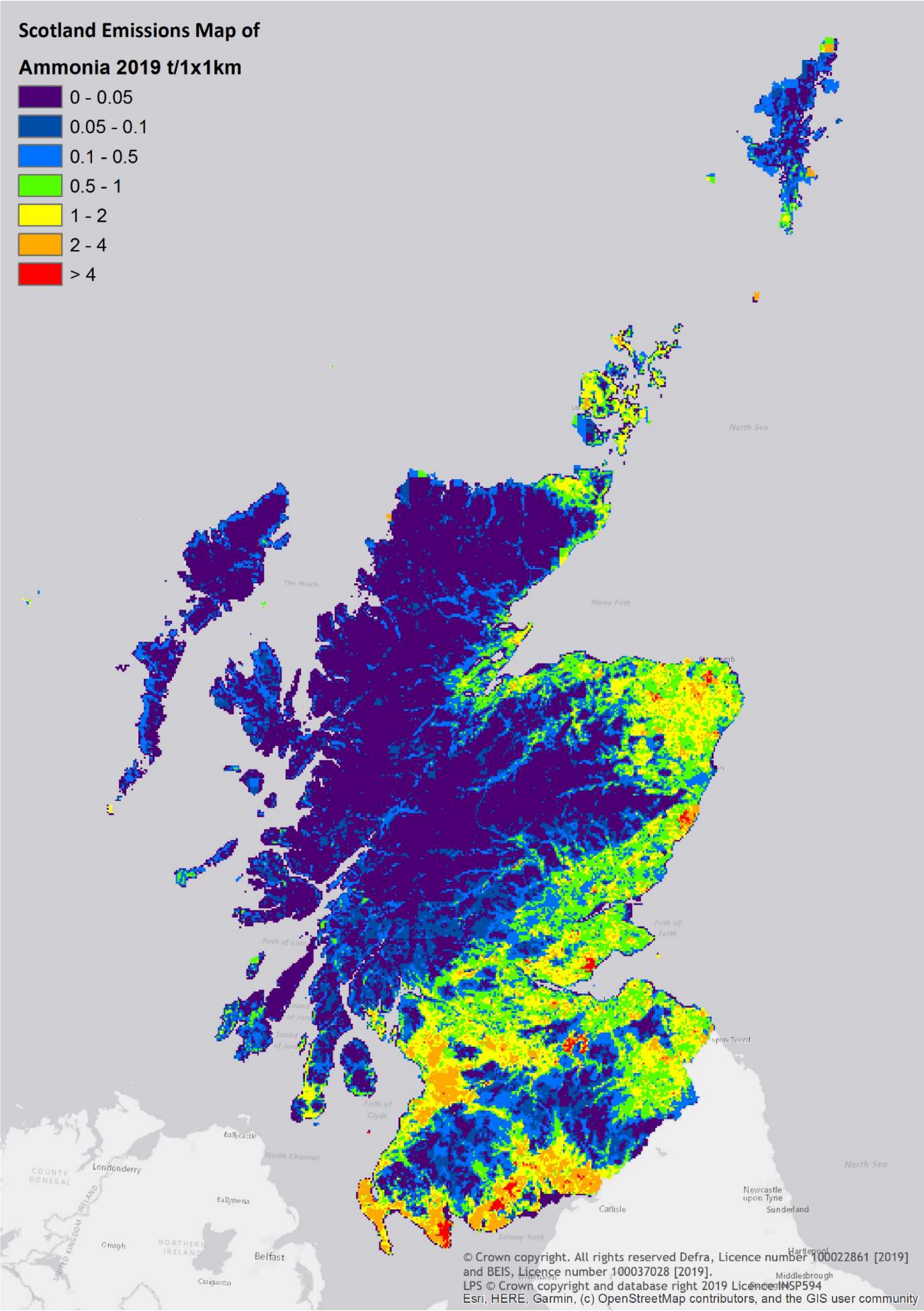
Units: kilotonnes (kt)
Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2019

Figure 9.8 Time series of Scotland's Ammonia emissions 1990-2018



Emissions of **ammonia** in Scotland were estimated to be 31kt in 2019. These emissions have declined by 9% since 2005 and accounted for 12% of the UK total in 2019. Agriculture sources have dominated the inventory throughout the time series, with cattle manure management accounting for at least 33% 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 Map of Ammonia Emissions in Scotland, 2019



Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2019

9.6 Scotland VOC Inventory by NFR Sector 2005 – 2019

Table 9-5 and figure 9.10 provides a summary of Non Methane Volatile Organic Compounds (VOC) emission estimates for Scotland by category. The detailed data are available in the report and website citied in the introduction to this chapter.

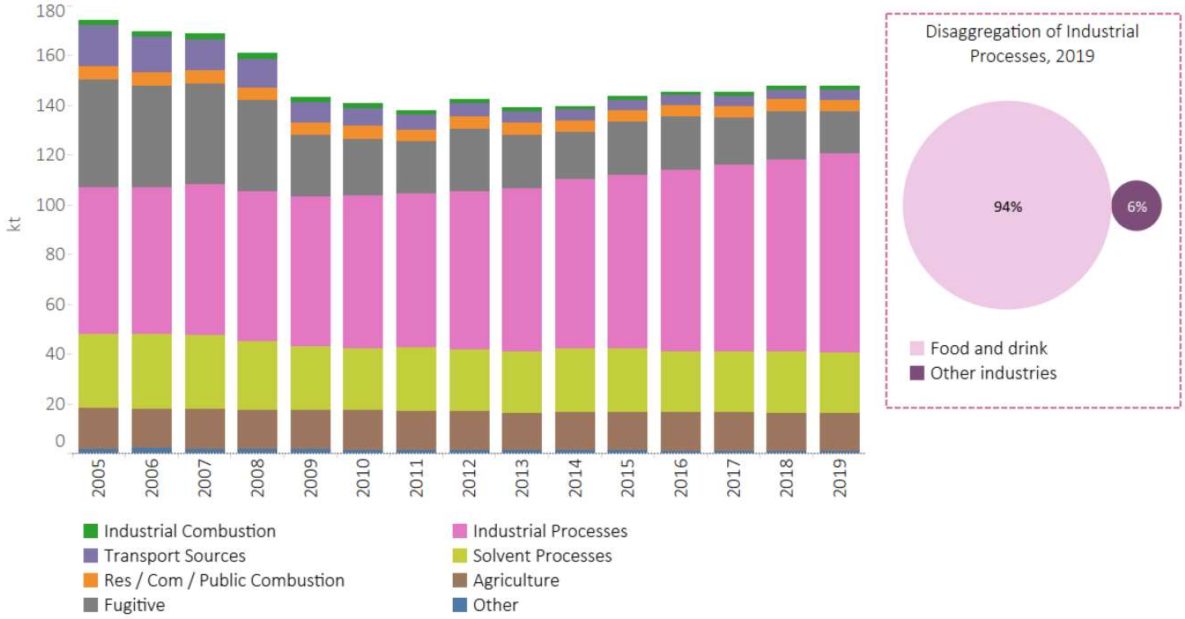
Table 9-5 Summary of NMVOC estimates for Scotland (2005 – 2019)

Category	2005	2006	2007	2008	2009	2010	2011
Agriculture	16.5	16.0	16.3	15.8	15.7	16.1	15.7
Fugitive	43.4	40.9	40.5	36.8	24.8	22.7	21.2
Industrial Combustion	2.2	2.2	2.3	2.3	1.9	1.9	1.8
Industrial Processes	58.8	59.1	60.8	60.0	60.2	61.4	61.7
Residential, Commercial & Public Sector Combustion	5.3	5.1	5.0	5.2	4.9	5.2	4.6
Solvent Processes	29.7	30.1	29.6	27.8	25.9	24.7	25.5
Transport	16.8	14.9	13.2	12.0	8.7	7.5	6.5
Other	12.0	12.1	11.8	11.7	11.7	11.6	12.0
Total:	184.7	180.4	179.4	171.5	153.7	151.2	149.0

Category	2012	2013	2014	2015	2016	2017	2018	2019
Agriculture	15.7	15.1	15.4	15.5	15.5	15.3	15.2	15.2
Fugitive	25.4	21.4	19.3	21.5	21.4	19.0	19.5	17.0
Industrial Combustion	1.8	1.4	1.5	1.7	1.5	1.7	1.7	1.7
Industrial Processes	63.3	65.8	68.0	69.9	72.9	75.2	77.2	80.1
Residential, Commercial & Public Sector Combustion	4.8	4.7	4.3	4.5	4.6	4.5	4.7	4.5
Solvent Processes	24.9	24.5	25.5	25.4	24.4	24.5	24.6	24.2
Transport	5.8	5.2	4.8	4.6	4.4	4.4	4.2	4.3
Other	11.4	11.4	11.3	11.3	11.2	11.2	11.2	11.2
Total:	153.0	149.5	150.1	154.3	155.9	155.8	158.3	158.2

Units: kilotonnes (kt)
Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2019

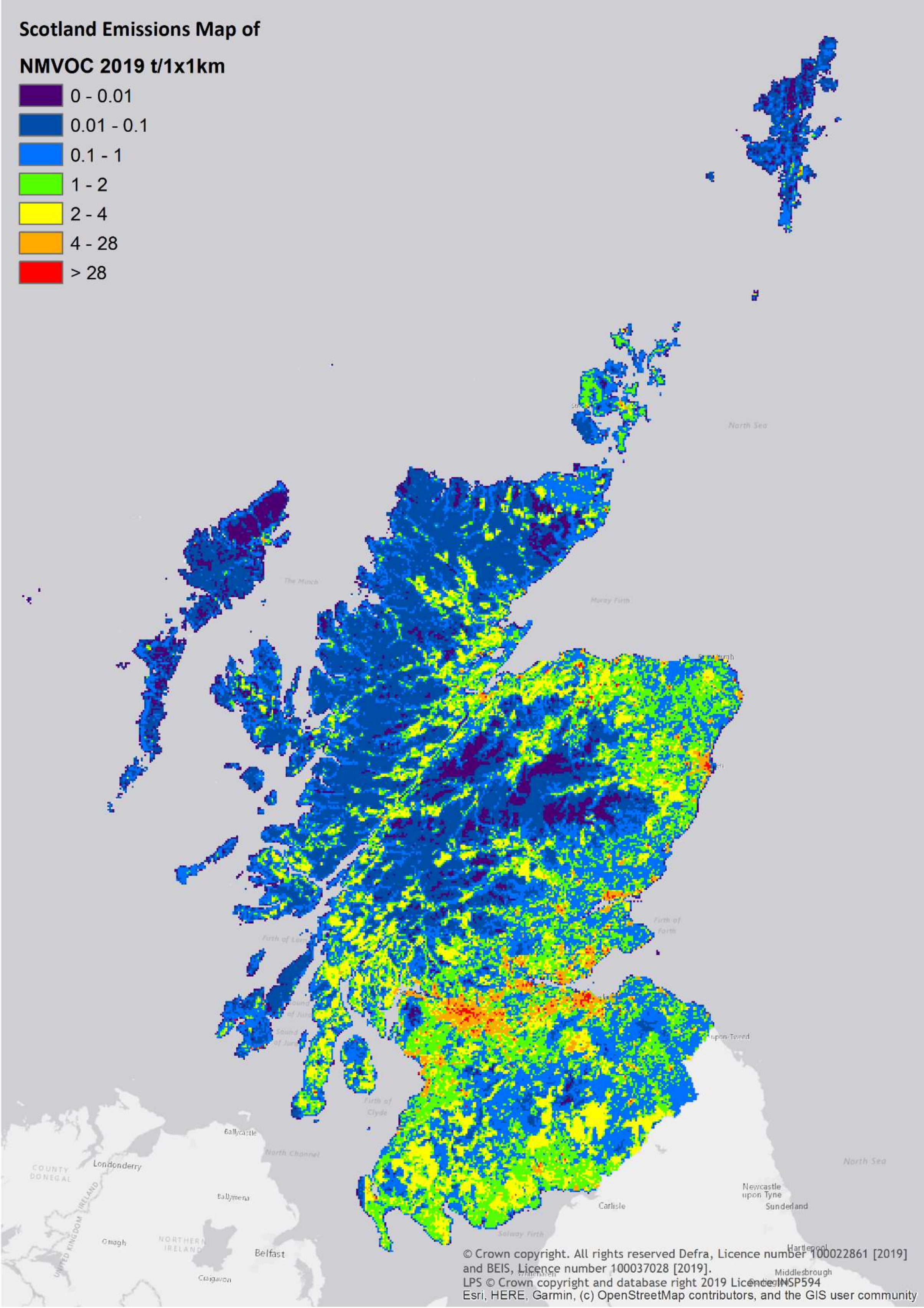
Figure 9.10 Time series of Scotland's NMVOC emissions 2005-2019



