Scottish Air Quality Database

Annual Report 2019

Report for Scottish Government

ED 11194 | Issue Number 1 | Date 25/11/2020

Customer:

Scottish Government

Customer reference:

ED11194

Confidentiality, copyright & reproduction:

Contact:

David Hector
Ricardo Energy & Environment
Gemini Building, Harwell, Didcot, OX11 0QR, United Kingdom

t: +44 (0) 1235 75 3523
e: david.hector@ricardo.com

Ricardo is certificated to ISO9001, ISO14001 and OHSAS18001

Author:

Hector, David: Stratton, Stephen: Gray, Stephen

Approved By:

Dr Stuart Sneddon

Date:

25 November 2020

Ricardo Energy & Environment reference:

Ref: ED11194- Issue Number 1

Executive summary

In April 2007, Ricardo Energy & Environment (Ricardo) were commissioned by the Scottish Government to undertake a 3-year project (Apr 2007 – Apr 2010) to develop an Air Quality Database and Website for Scotland. This contract has been renewed in recent years, with the latest contract running from 2019-2022.

This report brings together all the Scottish Air Quality Database data for calendar year 2019 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 report will also include a section on the effects of Covid-19 pandemic on air quality in Scotland.

Legislation and Policy

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 is 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 as soon as possible. CAFS outlines the contribution that better air quality can make to sustainable development whilst improving health and the natural environment and reducing health inequalities for the citizens of Scotland.

In addition to the six main objectives, CAFS outlines new initiatives to be implemented to compliment the objectives set; these initiatives include a National Modelling Framework and National Low Emissions Framework. CAFS outlines further changes such as the adoption of the WHO annual mean guideline value for $PM_{2.5}$ of 10ug m^{-3}; this was incorporated into domestic legislation by the Air Quality (Scotland) Amendment Regulations 2016.

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 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 2019 five automatic monitoring sites exceeded the annual mean objective for NO_2. At the time of writing this report not all diffusion tube data for 2019 had been published due to delays caused by the covid-19 pandemic. Due to this the full number of NO_2 diffusion tube data has not been reported for 2019. In 2018, 74 diffusion tube sites exceeded the NO_2 annual mean objective.

In 2019, no sites exceeded the PM_{10} annual objective for PM_{10}. One site exceeded the daily mean objective of 50 µg m^{-3} not to be exceeded more than 7 times in a year. The pattern of measured concentrations is similar to previous years in that where exceedances of the Scottish air quality objectives occur, these are in areas where the relevant local authority has already declared or is in the process of declaring an Air Quality Management Area (AQMA).

In 2019, the Air Quality Strategy Objective for ozone (not more than 10 days with a maximum 8 hour running mean greater than 100 µg m^{-3}) was exceeded at seven out of the 11 sites measuring the pollutant in Scotland.

In 2019, 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.

Air Quality Mapping of Scotland

Ricardo 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). This report provides maps modelled using 2018 data, the most recent year for which inventory data is available.

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 42 road links (85.7 km of road) in the Glasgow Urban Area and at 18 road links (41.2 km of road) in Central Scotland. In the Edinburgh Urban Area seven road links (9.2 km of road) exceedances were modelled and in the North East Scotland zone only two roads had an exceedance (4.8 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 some 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 downward trends.

Examination of trends at the same nine sites over the most recent five complete years (2015 to 2019) indicates that the patterns are mostly very similar to the 10-year trends but with varying statistical significance.

PM_{10}

PM_{10} at Scotland's eight long-running urban non-roadside sites showed a significant or highly significant negative trend. PM_{10} at Scotland's nine long-running urban traffic (roadside and kerbside) sites showed statistically significant downward trends at all sites (at the 0.001 level in all but one case). Examination of trends in PM_{10} at the same nine sites over the most recent five years indicates that, at some of these, the decreasing trends have continued but at others they have weakened, levelled off or switched to an increasing trend.

$PM_{2.5}$

At the time of writing this report there are 66 sites monitoring $PM_{2.5}$ in Scotland. However, the vast majority of these sites started monitoring in the last three years with the introduction of the $PM_{2.5}$ objective and the requirement for local authorities to measure the pollutant. By the end of 2018 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 downward trends for $PM_{2.5}$. Contrary to this, the rural site Auchencorth Moss shows a slight upward trend however not statistically significant.

Ozone

Ozone has been measured at three rural sites in Scotland for 30 years. All three sites showed small positive trends over this very long period, 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 a not statistically significant decreasing trend. The 10 year trend analysis of ozone concentrations showed increasing trends (at vary statistical significance) at all three Scottish urban background sites.

Emissions of Pollution Species

Scotland NOx emissions have declined by 73% since 1990 and were estimated to be 86kt in 2018 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 2017 passenger car emissions is due to diesel cars).

Emissions of PM_{10} have declined by 62% since 1990 and in 2018 and were estimated to be 15kt (9% of the UK total). PM_{10} exhaust emissions from diesel vehicles have been decreasing due to the successive introduction of tighter emission standards over time. The decline in PM_{10} emissions has basically stopped across all sectors over the past few years with some, such as Industrial Processes increasing. This has been attributed to an increased quantity of wood fuel use. In addition, almost all other emissions sources have remained stable since 2011. Though PM_{10} emissions have reduced since 1990, overall, there has been no significant reduction in PM_{10} emissions since 2011.

Emissions of $PM_{2.5}$ have declined by 67% since 1990 and in 2018 were estimated to be 8kt (8% of the UK total). For $PM_{2.5}$, the residential, commercial and public sector combustion category accounts for 44% of 2018 emissions. The decline in emissions has significantly reduced over the past few years with no significant decrease since 2013. 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 of ammonia have declined by only 16% since 1990 and were estimated to be 31kt (11% 0f the UK total) in 2018. 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, which have tended to decrease emissions across the time-series. However, an increased use of urea-based fertilisers, which are associated with higher NH_3 emission factors, has had the opposite effect in recent years. The land-spreading of non-manure digestates have caused additional increases.

Emissions of Non-Methane Volatile Organic Compounds have declined 64% since 1990 and were estimated to be 144kt in 2018 (18% of the UK total). This reduction has been dominated by the 90% decrease in fugitive emissions since 1990. This is primarily due to the decrease in emissions from the exploration, production, and transport of oil, specifically emissions from the onshore loading of oil. There has been an upward 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 (51% of emissions in 2018).

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

Initial analysis indicates that the Covid-19 lockdown resulted in a significant drop in NO_2, PM_{10} and $PM_{2.5}$ concentrations levels in Scottish busy urban areas and especially in city centres. This is attributed to the huge decrease in vehicle traffic. More in-depth analysis may also help identify vehicle traffic contribution to particulate matter in Scotland.

Table of contents

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 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 2019 in the on-going project tasks and also highlights the new work undertaken during 2019 and into early 2020.

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 Scottish Air Quality Database is dynamic and forever 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 2019.

Quality Assurance and Quality Control (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 Scottish Air Quality Database during 2019.

A statistical summary of all the available 2019 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 Scottish Air Quality Database 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. The Scottish pollution climate mapping work carried out in 2018 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 pollutants nitrogen dioxide (NO_2) and particulate matter (PM_{10} and $PM_{2.5}$).

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 2019 report will include a section on the effects the 2020 Covid-19 pandemic had on air pollution concentrations in Scotland. This will obviously take into consideration 2020 data and mainly the data between March and June 2020. The Scottish Government believes that it is important to provide this information now rather than wait for the 2020 annual report next year.

2 Legislation and Policy

Air quality management is shaped by legislation and policy set at Scottish, UK and EU levels. The foundations of Scotland's air quality management system are based on the following air quality directives adopted by all Member States of the European Union:

- 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.

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

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. 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. The National Emission Ceilings Directive was transposed on a UK basis by the National Emission Ceilings Regulations 2018. The 2010 Regulations also incorporate the 4th air quality daughter directive (2004/107/EC), which sets targets for ambient concentrations of specific heavy metals and polycyclic aromatic hydrocarbons. Equivalent regulations exist in England, Wales and Northern Ireland.

A substantial review of the EU's air quality policy, including the Air Quality Directive was undertaken in 2013 with the Commission adopting a new Clean Air package, including a new Clean Air programme for Europe 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.

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 European 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 is 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 considers the impact of air quality on health and looks at the estimated costs as well as the premature deaths associated with poor air quality. It has been estimated that around 1,700 premature deaths across the Scottish population are associated with fine particulate air pollution[1].

During the first half of 2019 the Scottish Government carried out an in-depth independent review of CAFS. The review report was published in August 2019. A consultation on a draft new air quality strategy, taking into account the review recommendations, was published in October 2020. The consultation concludes in January 2021 and the new air quality strategy will be published later that year after having taken consultation responses into account. More information can be found on the Air Quality in Scotland website (http://www.scottishairquality.scot/lez/cafs-review-documents).

2.2.1 Cleaner Air for Scotland - Objectives

The Strategy outlines six main objectives. The document sets out the main objectives and actions required to achieve improvements in air quality. A summary of the six main objectives and the 40 actions stated in CAFS are set out below.

i. TRANSPORT

A Scotland that reduces transport emissions by supporting the uptake of low and zero emission fuels and technologies, promoting a modal shift away from the car, through active travel (walking and cycling) and reducing the need to travel.

This will be achieved by:

- Ensuring that all local authorities have a corporate travel plan which is consistent with any local air quality action plan.
- Delivering National Walking Strategy & Cycling Action Plan.
- Working collaboratively with delivery partners to deliver our shared vision in the cycling Action Plan for Scotland.
- Review supporting green buses including scope for supporting retrofitting existing vehicles, taking account of Technology and market developments, and climate change.
- Evaluating the Bus Investment Fund.
- Reviewing Bus Operators Grant to incentivise the use of low emission buses.
- Reviewing guidance & legislation on the powers of local transport authorities regarding bus services.
- Delivering Switched On Scotland: A Roadmap to widespread Adoption of Plug in Vehicles.
- Review the Roadmap and develop a post 2015 plug in vehicle action plan.
- With key partners investigate the use of hydrogen as a transport fuel and energy applications.
- Review the role less carbon intensive fuels such as LPG, CNG and biofuels can play towards a near zero emission road transport sector by 2050.
- Encourage Freight Quality Partnerships to consider their Environmental impact.
- Encourage LAs with AQMAs to establish a Freight Quality Partnership to achieve improved air quality.
- Review Ministerial guidance on regional and local transport strategies considering air quality management and to support a modal shift towards sustainable and active travel.
- Review the impacts of trunk roads on AQMAs and implement mitigation where trunk roads are the primary contributor.

ii. HEALTH

[1] https://www.hps.scot.nhs.uk/web-resources-container/air-pollution-and-health-briefing-note-mortality-associated-with-exposure-to-fine-particulate-matter-pm25-attributable-mortality-in-scotland/

A Scotland which protects its citizens from the harmful effects of air pollution and reducing health inequalities

This will be achieved by:

- NHS boards and their local authority partners to include reference to air quality and health in joint health protection plans.
- Include in legislation as Scottish objectives, World Health Organization (WHO) guideline values for PM_{10} and $PM_{2.5}$.

iii. LEGISLATION and POLICY

A Scotland where all European and Scottish legal requirements relating to air quality are as a minimum complied with.

This will be achieved by:

- Refocus the Local Air Quality Management system.
- Establish a $PM_{2.5}$ monitoring network.
- Produce revised and updated Scottish action plans to demonstrate how compliance with the EU ambient air quality Directives will be achieved.
- Design develop and implement a two-level modelling system for regional and local scales to support potential transport and planning solutions to air quality issues.
- Develop guidance and promote s support network for all practitioners in review and assessing air quality.
- Undertake detailed modelling of all four major cities in Scotland (National Modelling Framework).
- Identify requirements and undertake data collection for additional urban areas within three years.
- Implement the national databases for traffic data collection and local modelling outputs associated with CAFS.
- Ensure the NLEF criteria, test, and processes are developed agreed and finalised.
- Design and implement a standard appraisal process for assessing local air quality measures.
- Develop software tools and guidance for the NLEF including funding options and technical reports.

iv. PLACEMAKING

A Scotland where air quality is not compromised by new or existing development and where places are designed to minimise air pollution and its effects.

This will be achieved by:

- Ensuring Scottish Planning Policy and the National Planning Framework take account of CAFS.
- Ensuring Local Development Plans policies are consistent with CAFS objectives and any local authority air quality action plans.
- Work with Environmental Protection Scotland to produce updated guidance on air quality and planning.
- Work with SEPA to introduce air quality training for local authority planners.
- Support SEPA in revising its guidance on Strategic Environmental Assessment to bring it into line with CAFS.

v. COMMUNICATION

A Scotland where all are well informed engaged and empowered to improve our air quality.

This will be achieved by:

- Develop a Scottish Air Quality Indicator to assist in assessing compliance with air quality legislation and delivery of CAFS objectives;
- Developing a national air quality public awareness campaign
- Support the ongoing Greener Scotland communication campaigns, encouraging individuals to use the car less to improve their health and their local environment.

vi. **CLIMATE CHANGE**

Reducing greenhouse gas emissions and achieving renewable energy targets whilst delivering co-benefits for air quality.

This will be achieved by:

- Ensuring 'Low Carbon Scotland: Meeting Our Emissions Reduction Targets' publication takes into account air quality impacts.
- Expecting Scottish local authorities to ensure a Sustainable Energy Action Plan includes air quality considerations.
- Working with Forestry Commission Scotland to publish updated guidance on the impact of biomass on air quality to help local authorities fulfil their statutory responsibilities.

2.2.2 Cleaner Air for Scotland- $PM_{2.5}$

In addition to the six main objectives, CAFS outlines new initiatives to be implemented to compliment the objectives set; these initiatives include a National Modelling Framework and National Low Emissions Framework. CAFS outlines further changes such as the adoption of the WHO annual mean guideline value for $PM_{2.5}$ of 10 µg m^{-3}; this was incorporated into domestic legislation by the Air Quality Scotland Amendment Regulations 2016. Scotland was the first country in Europe to adopt the guideline value in legislation.

2.3 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.

2.4 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. NLEF assessments for those local authorities required to undertake them have been included in 2020 annual progress reports.

2.5 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 although the remaining schedule has been delayed due to the Covid-19 pandemic

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 UK. 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 LAQM Policy and Technical Guidance are available at http://www.scottishairquality.scot/air-quality/legislation.

3 Air Quality Seminar

As part of the Scottish Air Quality Database project, Ricardo Energy & Environment, on behalf of the Scottish Government, organise an annual air quality seminar. The most recent Scottish Government Annual Air Quality Seminar was held at the University of Strathclyde's Technology and Innovation Centre, 99 George Street, Glasgow. The event was attended by over 80 air quality experts 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 interesting topics in the field of air quality. These subjects included amongst others; Air Quality at the interface: Between the ambient and indoor environment (Dr Gavin Phillips), Air Pollution and health in Scotland (Dr Duncan Lee), Ozone in the UK (Dr David Fowler), Urban pollution "hot spots" measured from Real World Driving Emissions Tests (Mark Peckham, Cambustion Ltd), The environmental Impact of from Domestic solid fuel burning – Seeking clarity (Bruce Allen, HETAS), Ammonia: Emission, Effects and Mitigation (Dr Jeremy Wiltshire), The European CleanAir@Schools Project (Dr Colin Gillespie). All presentations can be found on the Scottish air Quality website http://www.scottishairquality.scot/). The full agenda for the day is 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 on 4th March 2020

The Scottish Government

RICARDO

SCOTTISH AIR QUALITY DATABASE AND WEBSITE ANNUAL SEMINAR

Wednesday 4 March 2020

Technology & Innovation Centre, University of Strathclyde, 99 George Street, Glasgow, G1 1RD

Final Agenda

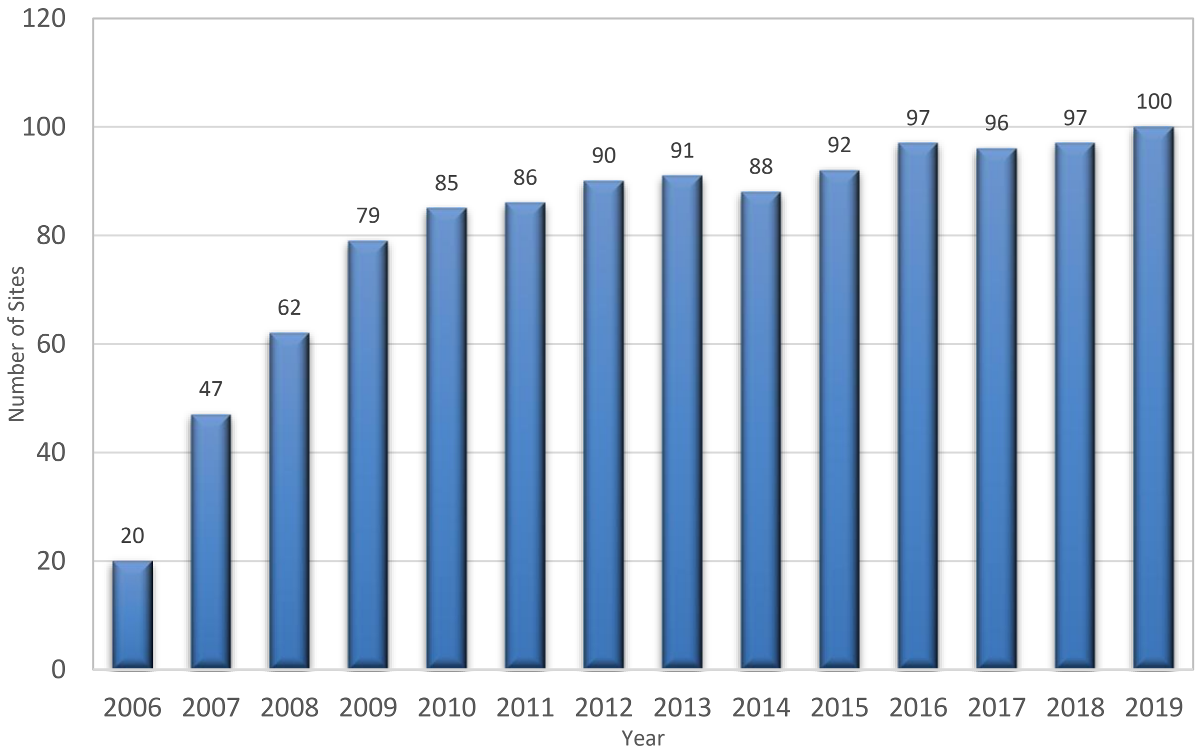
09:15	Registration	
10:00	Welcome/Introduction and CAFS update	Andrew Taylor (Scottish Government)
10:10	Brief overview of project and the aims of the day	Stuart Sneddon (Ricardo Energy & Environment)
10:15	SAQD Project Update	David Hector (Ricardo Energy & Environment)
10:35	Air quality at the interface: Between the ambient and indoor environment	Dr Gavin Philips (University of Chester)
10:55	Low Emission Zone Update	Derek McCreadie (Transport Scotland)
11:15	Tea/Coffee Break	
11:35	Urban pollution "hot spots" measured from Real World driving Emissions tests	Dr Mark Peckham (Cambustion Ltd)
11:55	Sensor Technology: Breathe London Network	Prof Rod Jones (University of Cambridge)
12:15	Air Quality Management and Traffic Management	Nicolina Cooper (Traffic Environment Systems Ltd)
12:35	Particulate Matter Inter-comparison Study Scotland	Stephen Stratton (Ricardo Energy & Environment)
12:50	Lunch	
13:30	The evidence base for the health impact of air pollution in Scotland	Prof Duncan Lee (University of Glasgow)
13:50	The European CleanAir@Schools Project	Dr Colin Gillespie (SEPA)
14:10	Emissions from Domestic Combustion	Bruce Allen (HETAS)
14:30	Ozone in the UK	Prof David Fowler (CEH)
14:50	Tea/Coffee Break	
15:10	Ammonia: emissions, effects and mitigation	Dr Jeremy Wiltshire (Ricardo Energy & Environment)
15:30	Clean Air Day: Inspiring behaviour change	John Bynorth – (Environmental Protection Scotland)
15:50	Questions / Answer Session	
16:05	Close	

4 Data Availability

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

At the end of 2019 the Scottish Air Quality Database contained data for of 100 automatic monitoring sites. In total, six new monitoring sites were incorporated into the database during 2019: Inverness Acadamy street 1st Floor, Renfrew Inchinnan Road, North Lanarkshire Airdrie Kenilworth Dr, North Lanarkshire Coatbridge Sunnyside, North Lanarkshire Uddingston New Edinburgh Rd, South Lanarkshire Blantyre. Three monitoring sites, Glasgow Abercromby Street, North Lanarkshire Motherwell Civic Centre and Paisley St James, were decommissioned during 2019. Figure 4.1 shows the growth of the SAQD from 20 sites in 2006 pilot study to 100 sites during 2019.

Figure 4.1 Number of Monitoring Sites within the Scottish Air Quality Database Network 2006 – 2019



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

Data availability for 2019, 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 Scottish Air Quality Database Network (SAQD) or the Automatic Urban and Rural Network (AURN).

Table 4.1 also provides the start date for each site. However, not all pollutants are measured over the same period at all sites – measurements of some pollutants may commence or cease during the lifetime of monitoring at a particular site. The dates of availability of data for each pollutant measured at each site can be found by selecting the site 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 2019

Site Name	Type	East	North	Pollutants	Network	Start Year#	Data in 2019
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
Dumbarton Roadside	RS	240234	675193	NO_2	AURN	2010	Jan – Dec
Dumfries	RS	297012	576278	NO_2	AURN	2001	Jan – Dec
Dundee Broughty Ferry Road	RS	341970	730997	PM_{10} SO_2	SAQD	2006	Jan – Dec
Dundee Lochee Road	KS	330773	738861	NO_2 PM_{10} $PM_{2.5}$	SAQD	2006	Jan – Dec
Dundee Mains Loan	UB	340972	731893	NO_2 PM_{10} $PM_{2.5}$	SAQD / AURN	2006	Jan – Dec
Dundee Meadowside	RS	340241	730654	NO_2 PM_{10} $PM_{2.5}$	SAQD	2011	Jan – Dec
Dundee Seagate	KS	340487	730446	NO_2 PM_{10} $PM_{2.5}$	SAQD	2006	Jan – Dec
Dundee Whitehall Street	KS	330155	740279	NO_2 PM_{10} $PM_{2.5}$	SAQD	2006	Jan – Dec
East Ayrshire Kilmarnock St Marnock St	RS	242742	637705	NO_2 PM_{10} $PM_{2.5}$	SAQD	2012	Jan – Dec
East Dunbartonshire Bearsden	RS	254269	672067	NO_2 PM_{10} $PM_{2.5}$	SAQD	2005	Jan – Dec
East Dunbartonshire Bishopbriggs	RS	260995	670130	NO_2 PM_{10} $PM_{2.5}$	SAQD	2003	Jan – Dec
East Dunbartonshire Kirkintilloch	RS	265700	673500	NO_2 PM_{10} $PM_{2.5}$	SAQD	2007	Jan – Dec
East Dunbartonshire Milngavie	RS	255325	674115	NO_2 PM_{10}	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}	SAQD	2013	Jan – Dec
Edinburgh Glasgow Road	RS	313101	672651	NO_2 PM_{10}	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} $PM_{2.5}$	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}	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 – Dec
Falkirk Bo'ness	UI	299827	681462	SO2	SAQD	2016	Jan – Dec
Falkirk Grangemouth MC	UB	292816	682009	NO_2 PM_{10} SO_2	SAQD	2003	Jan – Dec
Falkirk Grangemouth Zetland Park	UI	292969	681106	SO_2	SAQD	2016	Jan – Dec
Falkirk Haggs	RS	278977	679271	NO_2	SAQD	2009	Jan – Dec
Falkirk Hope St	RS	288688	680218	NO_2 PM_{10} SO_2	SAQD	2007	Jan – Dec
Falkirk Main St Bainsford	RS	288569	681519	NO_2 PM_{10}	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 Abercromby Street	RS	260420	664175	PM_{10}	SAQD	2007	Jan – Jun
Glasgow Anderston	UB	257925	665487	NO_2 PM_{10} $PM_{2.5}$	SAQD	2005	Jan – Dec
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 – Dec
Glasgow Byres Road	RS	256553	665487	NO_2 PM_{10} $PM_{2.5}$	SAQD	2005	Jan – Dec
Glasgow Dumbarton Road	RS	255030	666608	NO_2 PM_{10} $PM_{2.5}$	SAQD	2012	Jan – Dec
Glasgow Kerbside	KS	258708	665200	NO_2	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	Jun – Dec
Lerwick~	R	445337	1139683	O_3	AURN	2005	Jan – Dec
North Lanarkshire Airdrie Kenilworth Dr	RS	277385	665831	NO_2 PM_{10}	SAQD	2019	Sept - Dec
North Lanarkshire Chapelhall	RS	278174	663124	NO_2 PM_{10} $PM_{2.5}$	SAQD	2005	Jan – Dec
North Lanarkshire Coatbridge Sunnyside Rd	RS	273054	665234	NO_2 PM_{10}	SAQD	2019	Aug - Dec
North Lanarkshire Coatbridge Whifflet	UB	273668	663938	NO_2 PM_{10}	SAQD	2007	Jan – Dec
North Lanarkshire Croy	RS	272775	675738	NO_2 PM_{10} $PM_{2.5}$	SAQD	2006	Jan – Dec
North Lanarkshire Kirkshaws	RS	272522	663029	NO_2 PM_{10}	SAQD	2016	Jan – Dec
North Lanarkshire Motherwell	RS	275460	656785	PM_{10} $PM_{2.5}$	SAQD	2007	Jan – Dec
North Lanarkshire Motherwell Civic Centre	UB	275814	656235	PM_{10} $PM_{2.5}$	SAQD	2018	Jan - May
North Lanarkshire Shawhead Coatbridge	RS	273411	662997	NO_2 PM_{10} $PM_{2.5}$	SAQD	2009	Jan – Dec
North Lanarkshire Uddingston New Edinburgh Rd	RS	269145	661499	NO_2 PM_{10}	SAQD	2019	Aug - Dec
North Ayrshire Irvine High Street	KS	232142	638892	NO_2 PM_{10} $PM_{2.5}$	SAQD	2009	Jan – Dec
Paisley Gordon Street	RS	248316	663611	NO_2 PM_{10}	SAQD	2004	Jan – Dec
Paisley St James St	RS	248175	664311	PM_{10}	SAQD	2010	Jan – Jul
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}	SAQD	2012	Jan – Dec
Renfrew Cockels Loan	RS	250467	665943	NO_2 PM_{10}	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 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}	SAQD	2012	Jan – Dec

+ Sites added to database in 2019
* Sites changed monitoring
^Changes in number of measured pollutants or monitoring method during 2018
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 2019

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

Sites opened during 2019:

- Inverness Academy Street 1st Floor NO_2 from 25/09/2019
- North Lanarkshire Airdrie Kenilworth Dr NO_2, PM_{10}, from 07/09/2019
- North Lanarkshire Coatbridge Sunnyside Rd NO_2, PM_{10}, from 17/08/2019
- North Lanarkshire Uddingston New Edinburgh Rd NO_2, PM_{10}, from 17/08/2019
- Renfrew Inchinnan Road NO_2 from 25/09/2019
- South Lanarkshire Blantyre NO_2, PM_{10}, $PM_{2.5}$ from 25/09/2019

Sites closed during 2019:

- Glasgow Abercromby Street PM_{10} on 29/06/2019
- North Lanarkshire Motherwell Civic Centre NO_2, PM_{10} on 31/05/2019
- Paisley St James St PM_{10} on 02/07/2019

Sites changes during 2019:

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

- Dundee Meadowside on 21/03/2019
- Dundee Seagate on 20/03/2019
- Dundee Whitehall on 19/03/2019
- Edinburgh Nicolson Street on 04/12/2019
- East Dunbartonshire Bearsden on 23/01/2019
- East Dunbartonshire Bishopbriggs on 23/01/2019

4.2 NO_2 and PM_{10} Data Capture Rates

Figures 5.2 and 5.3 show the average data capture rates achieved between 2008 and 2019 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 Particulate Matter (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 halfway through 2018 resulting in a decrease in the average data capture rate during 2018.