Emissions of **non-methane volatile organic compounds** in Scotland were estimated to be 148kt in 2019, representing 18% of the UK total. Emissions have declined by 15% since 2005. This reduction is a result of reductions in fugitive and transport emissions which have declined 66% and 75% since 2005, respectively. 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 94% of industrial processes emissions in 2019) have increased since 2009 due to the increased production and storage of whisky. This has resulted in a slight increase in overall emissions since 2013. In total, spirit manufacture contributed approximately 49% of NMVOC emissions in Scotland in 2019. 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 9.11 shows a map of NMVOC emissions in Scotland for 2019

Figure 9.11 Map of NMVOC Emissions in Scotland, 2018



Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2019

10 Covid-19 Lockdown and its Effect on Air Quality in Scotland 2020

In July 2021, Ricardo Energy and Environment produced a technical report for the Scottish Government which analysed the impact the Covid-19 lockdown measures had on air quality in Scotland[14]. This section provides a summary of the finding from this report. Additional analysis of the effect the Covid-19 pandemic lockdown has had on air pollution at a local authority level can be found here: http://www.scottishairquality.scot/news/reports?view=laqm.

10.1 Background

On March 23rd, 2020, a "stay at home" requirement was implemented by the UK Government in response to the Covid-19 pandemic. The lockdown continued until 29th May, at which point Scotland entered various phases of lockdown easing.

The initial lockdown and subsequent measures put in place, resulted in a large reduction in the volume of traffic on the road network in Scotland.

With a reduction in traffic, we may expect to see a change in the air quality. However, it is important to think about the best way to quantify any changes and also take into account any effects due to weather conditions, as the weather can have a large impact on pollutant levels observed.

This report focuses on changes in nitrogen oxides (NO, NO_2), ozone (O_3), and particulate matter (PM_{10} and $PM_{2.5}$), during 2020. Proven modelling techniques were used to take into account variations in weather conditions on ambient pollutant concentrations.

10.2 Statistical Models

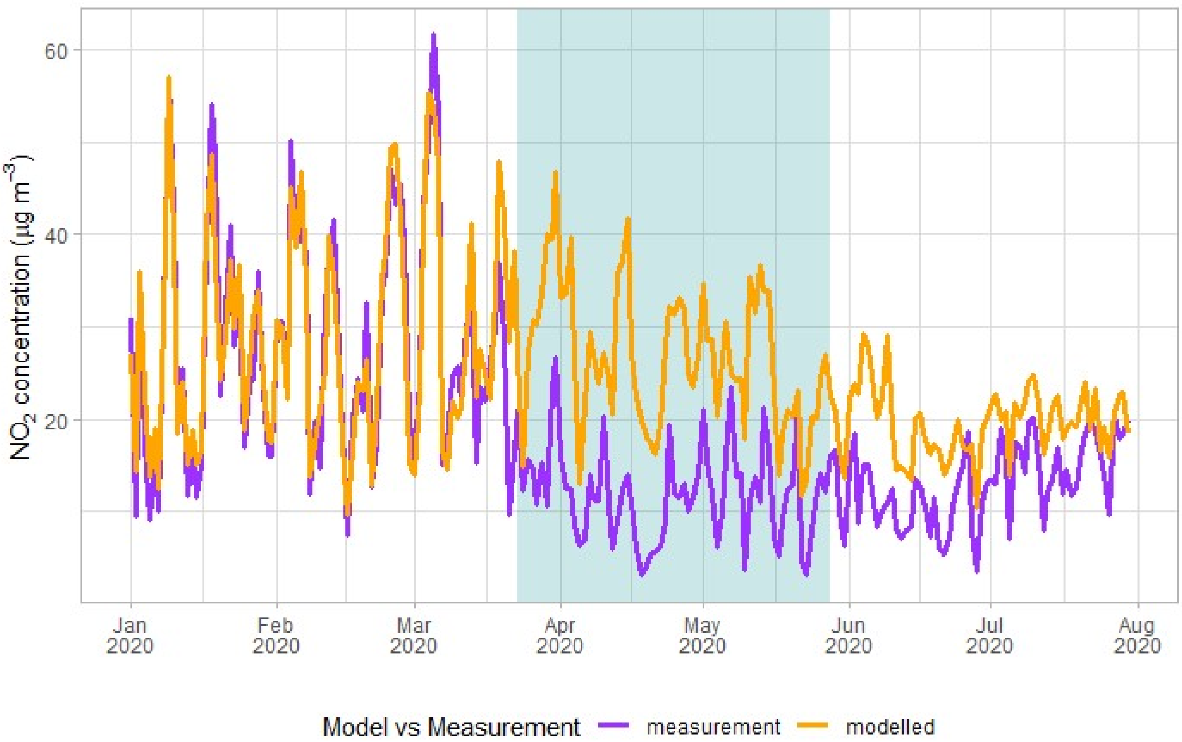
An issue when assessing changes in pollutant concentrations as a result of an intervention or mitigation measure, is determining how much is due to changes in emissions and how much is the result of variations in meteorology. One way of addressing this problem is to develop statistical models to determine what the pollutant concentrations would be if no changes were implemented, based on pollutant and weather data from previous years, i.e., the counterfactual or "business-as-usual" (BAU) scenario.

For this analysis Ricardo use the deweather (https://github.com/davidcarslaw/deweather) R package. This statistical approach uses Boosted Regression Trees to model the ambient pollutants. A model is built based on hourly concentration data from the Scottish Air Quality Database and local meteorological data from the WRF regional scale model. The model was trained over the period January 2018 to February 2020. Once a suitable model was built, it was then used to predict what the concentrations would be from March 1st 2020 onwards under a BAU scenario. The BAU pollutant concentrations can then be compared to the measured data to assess changes as a result of lockdown.

Figure 10.1 shows an example of measured and modelled (BAU) NO_2 concentrations at the Glasgow High Street monitoring station for the period 1st January to 1st August 2020. From January up until the lockdown started on 23rd March, the modelled and measured NO_2 concentrations are very similar, showing that the model is able to predict the measured concentrations before lockdown. Around 23rd March, the two lines deviate – with measured NO_2 concentrations consistently lower than BAU concentrations, which can be attributed to the reduction in NOx emissions due to reduced traffic activity in the area. As the initial lockdown ended and restrictions were eased, the two lines start to come together again.

[14] "Impact of Lockdown Measures on Scottish Air Quality in 2020",July 2021, Dr L Kramer http://www.scottishairquality.scot/news/reports?view=technical&id=653

Figure 10.1: Daily averaged measured (purple) and modelled BAU (purple) NO2 concentrations at the Glasgow High Street monitoring site from 1st January to 1st August 2020.



(The shaded region represents the period of the national lockdown between 23rd March and 28th May 2020)

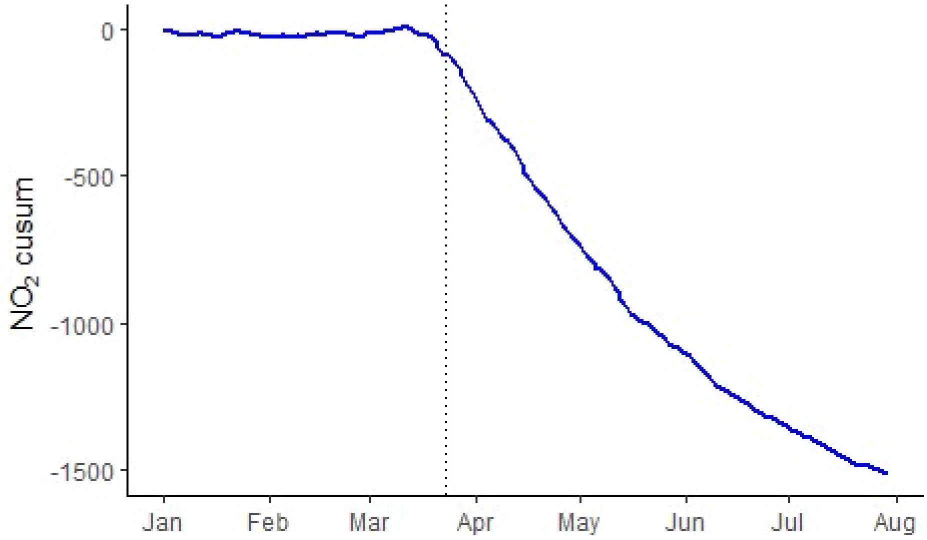
10.3 Cusum Analysis

In the example above for Glasgow High Street, the difference between measured and BAU NO_2 concentrations during lockdown is clear. However, this is not always the case, as some deviations may be small. In this report we use cumulative sum (cusum) analysis to determine how measured concentrations deviate from BAU concentrations. The cusum analysis can be useful when identifying small changes.

Figure 10.2 shows the NO_2 cusum analysis for Glasgow High Street between 1st January and 1st August 2020. Here the cusum value is the sum of the differences between measured and BAU NO_2 concentrations. So, on Jan 1st the cusum is the difference in measured and BAU NO_2 on that day, for Jan 2nd the cusum is the difference in measured and BAU NO_2 on Jan 2nd **plus** the difference on Jan1st, and so on.

In January and February, the average cusum is around zero, as the modelled and measured NO_2 levels are very similar. Around the time of the lockdown is when the differences become more apparent, and we see a negative cusum. The dashed vertical line represents the start of the first national lockdown on 23rd March 2020.

Figure 10.2: Daily NO_2 cusum for Glasgow High Street 1st January to 1st August 2020.



10.4 Changes in Pollutant Concentrations

Table provides a summary of the number and type of SAQD sites used within the analysis, for NOx, O_3, PM_{10} and $PM_{2.5}$. Only sites with data capture rates > 75% were used to ensure there was enough valid data

Table 10.1 Number of sites within the database with data to perform the modelling and analysis

Site type	NO_x	O_3	PM_{10}	$PM_{2.5}$
Rural Background	4	6	-	-
Suburban Background	2	2	-	-
Urban Background	6	2	5	4
Urban Industrial	3	-	2	1
Urban Traffic	36	-	32	21
Total	**51**	**10**	**39**	**26**

10.5 NO_2 Analysis

Figure 10.3 and Figure 10.4 show the daily averaged concentrations and cusum analysis for NO_2 concentrations for 16 sites across Scotland. The dark grey shading represents the national lockdown period between 23rd March and 29th May. The lighter grey shadings represent the periods of Phase 1 and Phase 2 easing of restrictions, ending on 10th July. The cusum analysis indicates a decrease in NO_2 concentrations when compared to BAU, at the time lockdown started on the 23rd March (represented by the dashed line). However, the sites that show the greatest decrease in NO_2 (highlighted lines in Figure 10.4) are not necessarily the same sites with the greatest decrease in NOx, due to the non-linear relationship between NOx and NO_2.

Figure 10.3 Time series of daily averaged NO_2 in 2020 for a range of monitoring sites across Scotland.

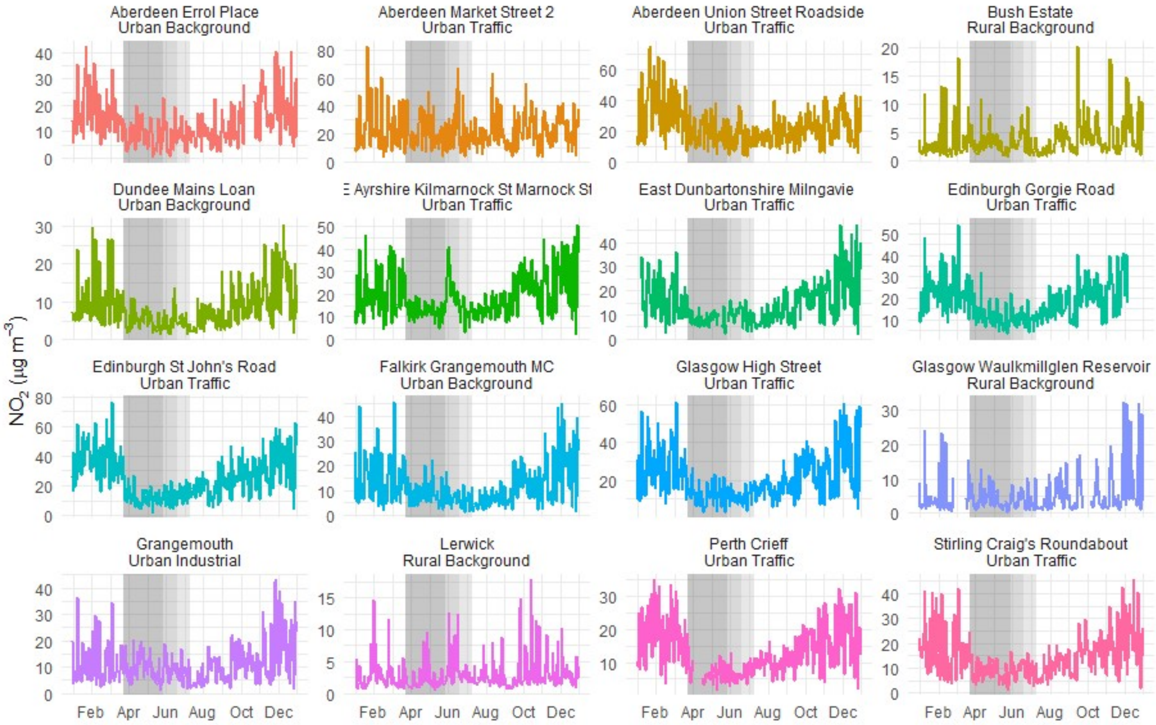
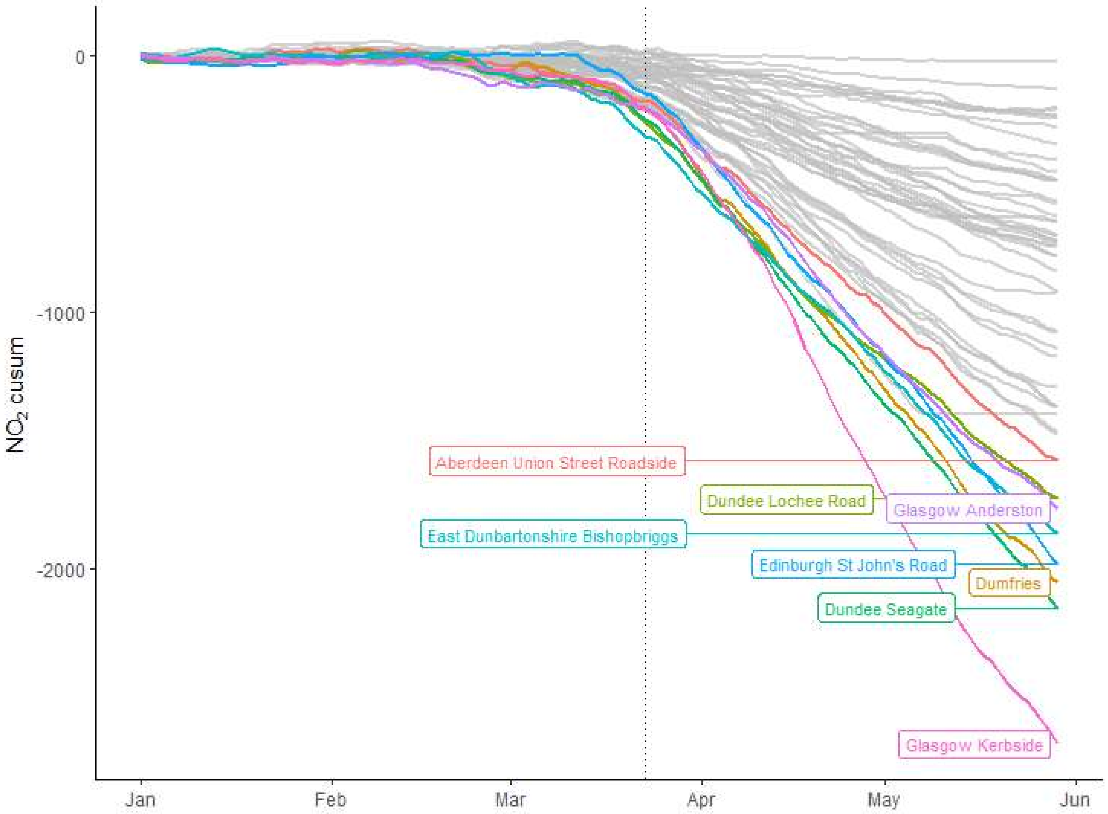
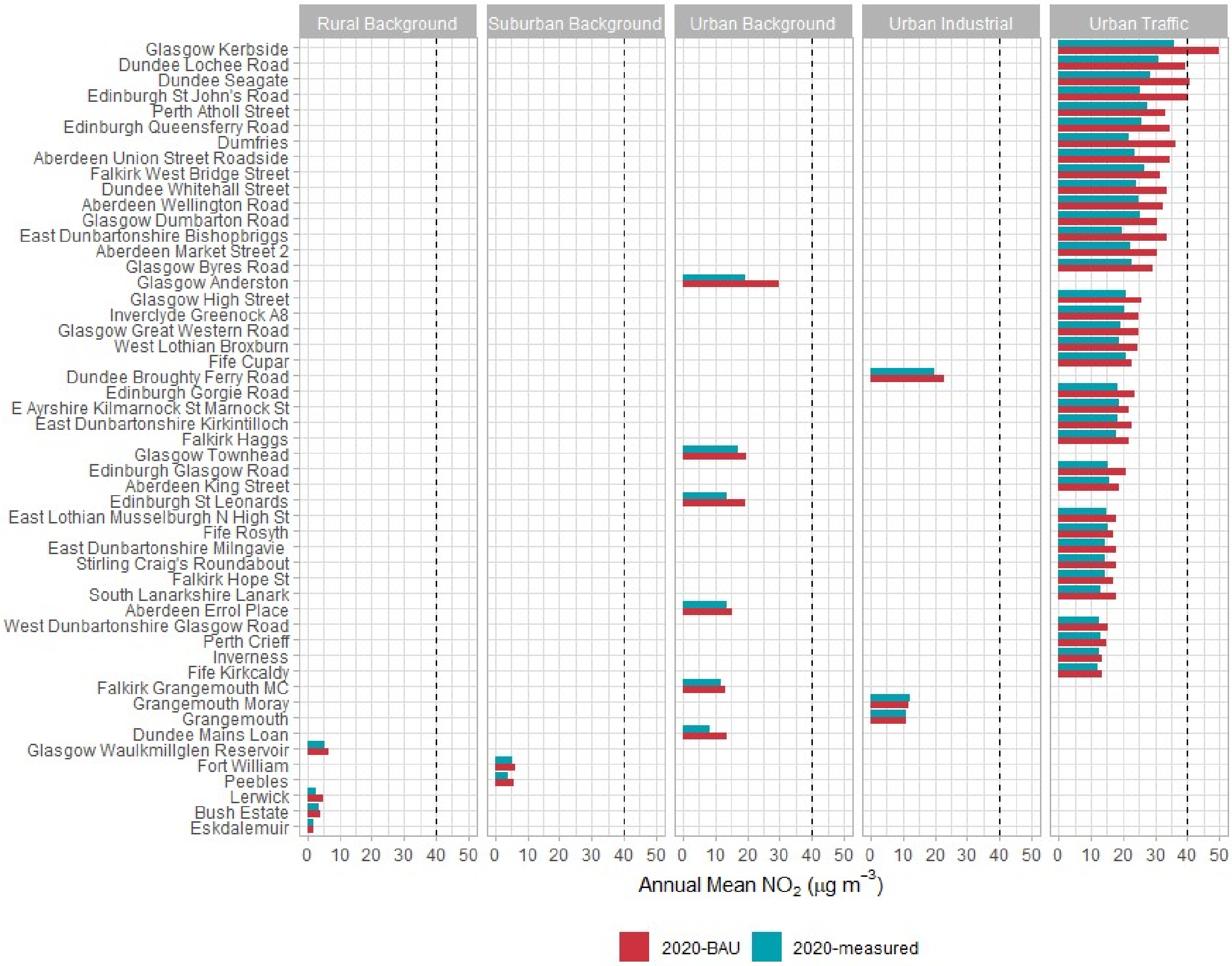


Figure 10.4 Daily NO_2 cusum analysis of measured minus BAU for sites in Scotland from 1st January to 29th May.