Figure 5.2 Network data capture rate for NO_2 monitoring, 2008 – 2019

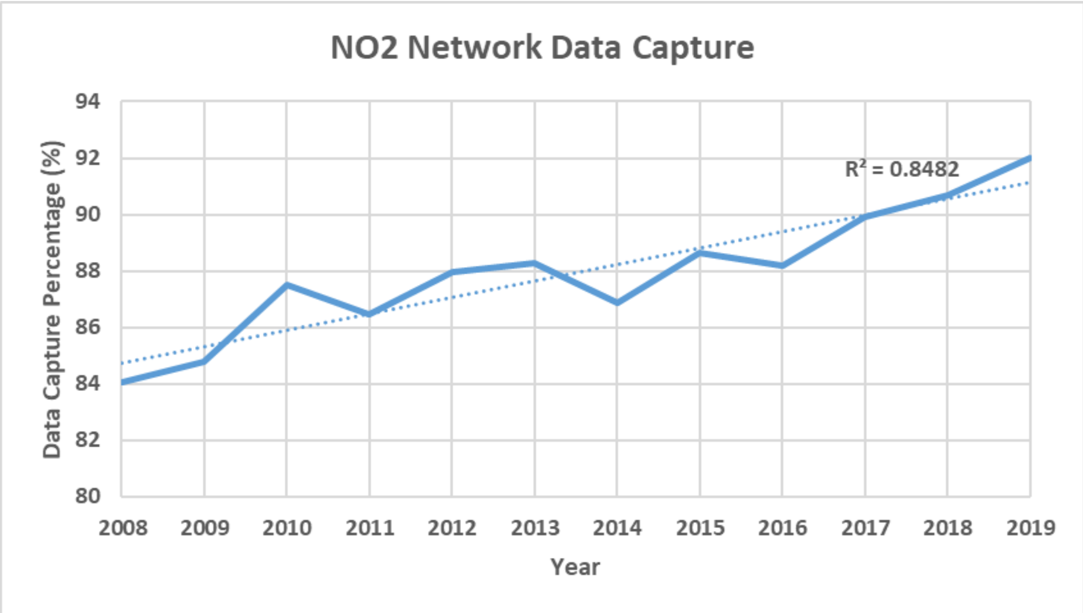
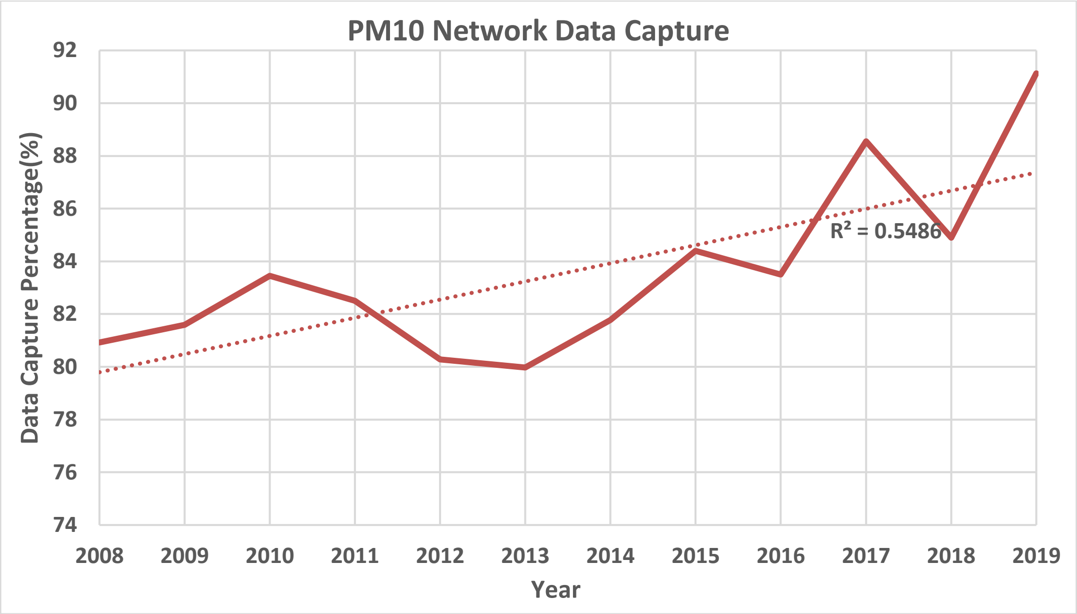


Figure 5.3 Network data capture rate for PM_{10} monitoring, 2008 – 2019



5 QA/QC of the Scottish Database

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

The main elements of the QA/QC programme are 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.

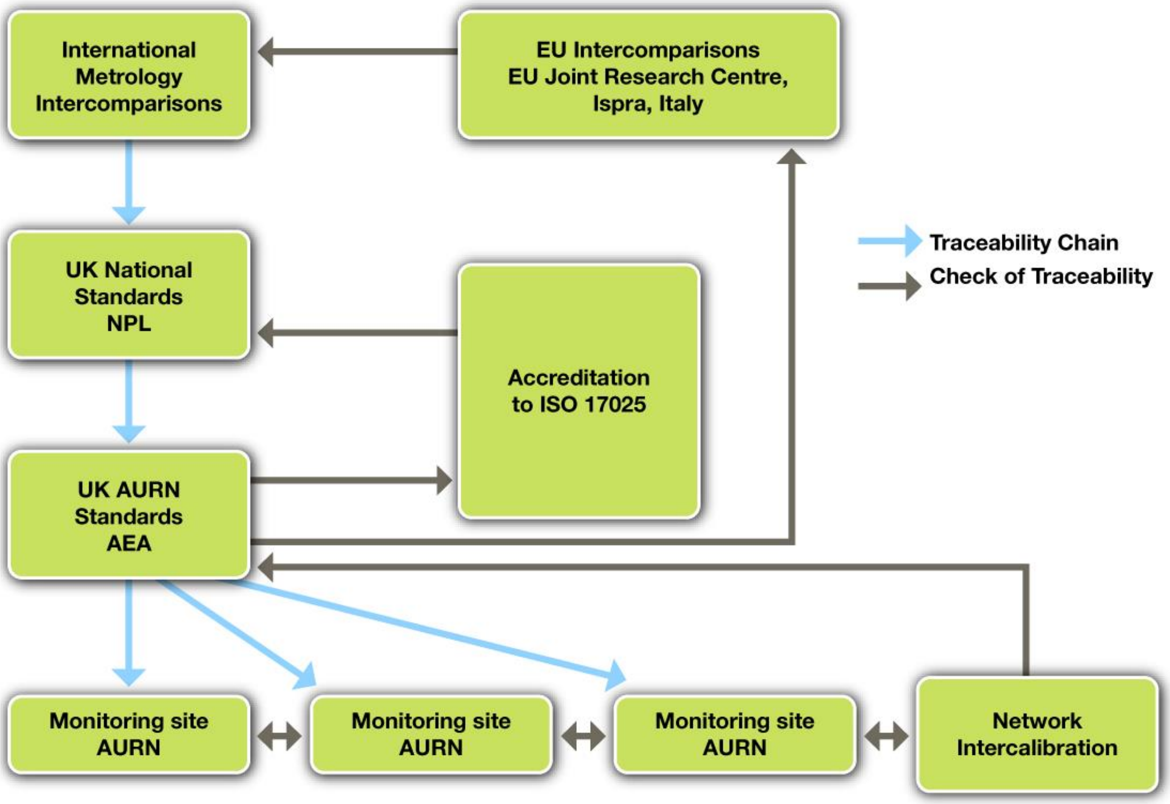
The assessment of the on-site calibration cylinder concentrations against accredited and traceable Ricardo Energy & Environment gas standard cylinders provides the essential final link in the measurement traceability chain (Fig 5.1). This process ensures that all monitoring stations in Scotland are traceable 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 2.

Figure 5.1 Traceability chain for the SAQD monitoring stations



5.2 Data Management

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

The process includes the following tasks:

- Data acquisition
- Data validation
- Ratification

The data acquisition and management system consist of a central computer and telemetry facility that has been developed by Ricardo 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 Scottish Database and Website. These operations are carried out automatically by computer systems, with all output manually checked by data management experts.

The validated data are then updated to the Scottish Air Quality Database – and accessible via the web - as provisional data. These data are therefore available to all users on a day-to-day basis. This gives the local authority the opportunity to easily view both their own data and data from other stations throughout Scotland. 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 for detailed Review and Assessment (LAQM.TG(16)).

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 2.

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

The ratified data are uploaded to the Scottish Database 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 2019

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 Scottish Database during 2019.

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 2019 audits

Site Faults Identified 2019	Number of Monitoring Sites Winter 2018/19	Number of Monitoring Sites Summer 2019
TEOM** and TEOM FDMS k_0 out by > 2.5%	4	2
Particulate Analyser*** flow out by >10%	2	1
NO_x analyser converter <97% efficiency	6	12
NO cylinder out by >10%	2	4
SO_2 cylinder out by >10%	1	4
CO cylinder out by >10%	0	0
O3 Analyser out by >5%	0	4

* Filter Dynamics Measurement System
** Tapered Element Oscillating Microbalance
*** These include TEOM, FDMS 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 2019 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. Table 5.2 summarises the site inter-calibrations and audits undertaken during 2019, where the period Winter 2018/19 corresponds to Dec-18 to Mar-19 and Summer 2019 corresponds to Jun-19 to Aug-19.

5.4.1 Data Ratification

In 2013 with the renewal of the Scottish Air Quality Database and Website 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 2019 have now been uploaded to the Scottish Air Quality website and Table 5.3 summarises the ratification undertaken during 2019. 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 5.2 Air quality site intercalibration and audits conducted during 2019

Site Name	Winter 2018/19	Summer 2019	Site Name	Winter 2018/19	Summer 2019
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	✓	✓
Dumbarton Roadside	✓	✓	Inverness*	✓	✓
Dumfries	✓	✓	Inverness Academy Street	✓	✓
Dundee Broughty Ferry Road	✓	✓	Inverness Academy Street 1st Floor	✓	✓
Dundee Lochee Road	✓	✓	Lerwick~	✓	✓
Dundee Mains Loan	✓	✓	North Lanarkshire Airdrie Kenilworth Dr	-	✓
Dundee Meadowside	✓	✓	North Lanarkshire Chapelhall	✓	✓
Dundee Seagate	✓	✓	North Lanarkshire Coatbridge Sunnyside Rd	-	✓
Dundee Whitehall Street	✓	✓	North Lanarkshire Coatbridge Whifflet	✓	✓
East Ayrshire Kilmarnock St Marnock St	✓	✓	North Lanarkshire Croy	✓	✓
East Dunbartonshire Bearsden	✓	✓	North Lanarkshire Kirkshaws	✓	✓
East Dunbartonshire Bishopbriggs	✓	✓	North Lanarkshire Motherwell	✓	✓
East Dunbartonshire Kirkintilloch	✓	✓	North Lanarkshire Motherwell Civic Centre	✓	-
East Dunbartonshire Milngavie	✓	✓	North Lanarkshire Shawhead Coatbridge	✓	✓
East Lothian Musselburgh N High St	✓	✓	North Lanarkshire Uddingston New Edinburgh Rd	-	✓
Edinburgh Currie	✓	✓	North Ayrshire Irvine High Street	✓	✓
Edinburgh Glasgow Road	✓	✓	Paisley Gordon Street	✓	✓
Edinburgh Gorgie Road	✓	✓	Paisley St James St	✓	-
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 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	✓	✓
Glasgow Dumbarton Road	✓	✓		□	□

Table 5.3 Data ratification undertaken during 2019

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**	✓	✓	✓	✓
Dumbarton Roadside	✓	✓	✓	✓	**Inverness***	✓	✓	✓	✓
Dumfries	✓	✓	✓	✓	**Inverness Academy Street**	✓	✓	✓	✓
Dundee Broughty Ferry Road	✓	✓	✓	✓	**Inverness Academy Street 1st Floor**	-	-	✓	✓
Dundee Lochee Road	✓	✓	✓	✓	**Lerwick~**	✓	✓	✓	✓
Dundee Mains Loan	✓	✓	✓	✓	**North Lanarkshire Airdrie Kenilworth Dr**	-	-	✓	✓
Dundee Meadowside	✓	✓	✓	✓	**North Lanarkshire Chapelhall**	✓	✓	✓	✓
Dundee Seagate	✓	✓	✓	✓	**North Lanarkshire Coatbridge Sunnyside Rd**	-	-	✓	✓
Dundee Whitehall Street	✓	✓	✓	✓	**North Lanarkshire Coatbridge Whifflet**	✓	✓	✓	✓
East Ayrshire Kilmarnock St Marnock St	✓	✓	✓	✓	**North Lanarkshire Croy**	✓	✓	✓	✓
East Dunbartonshire Bearsden	✓	✓	✓	✓	**North Lanarkshire Kirkshaws**	✓	✓	✓	✓
East Dunbartonshire Bishopbriggs	✓	✓	✓	✓	**North Lanarkshire Motherwell**	✓	✓	✓	✓
East Dunbartonshire Kirkintilloch	✓	✓	✓	✓	**North Lanarkshire Motherwell Civic Centre**	✓	✓	-	-
East Dunbartonshire Milngavie	✓	✓	✓	✓	**North Lanarkshire Shawhead Coatbridge**	✓	✓	✓	✓
East Lothian Musselburgh N High St	✓	✓	✓	✓	**North Lanarkshire Uddingston New Edinburgh Rd**	-	-	✓	✓
Edinburgh Currie	✓	✓	✓	✓	**North Ayrshire Irvine High Street**	✓	✓	✓	✓
Edinburgh Glasgow Road	✓	✓	✓	✓	**Paisley Gordon Street**	✓	✓	✓	✓
Edinburgh Gorgie Road	✓	✓	✓	✓	**Paisley St James St**	✓	✓	-	-
Edinburgh Nicolson Street	✓	✓	✓	✓	**Peebles**	✓	✓	✓	✓
Edinburgh Queensferry Road	✓	✓	✓	✓	**Perth Atholl Street**	✓	✓	✓	✓

Edinburgh Salamander St	✓	✓	✓	✓
Edinburgh St John's Road	✓	✓	✓	✓
Edinburgh St Leonards	✓	✓	✓	✓
Edinburgh Tower Street	✓	✓	✓	✓
Eskdalemuir	✓	✓	✓	✓
Falkirk Banknock	✓	✓	✓	✓
Falkirk Bo'ness	✓	✓	✓	✓
Falkirk Grangemouth MC	✓	✓	✓	✓
Falkirk Grangemouth Zetland Park	✓	✓	✓	✓
Falkirk Haggs	✓	✓	✓	✓
Falkirk Hope St	✓	✓	✓	✓
Falkirk Main St Bainsford	✓	✓	✓	✓
Falkirk West Bridge Street	✓	✓	✓	✓
Fife Cupar	✓	✓	✓	✓
Fife Dunfermline	✓	✓	✓	✓
Fife Kirkcaldy	✓	✓	✓	✓
Fife Rosyth	✓	✓	✓	✓
Fort William	✓	✓	✓	✓
Glasgow Abercromby Street	✓	✓	✓	✓
Glasgow Anderston	✓	✓	✓	✓
Glasgow Broomhill	✓	✓	✓	✓
Glasgow Burgher Street	✓	✓	✓	✓
Glasgow Byres Road	✓	✓	✓	✓
Glasgow Dumbarton Road	✓	✓	✓	✓
Perth Crieff	✓	✓	✓	✓
Perth High Street	✓	✓	✓	✓
Perth Muirton	✓	✓	✓	✓
Renfrew Cockels Loan	✓	✓	✓	✓
Renfrew Inchinnan Road	✓	✓	✓	✓
Renfrewshire Johnston	✓	✓	✓	✓
Shetland Lerwick~	✓	✓	✓	✓
South Ayrshire Ayr Harbour	✓	✓	✓	✓
South Ayrshire Ayr High St	✓	✓	✓	✓
South Lanarkshire Blantyre	✓	✓	✓	✓
South Lanarkshire Cambuslang	✓	✓	✓	✓
South Lanarkshire East Kilbride	✓	✓	✓	✓
South Lanarkshire Hamilton	✓	✓	✓	✓
South Lanarkshire Lanark	✓	✓	✓	✓
South Lanarkshire Raith Interchange 2	✓	✓	✓	✓
South Lanarkshire Rutherglen	✓	✓	✓	✓
South Lanarkshire Uddingston	✓	✓	✓	✓
Stirling Craig's Roundabout	✓	✓	✓	✓
Strath Vaich	✓	✓	✓	✓
West Dunbartonshire Clydebank	✓	✓	✓	✓
West Lothian Broxburn	✓	✓	✓	✓
West Lothian Linlithgow High St 2	✓	✓	✓	✓
West Lothian Newton	✓	✓	✓	✓
	□	□	□	□

5.5 Volatile Correction Model

5.5.1 Background

The EU Directive on Ambient Air Quality[2] and the UK Air Quality Strategy[3] 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 TEOM x 1.3 data were likely to overestimate PM_{10} concentrations. In Scotland, a lower correction 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[4] 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

---

[2] *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*

[3] *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*

[4] *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*

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 also 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) derived 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. For additional information regarding this visit http://www.scottishairquality.scot/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 2019 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 all FDMS analysers in Scotland are then used to provide an estimate of the volatile particle concentration in Scotland. 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 ($\mu g\ m^{-3}$)

For the 2019 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 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 nine FDMS sites were used for correcting hourly average TEOM data at 10 sites across Scotland. A list of sites used for correction is provided in Table 5.4 of this report. Table 5.5 provides the names of the sites where data was corrected using VCM.

Any outliers in the FDMS purge measurements were identified using Grubbs' Test[5] 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 2019 and calculated summary statistics have been provided to the local authorities. A flow chart showing the overall process employed for VCM correction of 2019 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-FDMS Sites, 2019

Site Name
Aberdeen Union St
Angus Forfar Glamis Rd
East Dunbartonshire Milngavie
Glasgow Abercromby Street
Glasgow Burgher St
Paisley Gordon Street
Perth Muirton
Renfrew Cockels Loan
West Lothian Newton

Table 5.5 TEOM Sites data corrected using VCM in 2019

Site Name	Local Authority
Aberdeen Anderson Dr	Aberdeen City Council
Dundee Broughty Ferry Road	Dundee City Council
Edinburgh Currie	Edinburgh City Council
Edinburgh Glasgow Road	Edinburgh City Council
Edinburgh Salamander St	Edinburgh City Council
Falkirk Bainsford	Falkirk Council
Falkirk Grangemouth MC	Falkirk Council
Falkirk Haggs	Falkirk Council
Falkirk Hope St	Falkirk Council
Stirling Craig's Roundabout	Stirling Council

[5] 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 2019

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 2019.

- Section 6.2 - Other pollutants covered by the Air Quality Strategy – PAH (benzo[a]pyrene), Benzene, 1,3-butadiene and lead - summary statistics for 2019 or 2018 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:
        a. The Precipitation Network
        b. NO_2 Rural Diffusion Tube Network
        c. Acid Gases and Aerosol Network (AGANET)
        d. 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 2019 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 Scottish Air Quality Database. 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 declare an Air Quality Management Area (AQMA). At the time of writing, 15 local authorities in Scotland have declared a total of 38 AQMAs (see http://www.scottishairquality.co.uk/laqm/aqma). Based on the data in the database, a brief 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 Ratified data annual average concentration and data capture for NO_2 in 2019 for monitoring sites in the Scottish Air Quality Database

Site Name	Type	Annual Average NO_2 2019 ($\mu g\ m^{-3}$)	No. hours >200 $\mu g\ m^{-3}$	Data capture NO_2 2019 (%)
Aberdeen Anderson Dr	RS	14.8	0	55.3
Aberdeen Errol Place	UB	16.7	0	96.8
Aberdeen King Street	RS	20.1	0	94.8
Aberdeen Market Street 2	RS	31.6	0	99.0

Site Name	Type	Annual Average NO_2 2019 ($\mu g\ m^{-3}$)	No. hours >200 $\mu g\ m^{-3}$	Data capture NO_2 2019 (%)
Aberdeen Union Street Roadside	RS	35.5	0	99.2
Aberdeen Wellington Road	RS	35.2	0	99.2
Alloa A907	RS	22.2	0	98.4
Bush Estate	R	5.3	0	94.5
Dumfries	RS	31.1	0	99.3
Dundee Broughty Ferry Road	RS	22.9	0	93.4
Dundee Lochee Road	RS	43.0	2	94.3
Dundee Mains Loan	UB	11.0	0	95.9
Dundee Meadowside	RS	33.9	0	86.6
Dundee Seagate	KS	44.5	0	99.5
Dundee Whitehall Street	KS	33.4	0	99.7
East Ayrshire Kilmarnock St Marnock	RS	24.4	0	99.8
East Dunbartonshire Bearsden	RS	31.9	0	98.7
East Dunbartonshire Bishopbriggs	RS	26.2	0	99.3
East Dunbartonshire Kirkintilloch	RS	26.6	0	99.3
East Dunbartonshire Milngavie	RS	19.4	0	91.6
East Lothian Musselburgh N High St	RS	20.3	0	96.1
Edinburgh Currie	UB	11.7	0	30.7
Edinburgh Glasgow Road	RS	25.1	0	98.9
Edinburgh Gorgie Road	RS	27.0	0	76.8
Edinburgh Nicolson Street	RS	50.4	4	99.4
Edinburgh Queensferry Road	RS	36.9	0	99.2
Edinburgh Salamander St	RS	24.3	0	95.6
Edinburgh St John's Road	KS	41.9	0	99.2
Edinburgh St Leonards	UB	20.8	0	95.1
Eskdalemuir	R	1.9	0	96.5
Falkirk Grangemouth MC	UB	17.2	0	75.5
Falkirk Haggs	RS	27.1	0	94.1
Falkirk Hope St	RS	20.0	0	93.7
Falkirk Main St Bainsford	RS	24.6	0	99.5
Falkirk West Bridge Street	RS	37.5	0	97.8
Fife Cupar	RS	23.6	0	99.3
Fife Dunfermline	RS	20.5	0	97.6
Fife Kirkcaldy	RS	15.8	0	98.4
Fife Rosyth	RS	21.5	0	99.7
Fort William	S	8.1	0	99.1
Glasgow Anderston	UB	25.5	0	99.2
Glasgow Burgher St.	RS	27.0	0	99.6
Glasgow Byres Road	RS	34.7	0	96.6
Glasgow Dumbarton Road	RS	34.8	0	99.6
Glasgow Great Western Road	RS	29.7	0	91.4
Glasgow High Street	RS	29.8	0	97.4
Glasgow Kerbside	KS	55.7	3	98.4
Glasgow Nithsdale Road	RS	31.3	0	99.8
Glasgow Townhead	UB	24.2	0	99.1
Glasgow Waulkmillglen Reservoir	R	9.4	0	99.3

Site Name	Type	Annual Average NO_2 2019 ($\mu g\ m^{-3}$)	No. hours >200 $\mu g\ m^{-3}$	Data capture NO_2 2019 (%)
Grangemouth	UI	15.2	0	88.6
Grangemouth Moray	UB	14.7	0	91.3
Inverclyde Greenock A8	RS	31.6	0	99.5
Inverness	RS	16.5	0	99.1
Inverness Academy Street	RS	42.8	0	74.8
Inverness Academy Street 1st Floor	RS	30.9	0	5.3
Lerwick	R	3.7	0	99.5
North Lanarkshire Airdrie Kenilworth Dr	RS	21.3	0	31.7
North Lanarkshire Chapelhall	RS	26.9	0	32.2
North Lanarkshire Coatbridge Sunnyside Rd	RS	24.9	0	35.5
North Lanarkshire Coatbridge Whifflet	UB	18.8	0	37.4
North Lanarkshire Croy	RS	20.5	0	33.9
North Lanarkshire Kirkshaws	RS	29.3	0	15.9
North Lanarkshire Shawhead	RS	29.2	0	20.3
North Lanarkshire Uddingston New Edinburgh Rd	RS	26.7	0	37.4
North Ayrshire Irvine High St	RS	17.7	0	68.8
Paisley Gordon Street	RS	28.6	0	99.8
Peebles	S	5.7	0	99.0
Perth Atholl Street	RS	36.4	0	96.9
Perth Crieff	RS	16.3	0	96.4
Perth High Street	RS	24.8	0	64.4
Renfrew Cockels Loan	RS	31.1	0	66.8
Renfrew Inchinnan Road	RS	24.1	0	86.6
South Ayrshire Ayr Harbour	RS	10.7	0	99.5
South Ayrshire Ayr High St	RS	14.0	0	66.0
South Lanarkshire Blantyre	RS	27.6	0	58.2
South Lanarkshire Cambuslang	RS	33.3	1	99.5
South Lanarkshire East Kilbride	RS	30.5	0	5.3
South Lanarkshire Hamilton	RS	28.8	0	99.5
South Lanarkshire Lanark	RS	18.9	0	99.6
South Lanarkshire Raith Interchange 2	RS	22.8	0	33.9
South Lanarkshire Rutherglen	RS	36.0	0	50.1
South Lanarkshire Uddingston	RS	25.7	0	93.2
Stirling Craig's Roundabout	RS	20.4	0	90.3
West Dunbartonshire Clydebank	RS	26.7	0	41.4
West Dunbartonshire Glasgow Road	RS	17.9	0	97.3
West Lothian Broxburn	RS	26.6	0	92.3
West Lothian Linlithgow High Street 2	RS	29.7	1	99.5
West Lothian Newton	RS	18.5	0	95.1
Aberdeen Anderson Dr	RS	14.8	0	55.3
Aberdeen Errol Place	UB	16.7	0	96.8