The annual mean measured and modelled BAU NO_2 concentrations for 2020, for each site, are shown in Figure 10.5. For most of the sites the annual mean measured NO_2 is lower than predicted by the model. Glasgow Kerbside, Dumfries, and Edinburgh St John's Road observe the greatest decrease in NO_2, when compared to BAU with the measured annual average NO_2 between 14 and 15 μgm^{-3} lower than predicted. At Glasgow Kerbside, the BAU NO_2 annual mean concentration exceeded the UK NO_2 annual mean limit of 40 μg m^{-3}. However the measured NO_2 concentration was actually much lower, at 36 μg m^{-3}, therefore no exceedance was observed at this site.

Figure 10.5 Measured and business as usual annual NO_2 concentrations by site. The dashed line represents the UK NO_2 annual mean limit of 40 μg m^{-3}.



Overall, the average NO_2 concentrations across Scotland monitoring sites were lower in 2020 when compared to BAU, by 20.5%. If we focus specifically on the lockdown period between 23rd March and 29th May, the difference between measured and modelled concentrations were even greater, with reductions of 48.8% when compared to BAU. The greatest decrease in NO_2 during lockdown, on average, were at Urban Traffic sites.

Table 10.2 Estimated percentage change in NO_2 concentrations between measured and business as usual for 2020, and for the lockdown period.

	Lockdown period	2020
Site type	NO_2(%)	NO_2 (%)
Rural Background	-35.9	-18.3
Suburban Background	-49.2	-25.2
Urban Background	-50.9	-23.5
Urban Industrial	-21.8	-3.9
Urban Traffic	-52.2	-21.3
All sites	**-48.8**	**-20.5**

10.6 Ozone Analysis

High up in the atmosphere ozone (O_3) protects us from harmful UV radiation, however closer to the ground ozone is a pollutant, which may cause irritation to eyes and breathing difficulties when present in high concentrations. High ambient ozone levels can also result in damage to vegetation.

Ambient O_3 is classified as a secondary pollutant as it is not directly emitted from sources in large quantities but formed via reactions with other pollutants, primarily volatile organic compounds (VOCs) and NOx, in the presence of sunlight. These reactions can take hours or even days to form ozone, therefore, ozone measured in one location may have been the result of emissions of VOCs and NOx hundreds or thousands of miles downwind.

One of the ways ozone is removed from the atmosphere is via reaction with nitrogen oxide (NO). NOx emissions as a result of combustion processes are primarily in the form of NO. Once emitted, NO can react rapidly with O_3 to form NO_2.

Close to roadsides where NO levels are high, O_3 levels are often very low as most of the ozone has reacted with NO shortly after the NO is emitted. Therefore, we typically observe higher O_3 concentrations in rural areas, rather than urban areas.

During the lockdown, with a reduction in traffic and decrease in NOx emissions, ozone concentrations may be expected to increase, as there is less NO available to remove it. The time series of daily averaged O_3 (Figure 10.6) does appear to show an increase in O_3 concentrations around the time of the lockdown, at some sites in Scotland. However, high O_3 concentrations are typically observed in the spring and summer in the UK, as temperatures are warmer (higher temperatures can accelerate ozone production), and more sunlight compared to winter.

The cusum analysis of measured minus BAU O_3, shown in Figure 10.7 indicates that the change in O_3 concentrations at the time of the lockdown (represented by the dashed line) varied greatly between sites. Rural background sites typically show a decrease in measured O_3 concentrations and suburban/urban background sites an increase (Table 10.3).

When looking at the whole of 2020 (Figure 10.8), on average, measured O_3 concentrations are lower than BAU, however, the estimated percentage differences are very small. The numbers in Figure 10.8 show the percentage change in measured O_3 concentration, relative to BAU.

Figure 10.6 Time series of daily averaged O_3 in 2020 monitoring sites across Scotland.

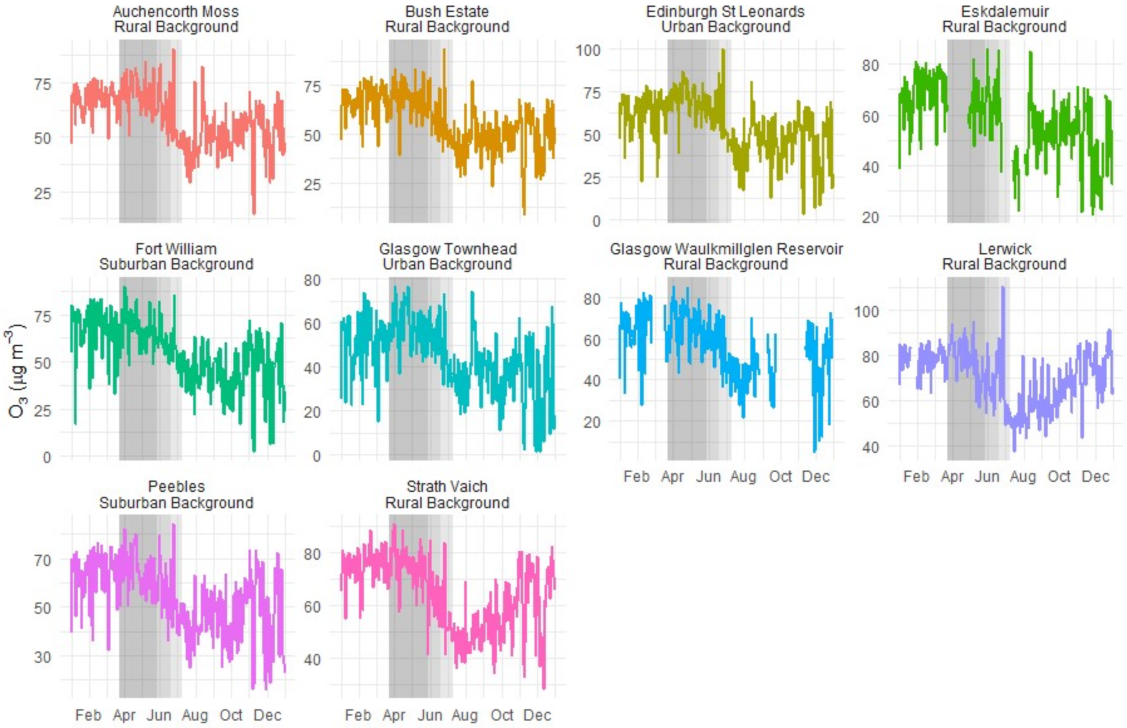


Figure 10.7 Daily O_3 cusum analysis of measured minus BAU for sites in Scotland from 1st January to 29th May.

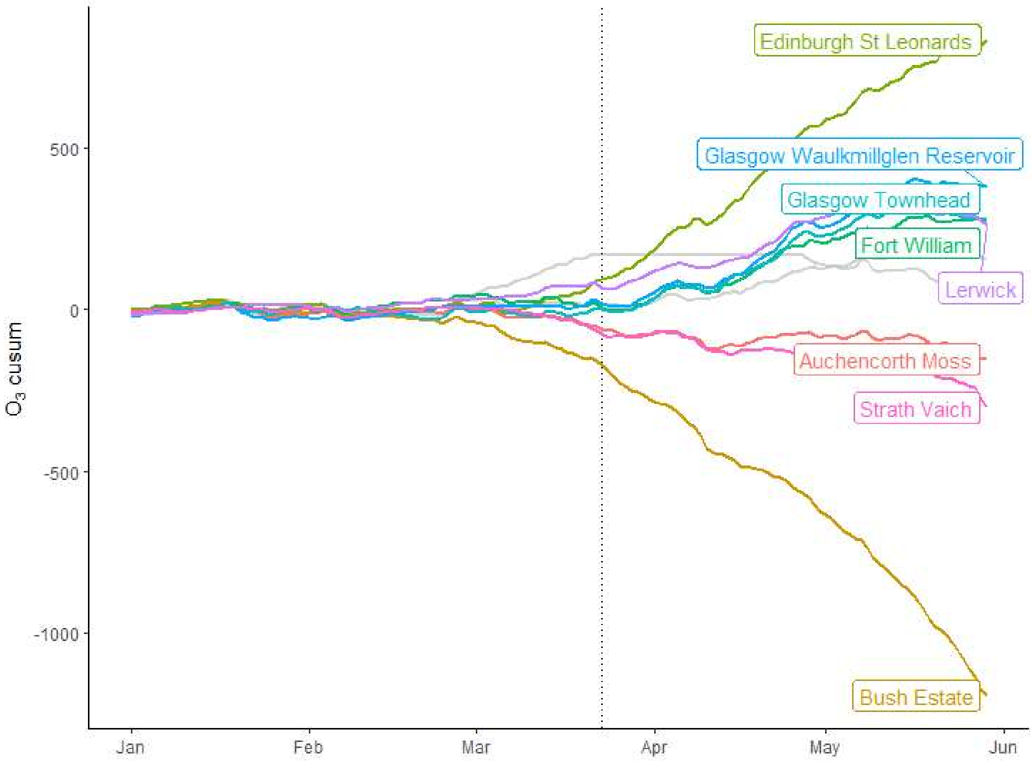
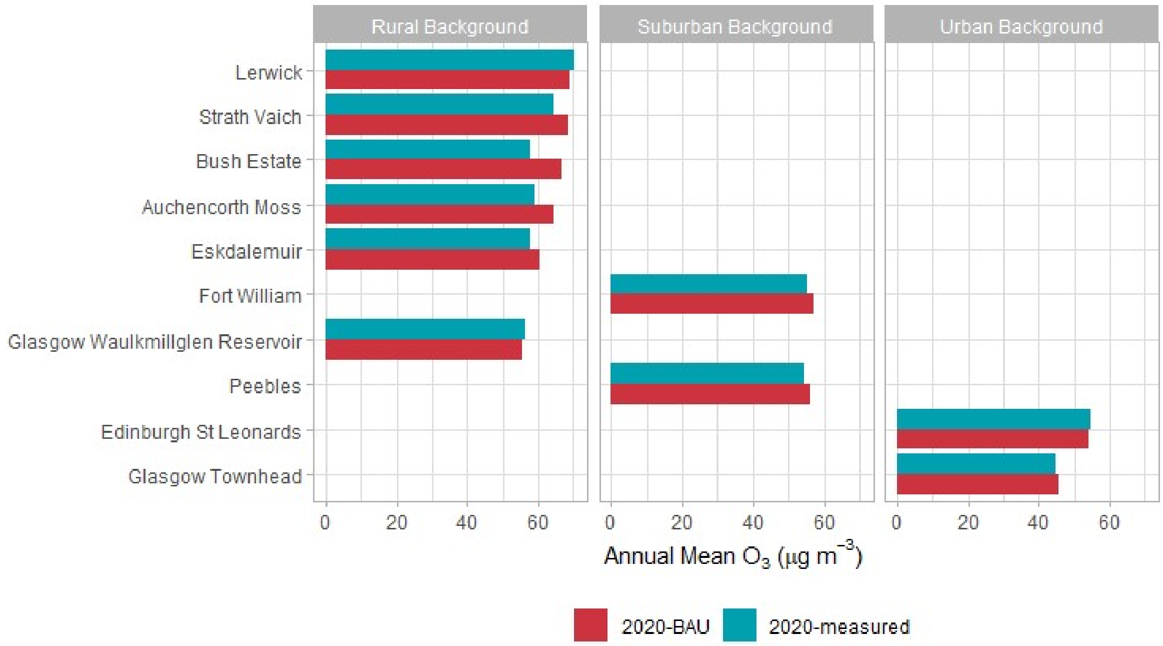


Table 10.3 Percentage change in O_3 concentrations between measured and business as usual for 2020, and for the lockdown period (23 March to 29 May).