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

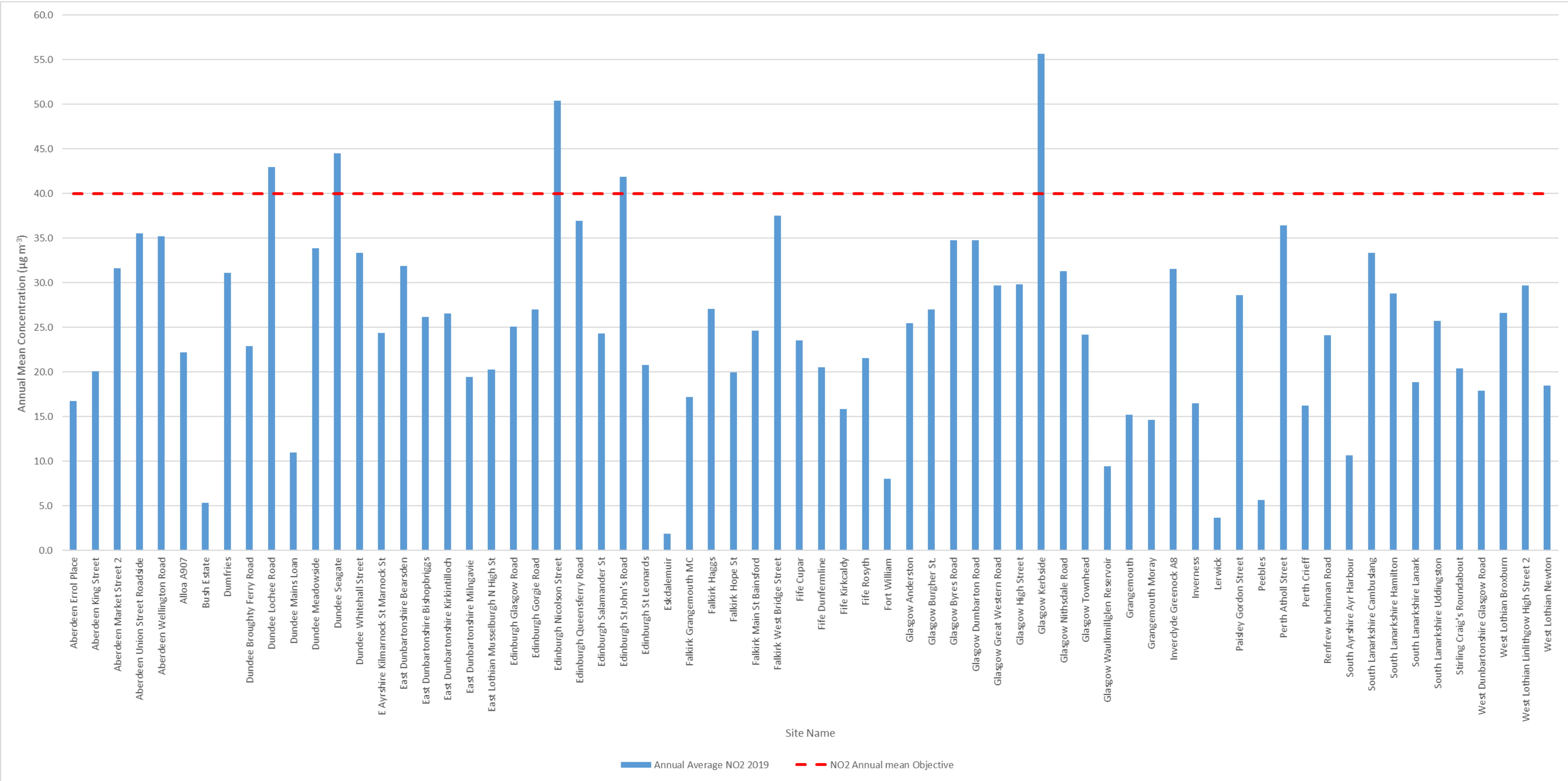
Highlighted figures (in yellow) indicate exceedances of Scottish Air Quality Objectives

Table 6.1.1 shows nitrogen dioxide data for 89 sites utilising automatic monitoring during 2019. Although, data for 21 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, sites which were closed for part of the year due to instrument problems.

Of the remaining 67 sites with 75% data capture or more, five of these (kerbside or roadside 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 not exceeded at any site.

The highest annual average concentrations were measured at Glasgow Kerbside, with a measured concentration of 55.7 µg m^{-3}. The greatest number of exceedances of the hourly mean objective was measured at Edinburgh Nicolson St with four exceedances. Figure 6.1.1 shows the 2019 annual average NO_2 concentrations for all SAQD monitoring sites (with 75% or more data capture) compared to the annual mean objective.

Figure 6.1.1 Annual Average NO_2 concentrations (µg m^{-3}) for all SAQD sites in 2019



6.1.2 Particulate Matter – PM_{10}

Table 6.1.2 Ratified data annual average concentration and data capture for PM_{10} in 2019 for monitoring sites in the Scottish Air Quality Database

Site Name	Type	PM_{10} Analyser Type*	Annual Average PM_{10} 2019 ($\mu g\ m^{-3}$)	No. Days > 50 $\mu g\ m^{-3}$	Data Capture (%)
Aberdeen Anderson Dr	RS	VCM	11.9	3	79.9
Aberdeen Errol Place	UB	FDMS/FIDAS	13.7	1	92.9
Aberdeen King Street	RS	FIDAS	13.9	3	79.3
Aberdeen Market Street 2	RS	FIDAS	12.8	4	99.1
Aberdeen Union Street	RS	TEOM FDMS	11.0	0	64.2
Aberdeen Wellington Road	RS	FIDAS	13.9	4	99.2
Alloa A907	RS	FIDAS	11.0	1	99.8
Angus Forfar Glamis Rd	RS	TEOM FDMS	12.7	0	89.5
Auchencorth Moss	R	FIDAS	6.7	0	99.9
Dundee Broughty Ferry Road	RS	VCM	13.6	1	86.9
Dundee Lochee Road	KS	FIDAS	11.8	1	99.8
Dundee Mains Loan	UB	FIDAS	9.2	1	99.2
Dundee Meadowside	RS	BAM (un-heated inlet)/FIDAS	14.1	3	85.6
Dundee Seagate	KS	BAM (un-heated inlet)/FIDAS	13.7	2	99.5
Dundee Whitehall Street	KS	BAM (un-heated inlet)/FIDAS	11.8	1	99.3
East Ayrshire Kilmarnock St	RS	FIDAS	11.3	2	99.9
East Dunbartonshire Bearsden	RS	Eberline/FIDAS	10.6	2	97.7
East Dunbartonshire Bishopbriggs	RS	Eberline/FIDAS	11.7	2	94.8
East Dunbartonshire Kirkintilloch	RS	FIDAS	12.6	3	88.4
East Dunbartonshire Milngavie	RS	TEOM FDMS	14.4	2	97.5
East Lothian Musselburgh N High St	RS	BAM (un-heated inlet)	11.6	1	85.2
Edinburgh Currie	UB	VCM	9.6	0	92.2
Edinburgh Glasgow Road	RS	VCM	15.2	3	97.4
Edinburgh Nicolson Street	RS	FIDAS	9.0	0	5.6
Edinburgh Queensferry Road	RS	FIDAS	10.8	0	22.2
Edinburgh Salamander St	UB	VCM	17.1	5	96.0
Edinburgh St John's Road	UB	FIDAS	13.6	3	80.1
Edinburgh St Leonards	RS	FDMS/FIDAS	10.9	1	90.9
Edinburgh Tower Street	RS	FIDAS	10.7	1	99.9
Falkirk Banknock	RS	FIDAS	11.4	3	97.8
Falkirk Grangemouth MC	UB	VCM	13.9	2	45.2
Falkirk Haggs	RS	VCM	14.1	4	91.5
Falkirk Hope St	RS	VCM	13.4	1	70.7
Falkirk Main St Bainsford	RS	VCM	14.4	5	91.4
Falkirk West Bridge Street	RS	FIDAS	10.5	1	98.0
Fife Cupar	RS	FIDAS	14.6	2	98.9
Fife Dunfermline	RS	FIDAS	11.2	3	99.7

Site Name	Type	PM_{10} Analyser Type*	Annual Average PM_{10} 2019 (µg m^{-3})	No. Days > 50 µg m^{-3}	Data Capture (%)
Fife Kirkcaldy	RS	FIDAS	11.6	3	92.2
Fife Rosyth	RS	FIDAS	10.0	1	91.4
Glasgow Abercromby Street	RS	TEOM FDMS	20.7	3	27.4
Glasgow Anderston	UB	FIDAS	11.5	2	76.4
Glasgow Broomhill	RS	FIDAS	13.0	4	98.7
Glasgow Burgher St.	RS	TEOM FDMS	12.0	2	98.8
Glasgow Byres Road	RS	FIDAS	15.0	6	92.1
Glasgow Dumbarton Road	RS	FIDAS	13.2	4	99.6
Glasgow High Street	RS	FIDAS	10.7	1	99.9
Glasgow Nithsdale Road	RS	FIDAS	15.2	5	94.7
Glasgow Townhead	UB	FIDAS	11.3	4	99.2
Glasgow Waulkmillglen Reservoir	R	FIDAS	8.8	1	98.2
Grangemouth	UI	FDMS/BAM (heated inlet)	12.6	2	93.9
Inverclyde Greenock A8	RS	FIDAS	11.8	5	99.7
Inverness	RS	FIDAS	9.4	0	88.5
North Lanarkshire Airdrie Kenilworth Dr	RS	BAM (un-heated inlet)	10.3	0	28.8
North Lanarkshire Chapelhall	RS	FIDAS	10.1	1	98.4
North Lanarkshire Coatbridge Sunnyside Rd	RS	BAM (un-heated inlet)	NA	0	0.0
North Lanarkshire Coatbridge Whifflet	RS	VCM	10.5	0	32.0
North Lanarkshire Croy	RS	FIDAS	11.4	3	99.9
North Lanarkshire Kirkshaws	RS	FIDAS	10.4	1	96.5
North Lanarkshire Motherwell	RS	FIDAS	10.5	2	96.7
North Lanarkshire Motherwell	RS	FIDAS	12.9	1	39.2
North Lanarkshire Shawhead	RS	FIDAS	9.9	2	99.9
North Lanarkshire Uddingston New Edinburgh Rd	RS	BAM (un-heated inlet)	11.4	0	29.6
North Ayrshire Irvine High St	RS	FIDAS	14.5	2	70.0
Paisley Gordon Street	RS	TEOM FDMS	12.1	4	94.7
Perth Atholl Street	RS	FIDAS	12.7	1	98.2
Perth Crieff	RS	FIDAS	9.3	1	82.9
Perth Muirton	RS	FDMS/FIDAS	8.5	1	99.0
Renfrew Cockels Loan	RS	TEOM FDMS	16.0	4	62.6
Renfrewshire Johnstone	RS	FIDAS	16.3	14	93.7
South Lanarkshire Blantyre	RS	FIDAS	10.9	2	96.2
South Lanarkshire Cambuslang	RS	FIDAS	13.3	7	99.6
South Lanarkshire East Kilbride	RS	FIDAS	10.4	1	97.6
South Lanarkshire Hamilton	RS	FIDAS	11.8	1	69.1
South Lanarkshire Lanark	RS	FIDAS	10.4	1	99.8
South Lanarkshire Raith Interchange 2	RS	FIDAS	9.8	1	89.4
South Lanarkshire Rutherglen	RS	FIDAS	13.6	4	98.0
South Lanarkshire Uddingston	RS	FIDAS	12.6	2	65.4
Stirling Craig's Roundabout	RS	VCM/FIDAS	10.8	1	99.2

Site Name	Type	PM_{10} Analyser Type*	Annual Average PM_{10} 2019 ($\mu g\ m^{-3}$)	No. Days > 50 $\mu g\ m^{-3}$	Data Capture (%)
West Dunbartonshire Clydebank	RS	FIDAS	11.3	4	97.0
West Lothian Broxburn	RS	FIDAS	14.4	4	99.9
West Lothian Linlithgow High	RS	FIDAS	12.0	5	99.8
West Lothian Newton	RS	FDMS/FIDAS	13.9	2	92.0

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
*FDMS data are equivalent to gravimetric and hence are not adjusted
FIDAS 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
Eberline data are adjusted using a correction factor of 1.3
VCM data are TEOM data corrected using the Volatile Correction Model

Table 6.1.2 shows the 2019 gravimetric equivalent PM_{10} data from 82 sites utilising automatic monitoring. Of these sites, 15 have less than 75% data capture. As discussed in Section 4.2.2, all TEOM data have been adjusted using the VCM.

Of the 67 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 seven times in a year was exceeded at one site, Renfrew Johnstone, with 14 exceedances. It should be noted that the majority of these exceedances occurred in June and July 2019 during the time when renovation works were being carried out at a commercial property close to the monitoring site.

The maximum PM_{10} annual mean concentration was measured at Edinburgh Salamander St with a measured annual mean concentration of 17.1 $\mu g\ m^{-3}$. No sites exceeded the UK AQS Objective of 40 µg m^{-3} for the annual mean PM_{10} and the daily mean objective of no more than 35 exceedances of 50 µg m^{-3}.

6.1.3 Particulate Matter – $PM_{2.5}$

Table 6.1.3 Ratified data annual average concentration and data capture for $PM_{2.5}$ in 2019 for monitoring sites in the Scottish Air Quality Database

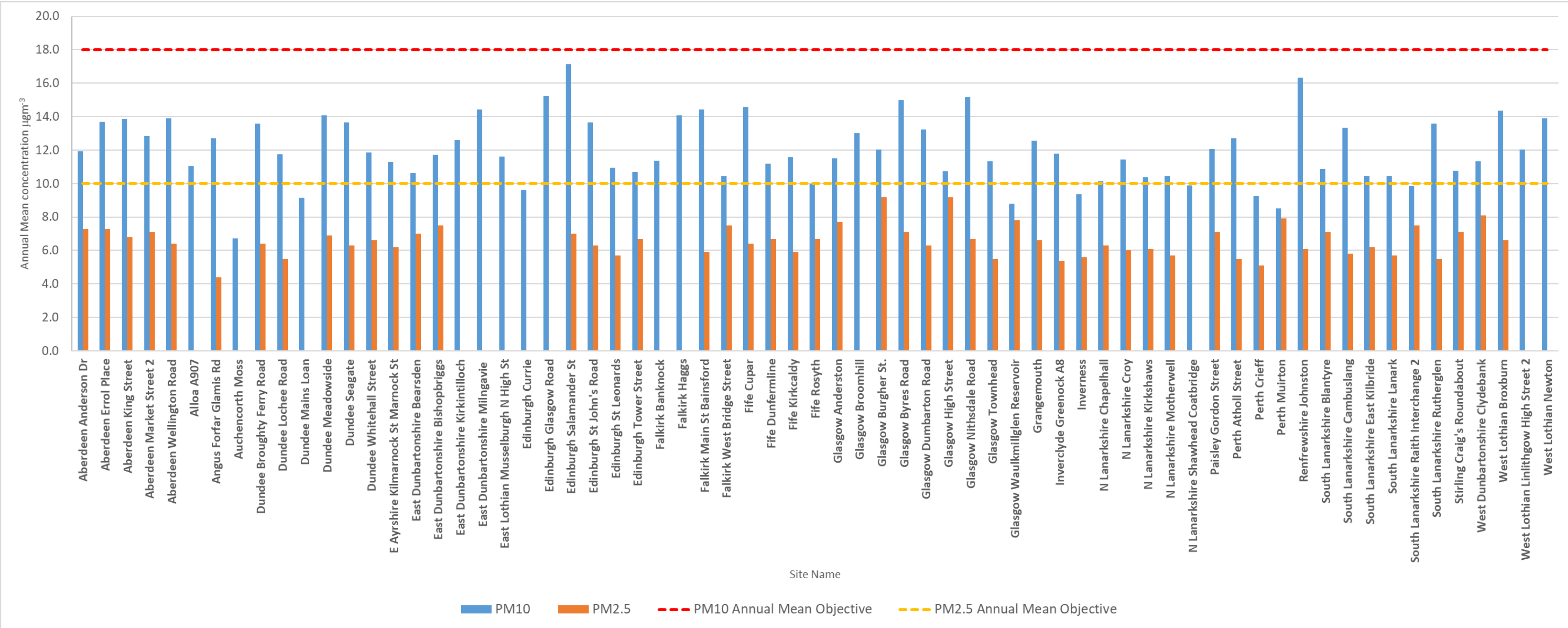
Site Name	Type	$PM_{2.5}$ Analyser Type	Annual Average $PM_{2.5}$ 2019 (µg m^{-3} gravimetric equivalent)	Data Capture (%)
Aberdeen Errol Place	UB	FDMS/FIDAS	7.3	93.5
Aberdeen King Street	RS	FIDAS	7.3	79.3
Aberdeen Market Street 2	RS	FIDAS	6.8	99.1
Aberdeen Union Street Roadside	RS	FIDAS	6.6	69.3
Aberdeen Wellington Road	RS	FIDAS	7.1	99.2
Alloa A907	RS	FIDAS	6.4	99.8
Auchencorth Moss	R	FIDAS	4.4	99.9
Dundee Lochee Road	KS	FDMS	6.4	99.8
Dundee Mains Loan	UB	FIDAS	5.5	99.2
Dundee Meadowside	RS	FIDAS	6.4	65.1
Dundee Seagate	KS	FIDAS	6.9	78.3
Dundee Whitehall Street	KS	FIDAS	6.3	78.5
East Ayrshire Kilmarnock St Marnock St	RS	FIDAS	6.6	99.9
East Dunbartonshire Bearsden	RS	FIDAS	6.2	91.9
East Dunbartonshire Bishopbriggs	RS	FIDAS	7.0	88.9
East Dunbartonshire Kirkintilloch	UB	FIDAS	7.5	88.4
Edinburgh Nicolson Street	RS	FIDAS	5.2	5.6
Edinburgh Queensferry Road	RS	FIDAS	6.1	22.2
Edinburgh St John's Road	KS	FIDAS	7.0	80.1
Edinburgh St Leonards	RS	FDMS/FIDAS	6.3	93.4
Edinburgh Tower Street	RS	FIDAS	5.7	99.9
Falkirk Banknock	RS	FIDAS	6.7	97.8
Falkirk West Bridge Street	RS	FIDAS	5.9	98.0
Fife Cupar	KS	FIDAS	7.5	99.0
Fife Dunfermline	RS	FIDAS	6.4	99.7
Fife Kirkcaldy	RS	FIDAS	6.7	92.2
Fife Rosyth	RS	FIDAS	5.9	91.4
Glasgow Anderston	UB	FIDAS	6.7	76.4
Glasgow Broomhill	RS	FIDAS	7.7	98.7
Glasgow Byres Road	RS	FIDAS	9.2	93.0
Glasgow Dumbarton Road	RS	FIDAS	7.1	99.6
Glasgow High Street	RS	FIDAS	6.3	99.9
Glasgow Nithsdale Road	RS	FIDAS	9.2	94.7
Glasgow Townhead	UB	FIDAS	6.7	99.2

Site Name	Type	$PM_{2.5}$ Analyser Type	Annual Average $PM_{2.5}$ 2019 (µg m^{-3} gravimetric equivalent)	Data Capture (%)
Glasgow Waulkmillglen Reservoir	R	FIDAS	5.5	98.2
Grangemouth	UI	BAM (heated inlet)	7.8	97.2
Inverclyde Greenock A8	RS	FIDAS	6.6	99.7
Inverness	RS	FDMS	5.4	88.5
North Lanarkshire Chapelhall	RS	FDMS	5.6	98.4
North Lanarkshire Croy	RS	FIDAS	6.3	99.9
North Lanarkshire Kirkshaws	RS	FDMS	6.0	96.5
North Lanarkshire Motherwell	RS	FIDAS	6.1	96.7
North Lanarkshire Motherwell Civic Centre	UB	FIDAS	8.1	39.2
North Lanarkshire Shawhead Coatbridge	RS	FIDAS	5.7	99.9
North Ayrshire Irvine High St	RS	FIDAS	8.0	70.0
Paisley St James St	RS	FDMS	8.9	42.1
Perth Atholl Street	RS	FIDAS	7.1	98.2
Perth Crieff	RS	FIDAS	5.5	82.9
Perth High Street	RS	TEOM	7.9	78.8
Perth Muirton	RS	FIDAS	5.1	91.5
Renfrewshire Johnstone	RS	FIDAS	7.9	93.7
South Ayrshire Ayr Harbour	RS	FDMS	6.7	96.4
South Ayrshire Ayr High St	RS	FDMS	6.3	99.3
South Lanarkshire Blantyre	RS	FIDAS	6.1	96.2
South Lanarkshire Cambuslang	RS	FIDAS	7.1	99.6
South Lanarkshire East Kilbride	RS	FIDAS	5.8	97.6
South Lanarkshire Hamilton	RS	FIDAS	6.7	69.2
South Lanarkshire Lanark	RS	FIDAS	6.2	99.8
South Lanarkshire Raith Interchange 2	RS	FIDAS	5.7	89.5
South Lanarkshire Rutherglen	RS	FIDAS	7.5	98.0
South Lanarkshire Uddingston	RS	FIDAS	7.4	65.4
Stirling Craig's Roundabout	RS	FIDAS	5.5	76.3
West Dunbartonshire Clydebank	RS	FIDAS	7.1	97.0
West Lothian Broxburn	RS	FIDAS	8.1	99.9
West Lothian Linlithgow High Street 2	RS	FIDAS	6.6	99.9
West Lothian Newton	RS	FIDAS	10.3	17.6

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

With 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 55 to 66 between 2018 and 2019. Data capture rates of less than 75% were measured at 10 sites. $PM_{2.5}$ concentrations in excess of the Scottish AQS Objective of 10 µg m^{-3} as an annual mean was not measured at any site. Figure 6.1.2 shows the 2019 annual average $PM_{2.5}$ and PM_{10} concentrations for all SAQD monitoring sites (with 75% or more data capture) compared to the respective annual mean objectives.

Figure 6.1.2 Annual Average PM_{10} and $PM_{2.5}$ concentrations (µg m^{-3}) for all SAQD sites in 2019



6.1.4 Carbon Monoxide

Table 6.1.5 Ratified data annual average concentration and data capture for CO in 2019 for monitoring sites in the Scottish Air Quality Database

Site Name	Type	Annual Average CO 2019 (mg m^{-3})	Max. Running 8hr Mean CO 2019 (mg m^{-3})	Data Capture (%)
Edinburgh St Leonards	UB	0.08	0	69.7

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

Table 6.1.5 shows carbon monoxide was monitored using automatic techniques at one site during 2019. Edinburgh St Leonards achieved the Air Quality Strategy Objective for this pollutant.

6.1.5 Sulphur Dioxide

Table 6.1.6 Ratified data annual average concentration and data capture for SO_2 in 2019 for monitoring sites in the Scottish Air Quality Database

Site Name	Type	Annual Average SO_2 2019 (µg m^{-3})	No. 15 min SO_2 > 266µg m^{-3} 2019	No. 1 hr SO_2 > 350µg m^{-3} 2019	No. 24 hr SO_2 > 125µg m^{-3} 2019	Data Capture (%)
Edinburgh St Leonards	UB	3.6	0	0	0	80.4
Falkirk Bo'ness	UI	1.5	0	0	0	88.7
Falkirk Hope St	UB	1.9	0	0	0	86.9
Falkirk Grangemouth Zetland Park	UI	1.3	0	0	0	95.3
Falkirk Grangemouth MC	RS	2.4	0	0	0	81.8
Grangemouth Moray	UI	3.1	12	1	0	95.8
Grangemouth	UB	2.8	2	0	0	91.8
Lerwick	R	1.2	0	0	0	75.5

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

Table 6.1.6 shows sulphur dioxide data from the eight sites utilising automatic monitoring for 2019. All sites in Scotland 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 2019.

6.1.6 Ozone

Table 6.1.7 Ratified data annual average concentration and data capture for O_3 in 2019 for monitoring sites in the Scottish Air Quality Database

Site Name	Type	Annual Average O_3 2019 (µg m^{-3})	No of days with running 8-hr mean >100 ug m^{-3}	Data capture O_3 2019 (%)
Aberdeen Errol Place	UB	47.6	7	88.4
Auchencorth Moss	R	59.5	13	99.7
Bush Estate	R	59.6	11	79.1
Edinburgh St Leonards	UB	48.2	5	97.9
Eskdalemuir	R	60	16	85.2
Fort William	S	52.1	11	99.3

Site Name	Type	Annual Average O_3 2019 ($\mu g\ m^{-3}$)	No of days with running 8-hr mean >100 ug m^{-3}	Data capture O_3 2019 (%)
Glasgow Townhead	UB	43.5	9	99.0
Glasgow Waulkmillglen Reservoir	R	50.5	7	88.3
Lerwick	R	72.1	34	99.2
Peebles	S	55.5	13	99.2
Strath Vaich	R	67.5	26	95.6

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

Table 6.1.7 shows ozone data from 11 sites utilising automatic monitoring for 2019. 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 2019, the Air Quality Strategy Objective of not more than 10 days with a maximum 8 hour running mean greater than 100 $\mu g\ m^{-3}$ was exceeded at seven of the 11 sites. In 2018 nine sites exceeded the objective.

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 2018. 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[6]

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

[6] 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 2018 and 2019 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 exceeded at Kinlochleven in 2019.

Table 6.2.2 Annual Average Benzo(a)Pyrene Concentrations for 2018 - 2019 at Four Sites in Scotland

Site	2018 Annual Mean B(a)P Concentration (ng m^{-3})	2019 Annual Mean B(a)P Concentration (ng m^{-3})
Auchencorth Moss	0.019	0.014
Edinburgh St Leonards	0.056	0.061
Glasgow Townhead	0.065	0.108
Kinlochleven	0.250	0.277

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 2018 and 2019 are provided in Table 6.2.3.

Table 6.2.3 Annual Mean Benzene Concentrations in 2018 and 2019 at 2 sites in Scotland in the UK Non-Automatic Hydrocarbon Network

Site Name	Annual Mean benzene for 2018 (µg m^{-3})	Annual Mean benzene for 2019 (µg m^{-3})
Glasgow Kerbside	0.66	0.68
Grangemouth	0.74	0.78

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 http://www.scottishairquality.scot/.

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 2019

Site	2018 Benzene Annual mean concentration (μg m^{-3})	2018 Benzene Maximum running annual concentration (μg m^{-3})	2019 % Data Capture
Auchencorth Moss	0.24	0.19	81.6

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 2019.

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 2019, 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 covering 1,3-butadiene.

Table 6.2.6. Annual Average 1,3-butadiene Concentration at Auchencorth Moss in the UK Automatic Hydrocarbon Network, for 2018 and 2019

Site	2017 1,3-butadiene Annual mean concentration (μg m^{-3})	2018 1,3-butadiene maximum running annual concentration (μg m^{-3})	2018 % Data capture
Auchencorth Moss	0.029	0.021	44.6

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 2019 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 2019 (Rural Network)

Site	Annual Mean Lead Concentration (ng m^{-3})	Annual Mean Nickel Concentration (ng m^{-3})	Annual Mean Arsenic Concentration (ng m^{-3})	Annual Mean Cadmium Concentration (ng m^{-3})
Auchencorth Moss	1.14	0.22	0.22	0.032
Eskdalemuir	0.98	0.21	0.17	0.026

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 monitoring 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:
8. The Precipitation Network
9. NO_2 rural diffusion tube Network
10. Acid Gases and Aerosol Network (AGANET)
11. 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.

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 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 2018; one in Scotland at Auchencorth Moss.

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

6.3.5 Heavy Metals Network

As discussed in Section 6.2.5 a wide range of metals are monitored in both air and rainwater within the National Monitoring Network for Heavy Metals. At the two sites in Scotland, Auchencorth Moss and Eskdalemuir, the following metals are monitored:
Arsenic (As), Cadmium (Cd), Cobalt (Co), Chromium (Cr), Copper (Cu), Iron (Fe), Lead (Pb), Manganese (Mn), Nickel (Ni), Selenium (Se), Vanadium (V) and Zinc (Zn).

6.3.6 United Kingdom Eutrophying & Acidifying Pollutant Network (UKEAP)

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

The UKEAP has four component networks:

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

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

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 1). 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 2.0 µg m^{-3} in 2018 with a data capture rate of 97%. Nitrogen dioxide is measured with diffusion tube samplers at nine sites in Scotland. The annual average concentrations measured in 2018 are provided in Table 6.3.1.

Table 6.3.1 NO_2 Annual Average Concentrations 2019 at Rural Monitoring Sites

Site	NO_2 (ug m^{-3})	Data Capture (%)
Allt a'Mharcaidh	1.3	100
Balquhidder 2	1.8	61.5
Eskdalemuir	2.4	100
Forsinard RSPB	1.5	100
Glensaugh	2.6	100
Loch Dee	2.5	100
Polloch	1.2	100
Strathvaich	1.2	84.6
Whiteadder	3.6	92.3

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 1.

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 1.