Site type	Lockdown period O_3(%)	2020 O_3 (%)
Rural Background	-4.70	-4.84
Suburban Background	3.57	-3.24
Urban Background	11.5	-1.11
All sites	**0.20**	**-3.78**

Figure 10.8 Measured and business as usual annual O_3 concentrations by site in 2020.



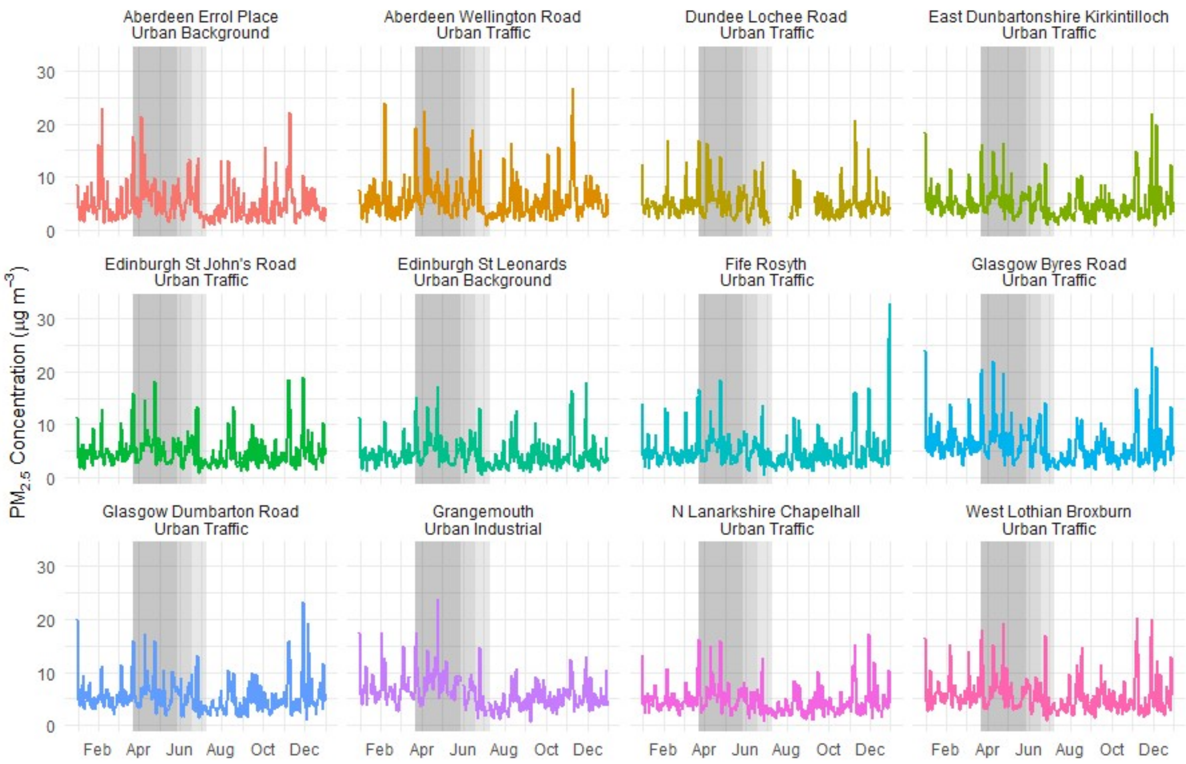
10.7 Particulate Matter (PM)

PM can come from natural sources (e.g. soil, sea salt, pollen), emitted directly from anthropogenic sources (vehicle exhausts, industrial combustion processes, domestic heating), and also formed via reactions between sulphur dioxide, NOx and other chemical species (known as secondary PM).

Secondary PM can be transported long distances, so PM in one location may be strongly influenced by the regional and continental transport of pollutants. As a result, it is much more challenging to assess changes in particulate matter as a result of lockdown, compared to NOx.

Figure 10.9 shows the daily mean $PM_{2.5}$ concentrations at various sites across Scotland. Unlike NOx, which indicated a decrease in concentrations during lockdown, the $PM_{2.5}$ actually seems to increase during this period. A springtime peak in $PM_{2.5}$ is however not uncommon, as agricultural activity over Europe increases during this period, resulting in an increase in ammonium nitrate from fertilisers, which can contribute to secondary $PM_{2.5}$.

Figure 10.9 Time series of daily averaged $PM_{2.5}$ in 2020 monitoring sites across Scotland.



10.7.1 Increment in PM

Investigating changes in PM as a result of lockdown requires careful consideration as any local change may be masked by long range transported pollutants.

Instead, we can consider the *urban increment in PM*, i.e., the PM level above the background. Subtracting the PM concentration measured at a rural background location (which is more representative of a wider area) from the PM measured at each site, should provide more information on changes in concentrations at a local level.

In the analysis presented here, concentrations measured at the Auchencorth Moss rural monitoring site were used to calculate the increment in $PM_{2.5}$ and PM_{10}.

The cusum analysis for the $PM_{2.5}$ and PM_{10} increments above background concentrations are shown in Figures 10.12 and Figure 10.13, respectively. Compared to NOx and O_3, it is less clear if changes in PM occurred when lockdown started (represented by the dashed line), and there is a large variation between sites. As previously, the Highlighted lines represent monitoring sites which displayed the largest decrease**.** However, there does appear to be some evidence of a decrease in $PM_{2.5}$ and PM_{10} (above background levels) at some sites.

Across all sites, the change in absolute PM when compared to BAU is very small over the lockdown period (Table 10.4), with an average decrease of 1.5 μgm^{-3} in PM_{10} and 0.59 μgm^{-3} in $PM_{2.5}$. These values are also more uncertain than for NOx and O_3, as the choice of the background site used for calculating the PM increment can have a large impact on the estimated PM increment.

Figure 10.12 Cusum analysis of daily averaged measured minus BAU increment in $PM_{2.5}$ for sites in Scotland from 1st January to 29th May.

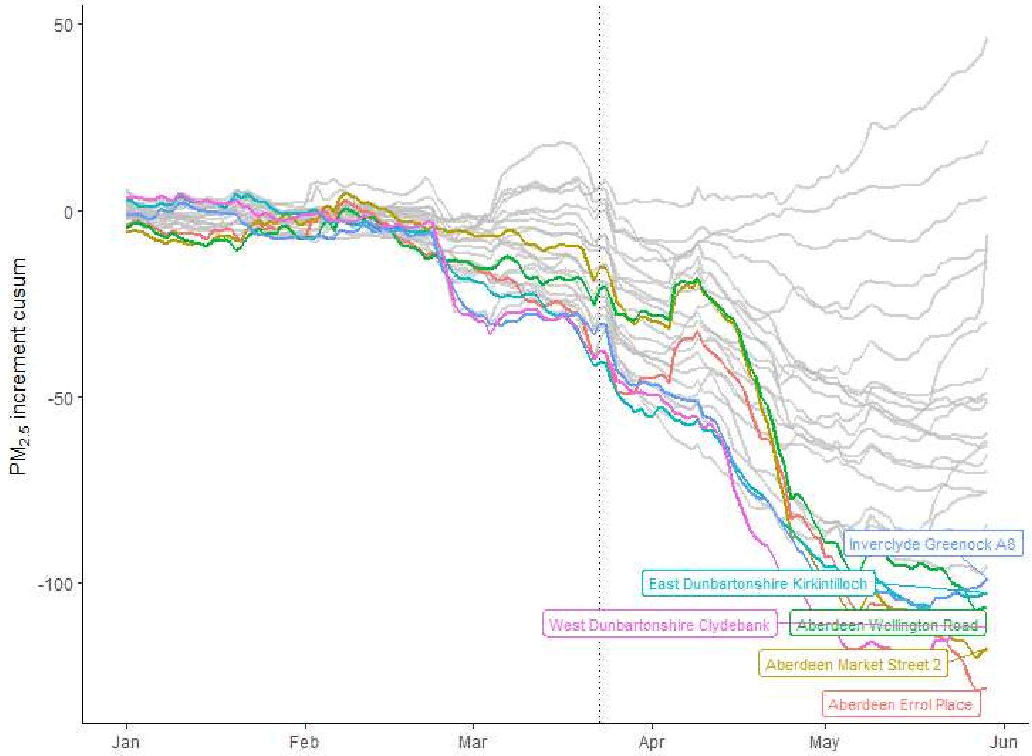


Figure 10.13 Cusum analysis of daily averaged measured minus BAU increment in PM_{10} for sites in Scotland from 1st January to 29th May.