7 Air Quality Mapping for Scotland

As part of the Scottish Air Quality Database 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 for the purposes of annual compliance reporting to the European Commission.

The PCM methodology has been applied to provide pollution maps of Scotland for the Scottish Government for 2018 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[7] 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 calculated for 2009, using Scotland-specific data, for use by Scottish local authorities for their Local Air Quality Management Review and Assessment (LAQM) reports. These Scotland-specific air pollutant source apportionment data and forward-projected concentrations of air pollutants for LAQM were updated to a base year of 2018 during 2020 and are available at: http://www.scottishairquality.scot/maps.php?n_action=data.

7.1 Air Quality Maps for Scotland 2018

The details of the methodology and full results of the mapping study are provided in a separate report[8]. In this report, we summarise the main findings of this work.

7.1.1 NO_2 maps for 2018

The 2018 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.

[7] 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

[8] Wareham, J., Rose, R., and Stedman, J. (2020). Scottish Air Quality Maps. Annual mean NO_X, NO_2, and PM_{10} modelling for 2018. http://www.scottishairquality.scot/assets/documents/Scottish_mapping_report_2018.html

Figure 7.1 Background NO_2 map for 2018, µg m^{-3} (Scotland-specific model)

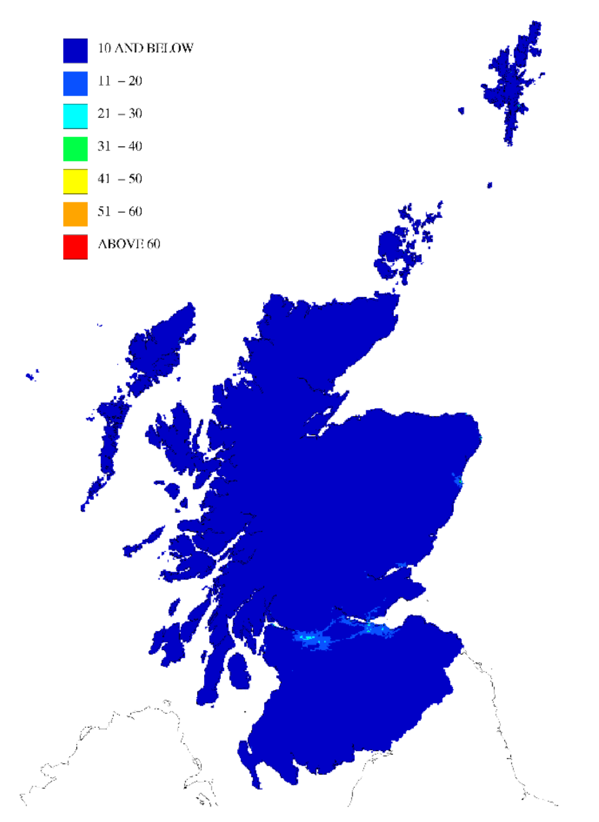


Figure 7.2 Roadside NO_2 map for 2018, µg m^{-3} (Scotland-specific model)

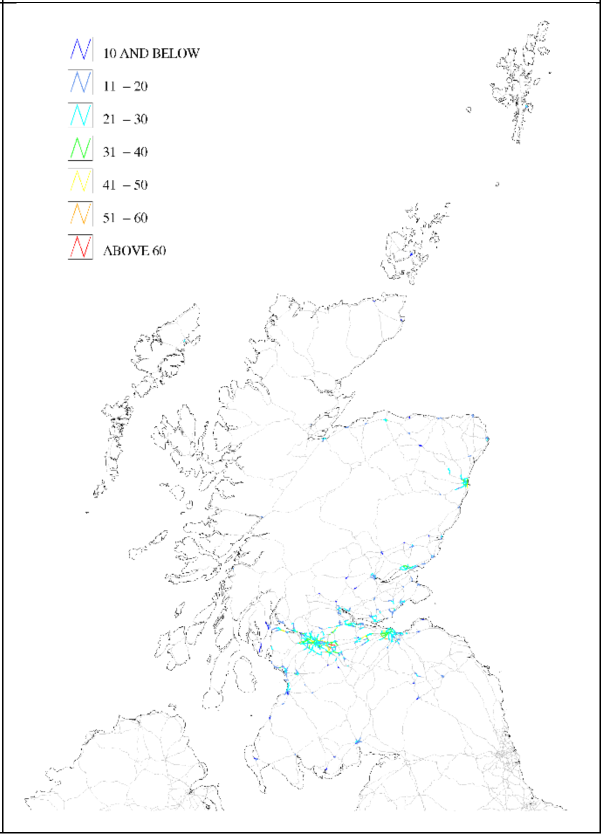


Table 7.1 shows that there were no modelled exceedances of the Scottish annual mean NO_2 objective of 40 µg m^{-3} at background locations. Overall exceedances of the Scottish annual mean NO_2 air quality objective were modelled at roadside locations in four of the six zones and agglomerations in Scotland. Exceedances of the annual mean NO_2 objective at roadside locations were modelled at 42 road links (85.7 km of road) in the Glasgow Urban Area and at 18 road links (41.2 km of road) in Central Scotland. In the Edinburgh Urban Area there were seven road links (9.2 km of road) where exceedances of the Scottish annual mean NO_2 air quality objective were modelled and in the North East Scotland zone only two roads had an exceedance (4.8 km of road). No roadside exceedances of the Scottish annual mean NO_2 air quality objective were modelled in the more rural zones and agglomerations 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 2018.

Table 7.1 Annual mean exceedance statistics for background NO_2 in Scotland based on the Scotland-specific model, 2018.[1]

Zone or agglomeration	Total		>40 µg m^{-3}	
	Area (km^2)	Population	Area (km^2)	Population
Glasgow Urban Area	367	1,135,190	0	0
Edinburgh Urban Area	134	502,072	0	0
Central Scotland	9,984	1,980,292	0	0
North East Scotland	19,024	1,148,282	0	0
Highland	43,514	395,051	0	0
Scottish Borders	11,400	264,463	0	0
Total	**84,423**	**5,425,350**	**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, 2018.[2]

Zone or agglomeration	Total		>40 µg m^{-3}	
	Road links	Length (km)	Road links	Length (km)
Glasgow Urban Area	296	411.8	42	85.7
Edinburgh Urban Area	71	117.9	7	9.2
Central Scotland	325	500.5	18	41.2
North East Scotland	178	260.9	2	4.8
Highland	43	65.3	0	0.0
Scottish Borders	49	57.9	0	0.0
Total	**962**	**1414.4**	**69**	**140.9**

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

7.1.2 PM_{10} maps for 2018

2018 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 2018 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 2018, µg m^{-3} (Scotland-specific model)

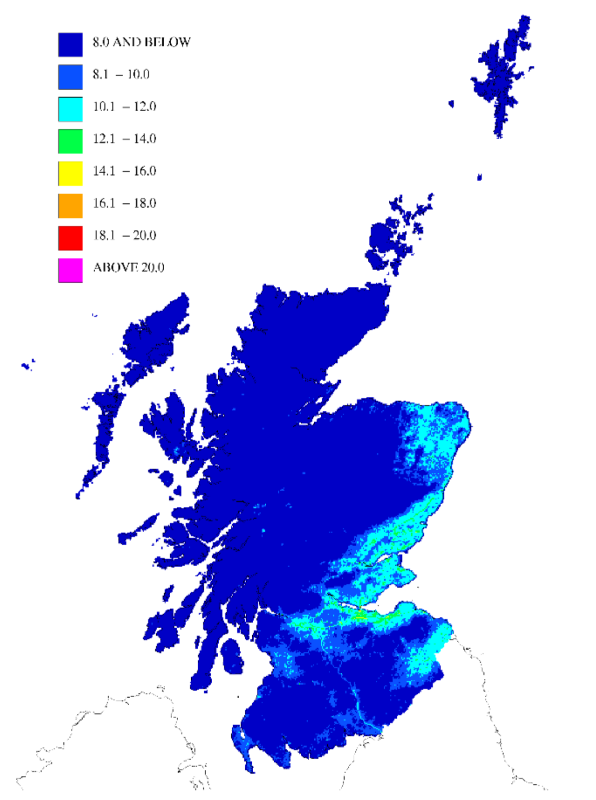


Figure 7.4 Roadside PM_{10} map for 2018, µg m^{-3} (Scotland-specific model)

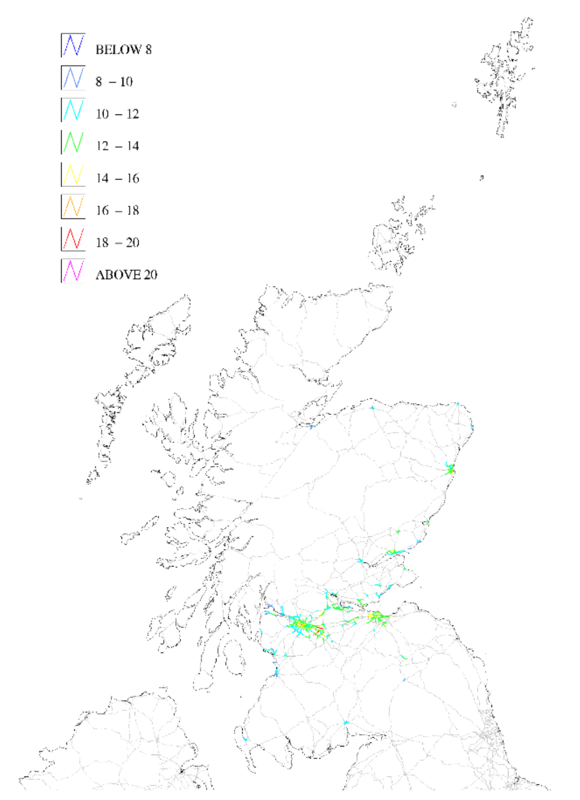


Table 7.3 shows that there were no modelled exceedances of the Scottish annual mean PM_{10} objective of 18 µg m^{-3} at background locations. Six road links (19.3 km of road) were identified as exceeding the Scottish annual mean PM_{10} air quality objective, as shown in Table 7.4. Exceedances of the Scottish annual mean PM_{10} objective were modelled in Glasgow Urban Area and Central Scotland.

Table 7.3 Annual mean exceedance statistics for background PM_{10} in Scotland based on the Scotland-specific model, 2018.[3]

Zone or agglomeration	Total		>18 µg m^{-3}	
	Area (km^2)	Population	Area (km^2)	Population
Glasgow Urban Area	367	1,135,190	0	0
Edinburgh Urban Area	134	502,072	0	0
Central Scotland	9,984	1,980,292	0	0
North East Scotland	19,024	1,148,282	0	0
Highland	43,514	395,051	0	0
Scottish Borders	11,400	264,463	0	0
Total	**84,423**	**5,425,350**	**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, 2018.[4]

Zone or agglomeration	Total		>18 µg m^{-3}	
	Road links	Length (km)	Road links	Length (km)
Glasgow Urban Area	280	389.1	5	14.9
Edinburgh Urban Area	60	105.3	0	0.0
Central Scotland	233	364.7	1	4.4
North East Scotland	134	197.8	0	0.0
Highland	10	18.4	0	0.0
Scottish Borders	33	32.9	0	0.0
Total	750	1,108.2	6	19.3

[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

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[9].

[9] 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, Rural Background, and Urban Traffic. Other site classifications used within this analysis also include Urban industrial and Suburban. 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[10]. 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 reporting exceedances for this pollutant (see Section 6 of this report). In particular, the objective of 40 µg m^{-3} for annual mean NO_2 concentration is the most widely exceeded. It is therefore important to understand how concentrations of this pollutant are varying with time.

8.1.1 NO_2 At Urban Background Sites

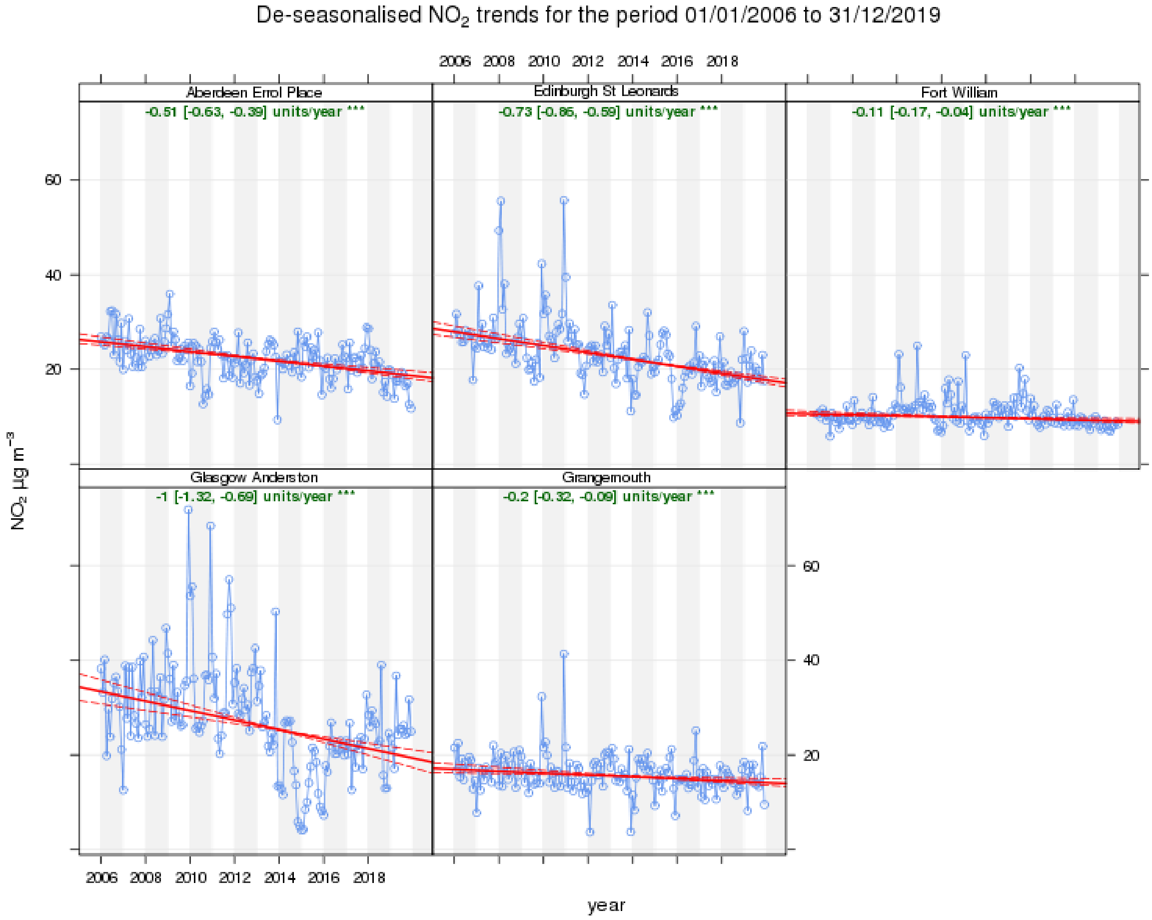
There are relatively few long-running urban background monitoring stations in Scotland. Five urban non-roadside sites have been in operation for the past 15 years. These are as follows: Aberdeen Errol Place, Edinburgh St Leonards, Fort William, Glasgow Anderston and Grangemouth. Fort William is classified 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*

[10] 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.

their 2014 and 2015 datasets: as stated above, where there are gaps in the data, Openair fills these in using an interpolation method.