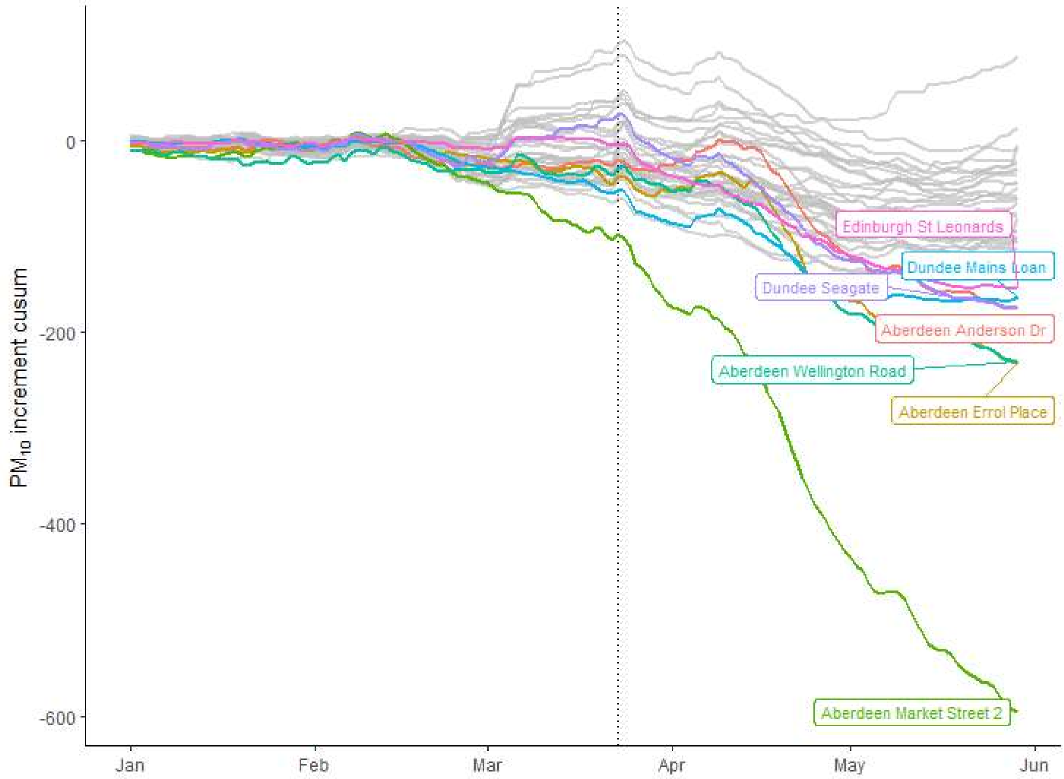


Table 10.4 Change in $PM_{2.5}$ and PM_{10} increment above background concentrations with respect to business as usual, for the lockdown period (23 March to 29 May)

Site type	Lockdown period	
	PM_{10} (μgm^{-3})	$PM_{2.5}$ (μgm^{-3})
Urban Background	-1.8	-0.92
Urban Industrial	-1.3	-0.26
Urban Traffic	-1.5	-0.54
All sites	**-1.5**	**-0.59**

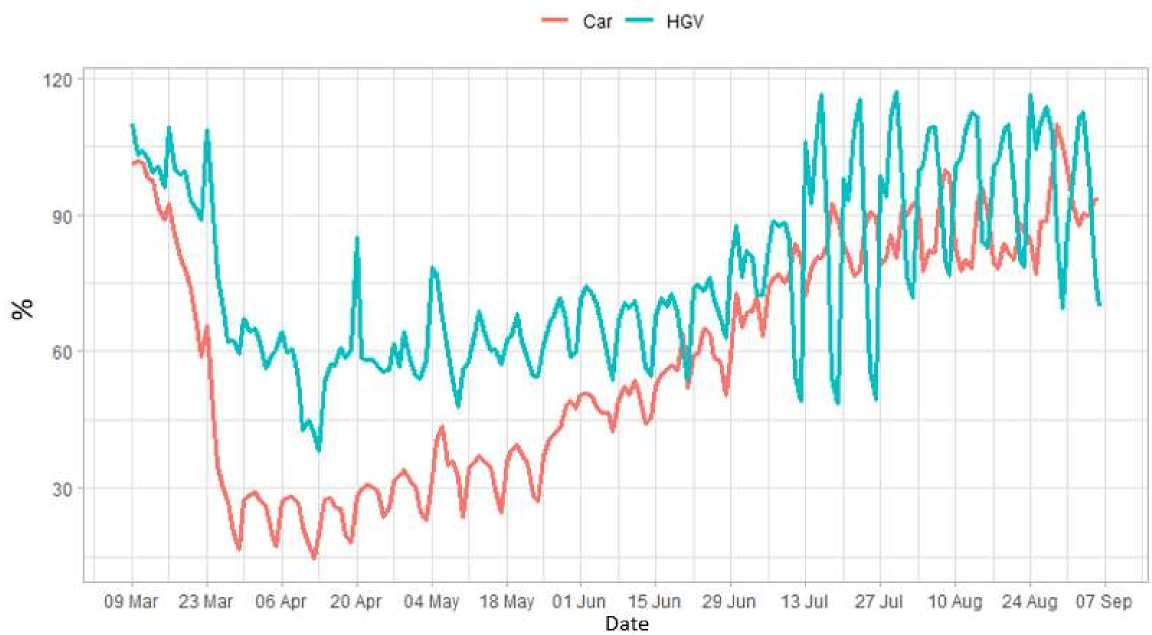
10.8 Change in Traffic Flow during 2020

The main source of NOx emissions in Scotland is the transport sector, accounting for 47.7% of total NOx emissions in 2018. Transport sources also contributed 15.3% of PM_{10} emissions and 20.1% of $PM_{2.5}$ emissions in Scotland in 2018[15].

Transport Scotland published a report on transport trends for the first 6 months of the pandemic [4]. **Figure** shows the national daily trend in Car and HGV vehicles for the period 9th March to 6th September 2020. The values given are based on the equivalent day in 2019, i.e., a value of 100 indicates the same level of traffic for the transport mode, on the same day in 2019.

As expected, there was a sharp decrease in the number of cars on the roads around the time social distancing was advised on 16th March and reaching a minimum towards the end of March.

Figure 10.14: Trend in daily car and Heavy Goods Vehicles (HGVs) compared to 2019



(equivalent day in 2019 = 100). Source: Transport Scotland. Contains public sector information licensed under the Open Government Licence v3.0[16].

[15] Air Pollutant Inventories for England, Scotland, Wales, and Northern Ireland: 1990-2018 https://uk-air.defra.gov.uk/assets/documents/reports/cat09/2010220959_DA_Air_Pollutant_Inventories_1990-2018_v1.2.pdf

[16] http://www.nationalarchives.gov.uk/doc/open-government-licence/version/3/

NOx concentrations in areas with high traffic volumes typically show a pattern associated with traffic emissions, i.e., high levels during morning and evening rush hour periods. With the large reduction in traffic numbers in March and April we would expect to see a change in this diurnal pattern. Figure 10.15 and Figure 10.16 show diurnal profiles of NOx adjusted for variations in local meteorology (windspeed, wind direction and air temperature) at two urban traffic monitoring sites - Glasgow Kerbside (Hope Street) and Edinburgh St Johns Road, before and after lockdown. In both cases the profile before lockdown (green line) is as expected – with peaks in NOx in the morning and evening. During lockdown (pink line), the diurnal profile is much lower overall, and the evening peak has all but disappeared. The observed change in the diurnal profile provides some indication that the reduction in NOx is consistent with a reduction in traffic emissions.

Figure 10.15 Meteorologically adjusted NOx for the periods before and after lockdown for Glasgow Kerbside (Hope Street) for Weekdays, Saturday, and Sunday.

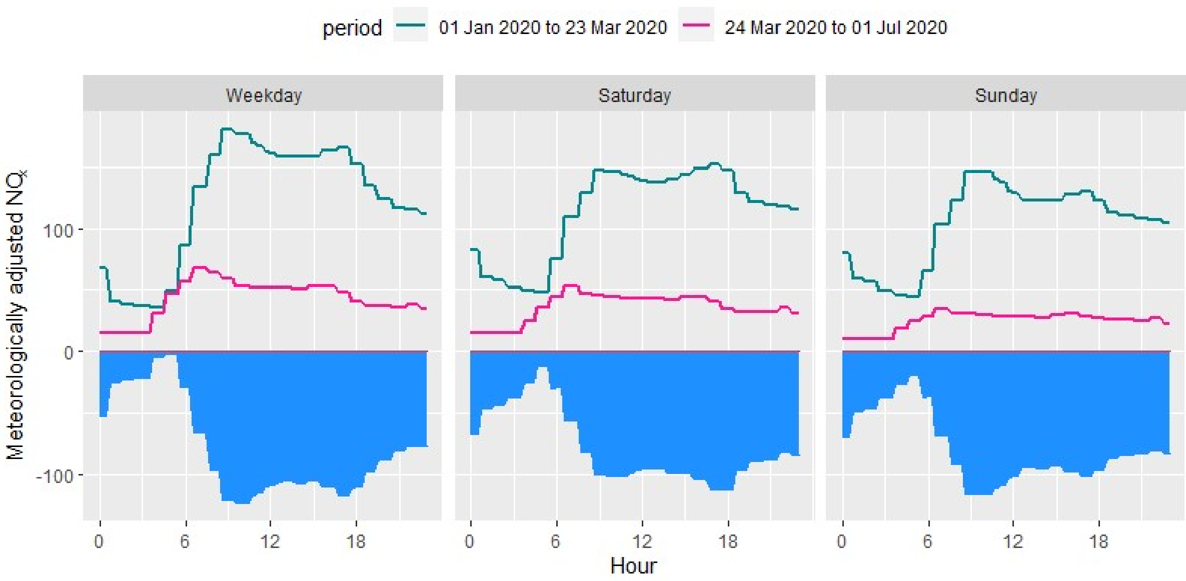
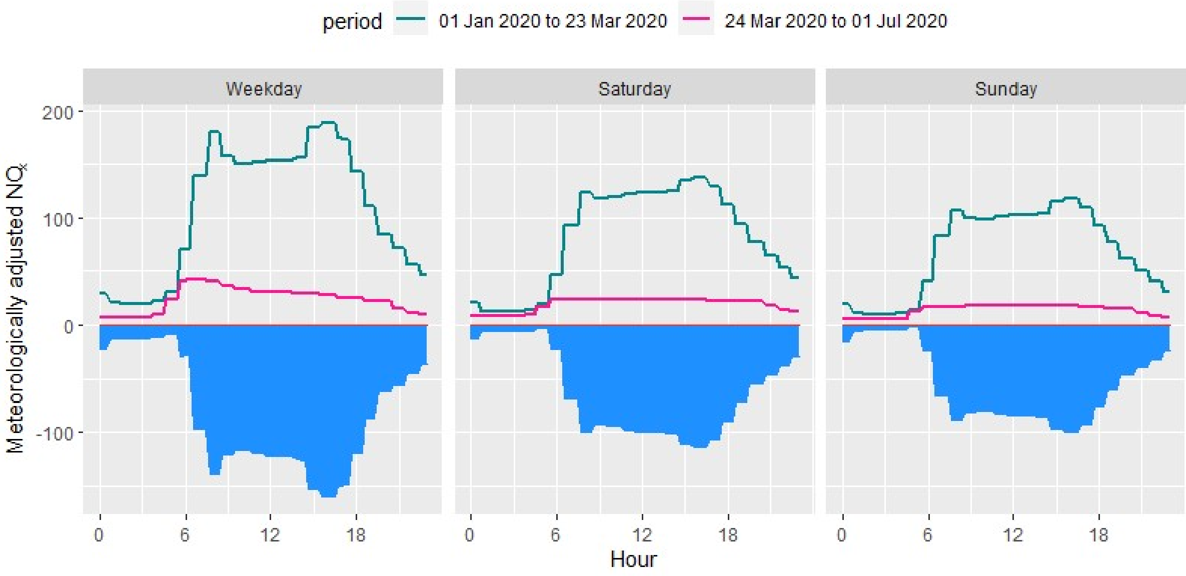


Figure 10.16 Meteorologically adjusted NOx for the periods before and after lockdown for Edinburgh St Johns road for Weekdays, Saturday, and Sunday.



11 Summary and Conclusions

This report brings together all the SAQD data for calendar year 2020 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 also includes a section on the effects of the Covid-19 pandemic on air quality in Scotland.

Legislation and Policy

In October 2020 Scottish Government published a consultation on a draft new air quality strategy[17]. Following the consultation, in July 2021, accompanied by a Delivery Plan, and replacing "Cleaner Air for Scotland – The Road to a Healthier Future", Scottish Government published Scotland's second air quality strategy called "Cleaner Air for Scotland 2 – Towards a Better Place for Everyone" (CAFS2). CAFS 2 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 100 automatic monitoring sites throughout Scotland are available in the database for all or part of 2019. All automatic data maintained within the Scottish database are subject to the same QA/QC procedures as at the national network air quality monitoring stations within the UK Automatic Urban and Rural Network. This ensures that all data in the database are quality assured and traceable to UK national calibration standards for the various pollutants.

Analysis shows that data capture rates since 2008 have continued to improve, year on year, for both nitrogen dioxide (NO_2) and Particulate Matter (PM_{10}). A significant improvement in PM_{10} data capture since between 2016 has been attributed to a change in analyser used within the network.

In 2020, no automatic monitoring sites exceeded the annual mean objective for NO_2. At the time of writing this report not all diffusion tube data for 2020 had been published. In 2019, 59 diffusion tube sites exceeded the NO_2 annual mean objective, 15 fewer than the previous year.

In 2020, no automatic monitoring sites measuring PM_{10} and $PM_{2.5}$ measured exceedances for any of the Scottish Air Quality objectives

The pattern of measured concentrations in 2020 for both NO_2 and PM is not consistent with previous years. A significant decline in concentrations, especially NO_2, is attributed to Covid-19 pandemic lockdown.

In 2020, the Air Quality Strategy objective for ozone was not exceeded at any site. This is a significant change from the previous year when seven sites exceed the objective.

In 2020, no exceedances of AQS Strategy objectives were observed for the pollutants $PM_{2.5}$, SO_2, CO, benzene, 1,3-butadiene and benzo(a)pyrene.

[17] https://www.gov.scot/publications/cleaner-air-scotland-2-draft-air-quality-strategy-consultation/

Air Quality Mapping of Scotland

For NO_2, there were no modelled exceedances of the Scottish annual mean objective of 40 µg m^{-3} at background locations. Exceedances of the annual mean NO_2 objective were modelled at roadside locations in four of the six zones and agglomerations in Scotland. Exceedances of the annual mean NO_2 objective at roadside locations were modelled at 52 road links (102.7 km of road) in the Glasgow Urban Area and at 20 road links (45 km of road) in Central Scotland. In the Edinburgh Urban Area seven road links (11.0 km of road) exceedances were modelled and in the North East Scotland zone only four roads had an exceedance (8.5 km of road). No roadside exceedances of the annual mean NO_2 objective were modelled in the more rural zones and agglomerations of Scotland.

There were no modelled exceedances of the Scottish annual mean PM_{10} objective of 18 µg m^{-3} at background locations. Six road links (19.3 km of road) were however identified as exceeding in the Glasgow Urban Area and Central Scotland.

Air Quality Trends for Scotland

Data held within the database covering many years have been used to assess possible trends in air pollution throughout Scotland. Air quality trends have been examined on the basis of individual monitoring sites, and subsets of long-running sites, rather than the composite dataset.

NO_2

Trend Analysis of nitrogen dioxide concentrations at Scotland's five long-running urban non-roadside sites suggests that NO_2 concentrations are displaying highly significant negative trends. More recent years analysis (five years) show a less consistent trend across the country with one site showing increasing trends contradicting the perception that NO_2 concentrations are decreasing at all urban background sites

Nitrogen dioxide concentrations at Scotland's three long-running rural sites showed decreasing trends.

Scotland has a large number of urban traffic monitoring sites monitoring NO_2, of which 30 have now been operating for at least 10 years. This trend analysis therefore focused on eight of these sites that have operated for 10 years and have reported exceedances of the AQS objective in recent years. As with the previous report in this series, all eight sites show highly significant decreasing trends

Examination of trends at the same eight sites over the most recent five complete years (2016 to 2020) indicates that the patterns are very similar to the 10-year trends.

PM_{10}

PM_{10} at Scotland's eight long-running urban/Industrial background sites showed highly significant negative trend. PM_{10} at Scotland's eight long-running urban traffic sites showed statistically highly significant decreasing trends at all sites.

Examination of trends in PM_{10} at the same eight sites over the most recent five years indicates that, at some of these, the decreasing trends have continued but at others they have weakened or levelled off.

$PM_{2.5}$

At the time of writing this report there are 76 sites monitoring $PM_{2.5}$ in Scotland. However, the vast majority of these sites started monitoring in the last five years with the introduction of the $PM_{2.5}$ objective and the requirement for local authorities to measure the pollutant. By the end of 2020 there were four sites with 10 consecutive years of $PM_{2.5}$ data. Aberdeen Errol Place, Edinburgh St Leonards, and Grangemouth sites show slight but highly statistically significant decreasing trends for $PM_{2.5}$. Contrary to this, the rural site Auchencorth Moss showed no obvious trend. At the end of 2020 there were nine sites with five years' worth of data. Four sites have decreasing trends with ranging levels of statistical significancy. Another four sites, though decreasing, have no real identifiable statistically significant trend. South Lanarkshire Uddingston has an increasing trend though not statistically significant.

Ozone

Ozone has been measured at three rural sites in Scotland for 30 years. All three sites showed small increasing trends, highly statistically significant at two of the three sites. Ozone has been measured for the past 10 years at six rural sites. In contrast to the 30-year trends, the ten-year trends were less consistent. Five of the sites showed increasing trends with varying levels of statistical significance. The remaining site showed no real trend.

10 year trend analysis of ozone concentrations showed increasing trends (at varying statistical significance) at all three Scottish urban background sites.

Additional Trend Analysis

Additional trend analysis was carried out at four sites located within the four major cities in Scotland. This analysis carried out using Openair compared 2020 data with data from the previous 10 years using a variety of analytical techniques.

Emissions of Pollution Species

Scotland NOx emissions have declined by 53% since 2005 and were estimated to be 85kt in 2019 representing 10% of the UK total. This decline is driven by the continued introduction of tighter vehicle emissions standards over the last decade. Since 2008, emissions from passenger cars have further decreased. This has been mainly driven by improvements in catalyst repair rates resulting from the introduction of regulations controlling the sale and installation of replacement catalytic converters and particle filters for light duty vehicles. However, the increasing number of diesel cars partly offsets these emissions reductions, because diesel cars emit higher NOx relative to their petrol counterparts (88% of 2019 passenger car emissions is due to diesel cars).

Emissions of PM_{10} have declined by 30% since 2005 and in 2019 and were estimated to be 14kt (8% of the UK total). Emissions from energy industries (and its movement away from Coal use) and transport sources (the fleet increasing compliance with Euro emission standards) have had the most notable impact on the trend. In 2019, 79% 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. Emissions levels since 2015 have plateau and slightly increased

Emissions of $PM_{2.5}$ have declined by 33% since 2005 and in 2019 were estimated to be 9kt (8% of the UK total). For $PM_{2.5}$, the residential, commercial and public sector combustion category accounts for 43% of 2019 emissions. The decline in emissions has significantly reduced over the past few years with no significant decrease since 2014. One of the reasons for this slowing has been attributed to the increase in emissions from the residential sector and in particular the combustion of wood. Emissions from the residential sector have increased by 50% since 2005.

Emissions of ammonia have declined by only 9% since 2005 and were estimated to be 31kt (12% 0f the UK total) in 2019. Agriculture sources dominate throughout the time-series. The trend in NH3 emissions has been largely driven by decreasing animal numbers and a decline in fertiliser use, which have tended to decrease emissions across the time-series. 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.

Emissions of Non-Methane Volatile Organic Compounds have declined 15% since 2005 and were estimated to be 148kt in 2019 (18% of the UK total). This reduction is a result of reductions in fugitive and transport emissions which have declined 66% and 75% since 2005, respectively. There has been an increasing trend in NMVOCs since 2009. This has been attributed to the increase emissions from the food and drink sector specifically the storage and production of whisky (49% of emissions in 2019).

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

Cusum analysis carried out indicates a decrease in NO_2 concentrations when compared to Business As Usual (BAU) modelled results, at the time lockdown started on the 23rd March 2020. For most of the monitoring sites the annual mean measured NO_2 was lower than predicted by the model. Glasgow Kerbside, Dumfries, and Edinburgh St John's Road observe the greatest decrease in NO_2, when compared to BAU with the measured annual average NO_2 between 14 and 15 μgm^{-3} lower than predicted. Overall, the average NO_2 concentrations across Scotland monitoring sites were lower in 2020 when compared to BAU, by 20.5%. When focused specifically on the lockdown period between 23rd March and 29th May, the difference between measured and modelled concentrations were even greater, with reductions of 48.8% when compared to BAU. The greatest decrease in NO_2 during lockdown, on average, were at Urban Traffic sites. NOx Diurnal analysis at two urban traffic sites shows that during lockdown the concentration profile is much lower overall, and the evening peaks normally seen all but disappeared. The observed change in the diurnal profile provides evidence that the reduction in NOx is consistent with a reduction in traffic emissions.

Compared to NOx it is less clear if changes in PM occurred when lockdown started, with large variation between sites.

Across all sites, the change in absolute PM when compared to BAU is very small over the lockdown period (Table 10.4), with an average decrease of 1.5 μgm^{-3} in PM_{10} and 0.59 μgm^{-3} in $PM_{2.5}$. These values are also more uncertain than for NOx, as the choice of the background site used for calculating the PM increment can have a large impact on the estimated PM increment.

Appendices

Appendix 1: Site Audit and Data Ratification Procedures
Appendix 2: Site Audits and Data ratification undertaken during 2020
Appendix 3: Process used for VCM Correcting SAQD TEOM Data
Appendix 4: National Monitoring Networks in Scotland 2020

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 many years' experience of our staff, 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 – Site Audited, and Data ratification undertaken during 2020

Table A2.1 Air quality site intercalibration and audits conducted during 2020

Site Name	Winter 2019/20	Summer 2020	Site Name	Winter 2019/20	Summer 2020
Aberdeen Anderson Dr	✓	✓	Glasgow Dumbarton Road	✓	✓
Aberdeen Errol Place	✓	✓	Glasgow Kerbside	✓	✓
Aberdeen King Street	✓	✓	Glasgow Great Western Road	✓	✓
Aberdeen Market Street 2	✓	✓	Glasgow High Street	✓	✓
Aberdeen Union Street Roadside~	✓	✓	Glasgow Nithsdale Road	✓	✓
Aberdeen Wellington Road	✓	✓	Glasgow Townhead	✓	✓
Alloa A907	✓	✓	Glasgow Waulkmillglen Reservoir	✓	✓
Angus Forfar Glamis Road	✓	✓	Grangemouth	✓	✓
Auchencorth Moss	✓	✓	Grangemouth Moray~	✓	✓
Bush Estate	✓	✓	Grangemouth Moray Scot Gov~	✓	✓
Dumbarton Roadside	✓	✓	Inverclyde Greenock A8	✓	✓
Dumfries	✓	✓	Inverness*	✓	✓
Dundee Broughty Ferry Road	✓	✓	Inverness Academy Street	✓	✓
Dundee Lochee Road	✓	✓	Inverness Academy Street 1st Floor	✓	✓
Dundee Mains Loan	✓	✓	Lerwick~	✓	✓
Dundee Meadowside	✓	✓	N Lanarkshire Airdrie Kenilworth Dr	✓	✓
Dundee Seagate	✓	✓	N Lanarkshire Chapelhall	✓	✓
Dundee Whitehall Street	✓	✓	N Lanarkshire Coatbridge Sunnyside Rd	✓	✓
East Ayrshire Kilmarnock St Marnock St	✓	✓	N Lanarkshire Coatbridge Whifflet	✓	✓
East Dunbartonshire Bearsden	✓	✓	N Lanarkshire Croy	✓	✓
East Dunbartonshire Bishopbriggs	✓	✓	N Lanarkshire Kirkshaws	✓	✓
East Dunbartonshire Kirkintilloch	✓	✓	N Lanarkshire Motherwell	✓	✓
East Dunbartonshire Milngavie	✓	✓	N Lanarkshire Motherwell Adele Street	-	✓
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 Crieff	✓	✓
Edinburgh St John's Road	✓	✓	Perth High Street	✓	✓
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	✓	✓

Site Name	Winter 2019/20	Summer 2020	Site Name	Winter 2019/20	Summer 2020
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	✓	✓
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	✓	✓

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.

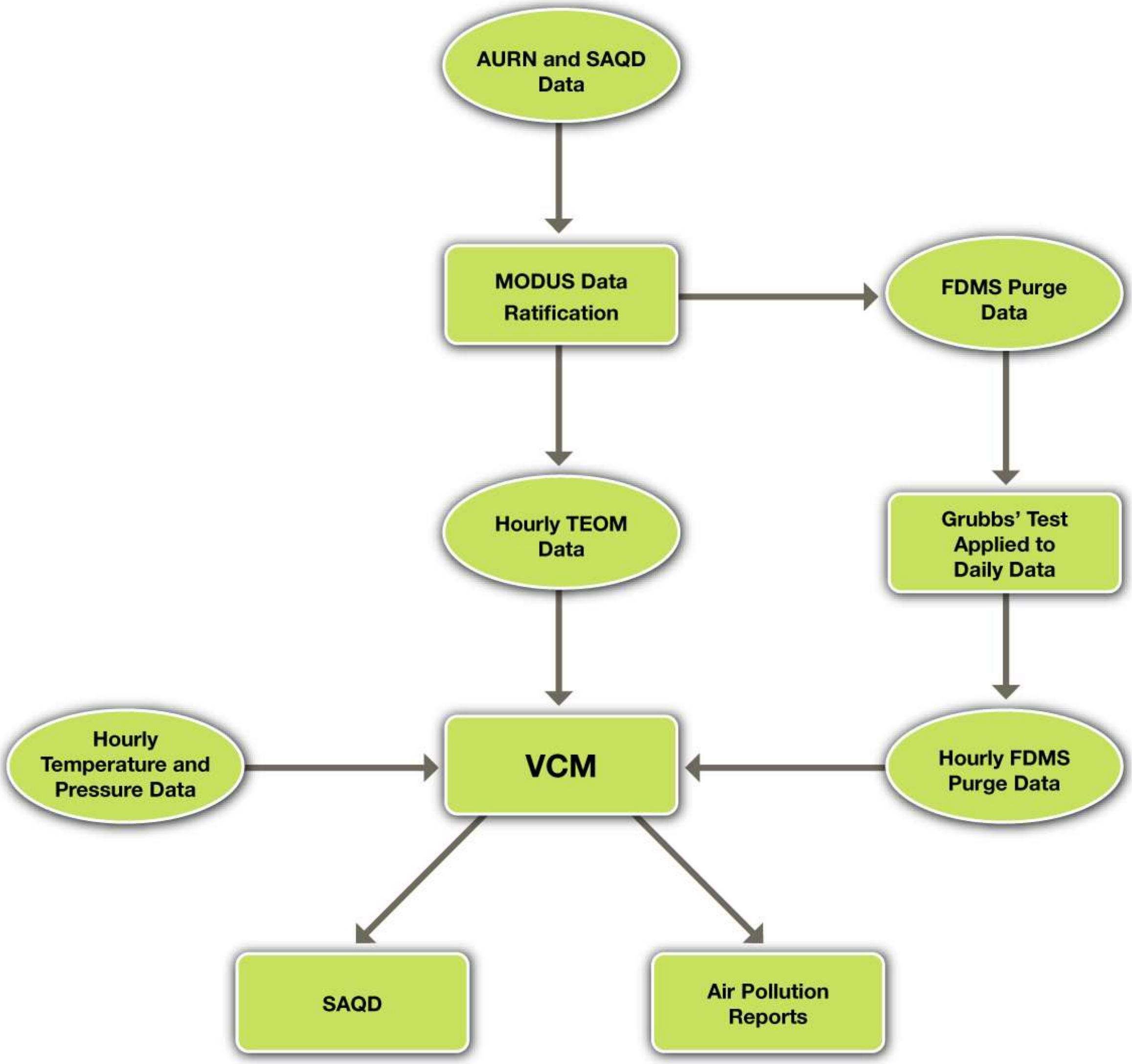
Table A2.2 Data ratification undertaken during 2020

Site Name	Q1	Q2	Q3	Q4	Site Name	Q1	Q2	Q3	Q4
Aberdeen Anderson Dr	✓	✓	✓	✓	**Glasgow Kerbside**	✓	✓	✓	✓
Aberdeen Errol Place	✓	✓	✓	✓	**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**	✓	✓	✓	✓
Dumfries	✓	✓	✓	✓	**Inverness***	✓	✓	✓	✓
Dundee Broughty Ferry Road	✓	✓	✓	✓	**Inverness Academy Street**	✓	✓	✓	✓
Dundee Lochee Road	✓	✓	✓	✓	**Inverness Academy Street 1st Floor**	✓	✓	✓	✓
Dundee Mains Loan	✓	✓	✓	✓	**Lerwick~**	✓	✓	✓	✓
Dundee Meadowside	✓	✓	✓	✓	**N Lanarkshire Airdrie Kenilworth Dr**	✓	✓	✓	✓
Dundee Seagate	✓	✓	✓	✓	**N Lanarkshire Chapelhall**	✓	✓	✓	✓
Dundee Whitehall Street	✓	✓	✓	✓	**N Lanarkshire Coatbridge Sunnyside Rd**	✓	✓	✓	✓
East Ayrshire Kilmarnock St Marnock St	✓	✓	✓	✓	**N Lanarkshire Coatbridge Whifflet**	✓	✓	✓	✓

Site Name	Q1	Q2	Q3	Q4	Site Name	Q1	Q2	Q3	Q4
East Dunbartonshire Bearsden	✓	✓	✓	✓	N Lanarkshire Croy	✓	✓	✓	✓
East Dunbartonshire Bishopbriggs	✓	✓	✓	✓	N Lanarkshire Kirkshaws	✓	✓	✓	✓
East Dunbartonshire Kirkintilloch	✓	✓	✓	✓	N Lanarkshire Motherwell	✓	✓	✓	✓
East Dunbartonshire Milngavie	✓	✓	✓	✓	N Lanarkshire Motherwell Adele Street	-	-	✓	✓
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 Crieff	✓	✓	✓	✓
Edinburgh St John's Road	✓	✓	✓	✓	Perth High Street	✓	✓	✓	✓
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 Street	✓	✓	✓	✓	South Lanarkshire Cambuslang	✓	✓	✓	✓
Falkirk Main St Bainsford	✓	✓	✓	✓	South Lanarkshire East Kilbride	✓	✓	✓	✓
Falkirk West Bridge Street	✓	✓	✓	✓	South Lanarkshire Hamilton	✓	✓	✓	✓
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 Dunbartonshire Glasgow Road	✓	✓	✓	✓
Glasgow Burgher Street	✓	✓	✓	-	West Lothian Broxburn	✓	✓	✓	✓
Glasgow Byres Road	✓	✓	✓	✓	West Lothian Linlithgow High St 2	✓	✓	✓	✓
Glasgow Dumbarton Road	✓	✓	✓	✓	West Lothian Newton	✓	✓	✓	✓

Appendix 3 - Process used for VCM Correcting SAQD TEOM Data

Figure A4.1 Process used for VCM Correcting SAQD TEOM Data



Appendix 4 – National Monitoring Networks in Scotland 2020

Table A2.1 AURN Measurement Sites in Scotland 2020

Site Name	Site Type	Species Measured	Grid Reference
Aberdeen	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 A3.2 Automatic Hydrocarbon Network Sites in Scotland 2020

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 A3.3 Non-Automatic Hydrocarbon Network Sites in Scotland 2020

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 A3.3 PAH Monitoring Sites in Scotland 2020

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 A3.4 Heavy Metals Monitoring Network Sites in Scotland 2020

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 A3.6 Rural Metal Deposition Monitoring sites in Scotland 2020

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 A3.7 The Precipitation Network (PrecipNet) Sites in Scotland 2020

Site Name	Grid Ref	Species included
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	

Site Name	Grid Ref	Species included
Forsinard RSPB	289309, 942826	
Glensaugh	366329, 780027	
Loch Dee	246907, 577768	
Polloch	179244, 768951	
Strathvaich	234787, 875022	
Whiteadder	366180, 663116	

Table A3.8 Acid Gas and Aerosol Network (AGANet) and Ammonia Network (NAMN) Sites in Scotland 2020

Name	Grid Ref	Ammonia	Nitric Acid
Allt a Mharcaidh	289184, 804320	✓	
Auchencorth Moss	322188, 656202	✓	✓
Auchincruive	238018, 623382	✓	
Bush	324629, 663891	✓	✓
Carradale	179870, 637801	✓	✓
Dumfries Grannoch	254650, 565848	✓	
Edinburgh St Leonards	326265, 673136	✓	
Ellon	394689, 830322	✓	
Eskdalemuir	323588, 602997	✓	✓
Forsinard RSPB	289309, 942826	✓	
Glen Shee	312187, 769016	✓	
Glensaugh	366329, 780027	✓	✓
Green Cabin	324646, 663902	✓	
Halladale	290285, 948838	✓	
Inverpolly	218695, 908820	✓	
Lagganlia	285684, 803720	✓	✓
Oldmeldrum	383297, 827323	✓	
Polloch	179244, 768951	✓	✓
Rannoch	260380, 753315	✓	
Sourhope	386796 621798	✓	
Strathvaich	234787, 875022	✓	✓
Tummel	274483, 761116	✓	

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