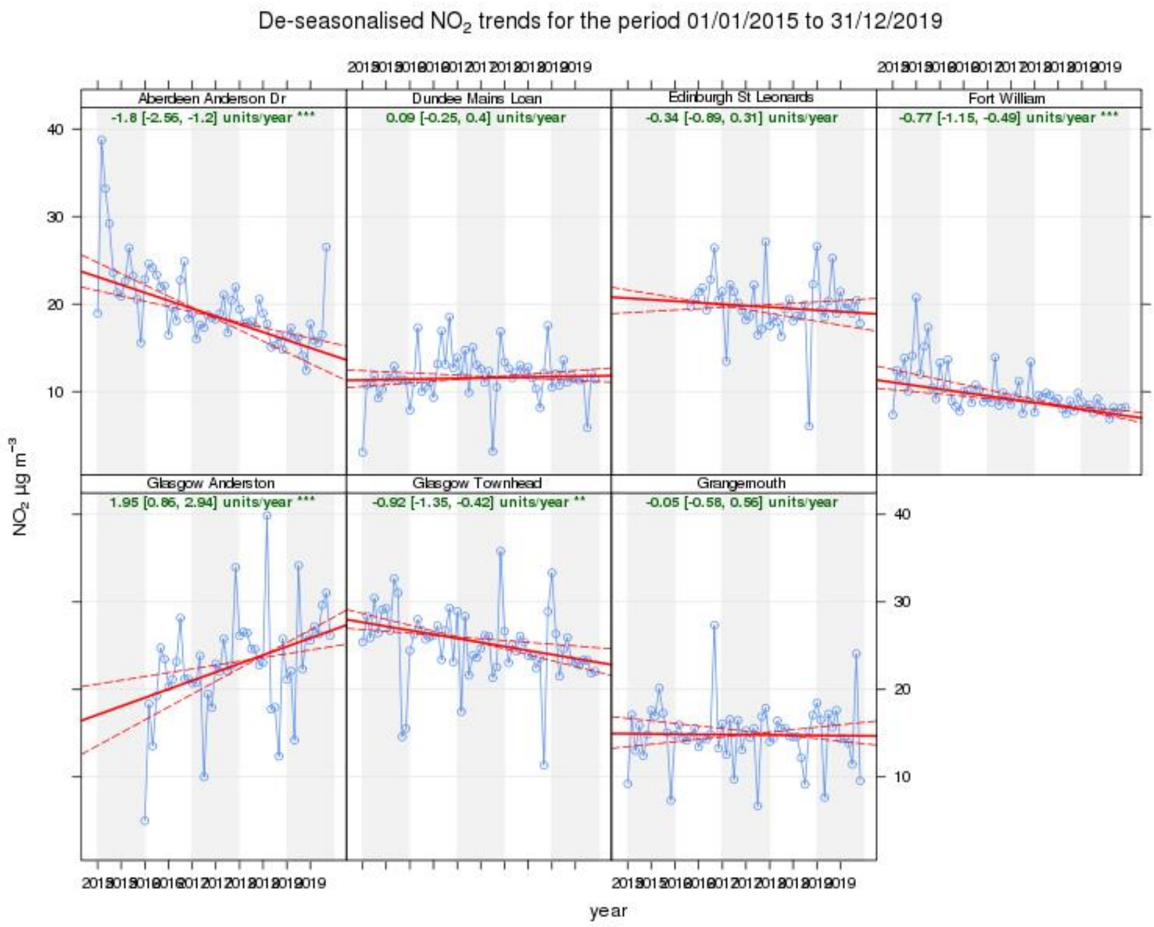
Figure 8-1 Trends in NO_2 Concentration at Five Long-running Urban Non-Roadside Sites, 2006-2019



All sites shown in Figure 8-1 display highly significant negative trends (at the 0.001 level) over this time period. This is a change from previous reports in this series were analysis has shown that Aberdeen Errol Place, Fort William and Grangemouth were significant negative trends at the 0.05 level. This analysis indicates that the downward 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 down trends are not as consistent across all sites with only Aberdeen Anderson Drive and Fort William retaining their highly significant downward trends. Glasgow Townhead, Edinburgh St Leonards and Grangemouth show downward trends but not at highly significant as in Figure 8-1. Dundee Mains Loan (not statistically significant) and Glasgow Anderston (highly significant) show increasing trends contradicting the perception that NO_2 concentrations are decreasing at all urban background sites.

Figure 8-2 Trends in NO_2 Concentration at all Urban Non-Roadside Sites, 2015-2020

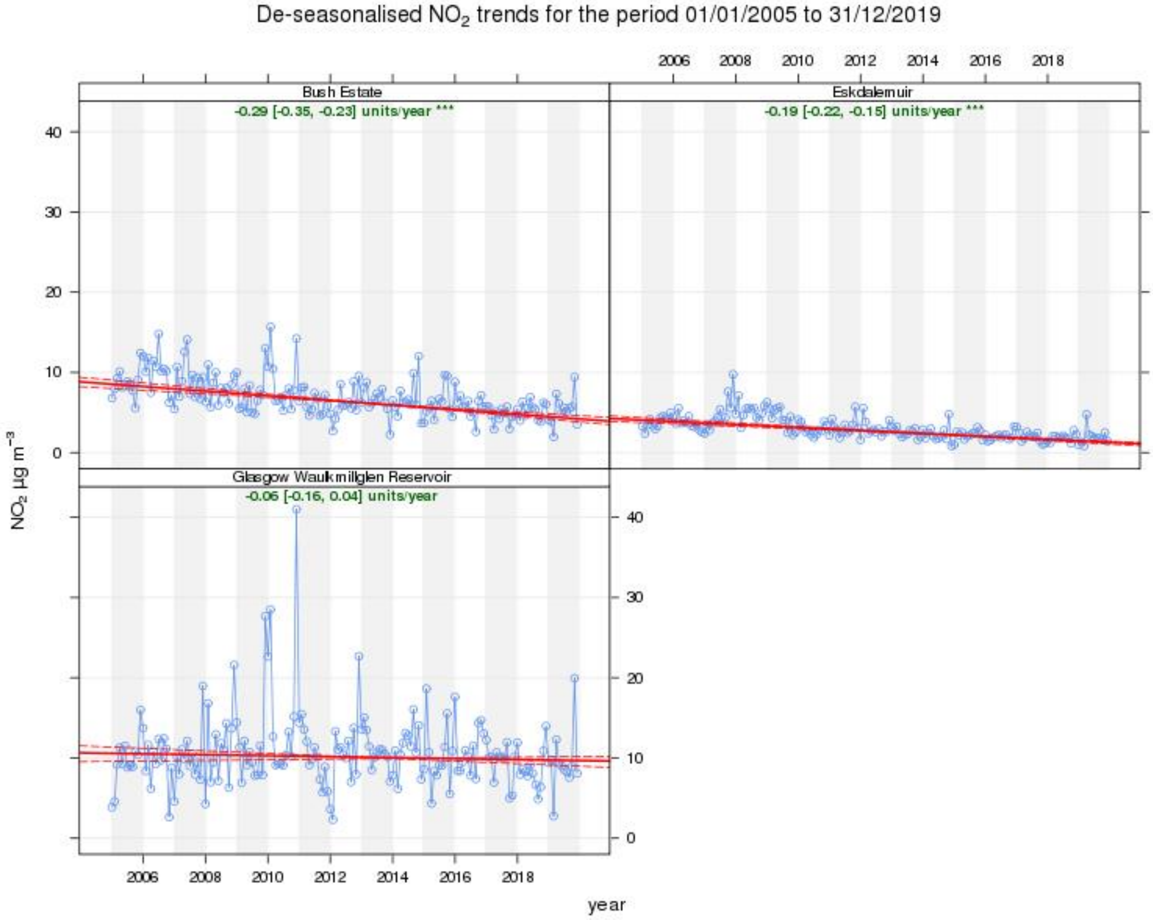


8.1.2 NO_2 at Rural Sites

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.

The sites at Bush Estate and Eskdalemuir showed small but highly significant downward trends. However, this was not the case for Glasgow Waukmillglen Reservoir, where concentrations were decreasing very slightly year-on-year, though the trend was not significant. This has not changed from previous reports in this series.

Figure 8-3 Trends in NO_2 Concentration at Three Rural Sites, 2005 – 2019



8.1.3 NO_2 at Urban traffic Sites

Recent years have seen a substantial increase in the number of monitoring stations at urban traffic-related sites in Scotland. There are now 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
- NorthLanarkshire 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 2019). 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 downward trends (at the 0.001 level).

Trends over the most recent five complete years, 2014 – 2018, 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 downward trends but of varying significance. At Aberdeen Union, Dundee Seagate, Edinburgh St Johns Road, N Lanarkshire Chapelhall, and Perth Atholl Street, the downward trend has become greater in magnitude over the past five years compared to the past 10. Glasgow Kerbside (Hope Street) is the only site out of this group that shows a reduction in the decreasing trend and the statistical significance going from highly significant to significant.

Figure 8-4 Trends in NO_2 Concentration at Eight Long-running Urban Traffic Sites with Exceedances, 2010 - 2019

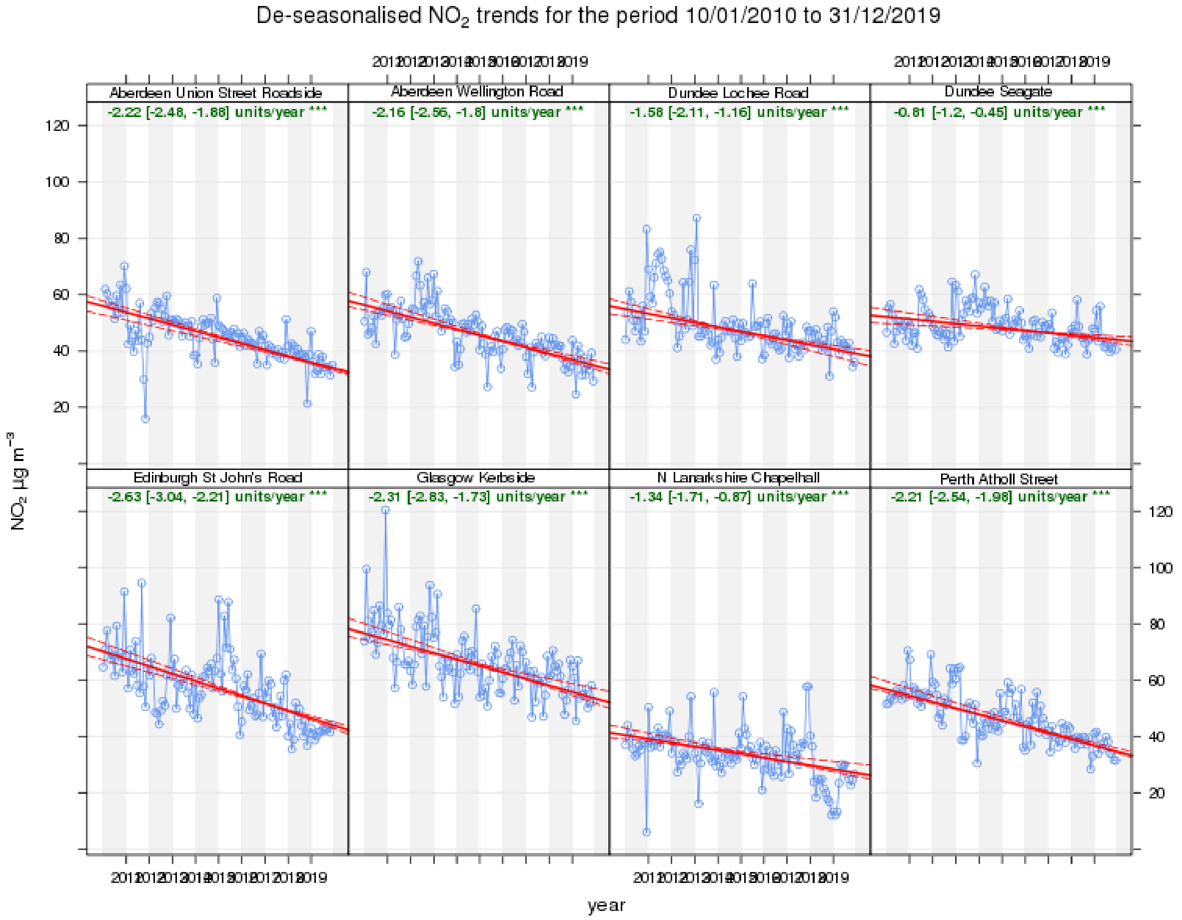
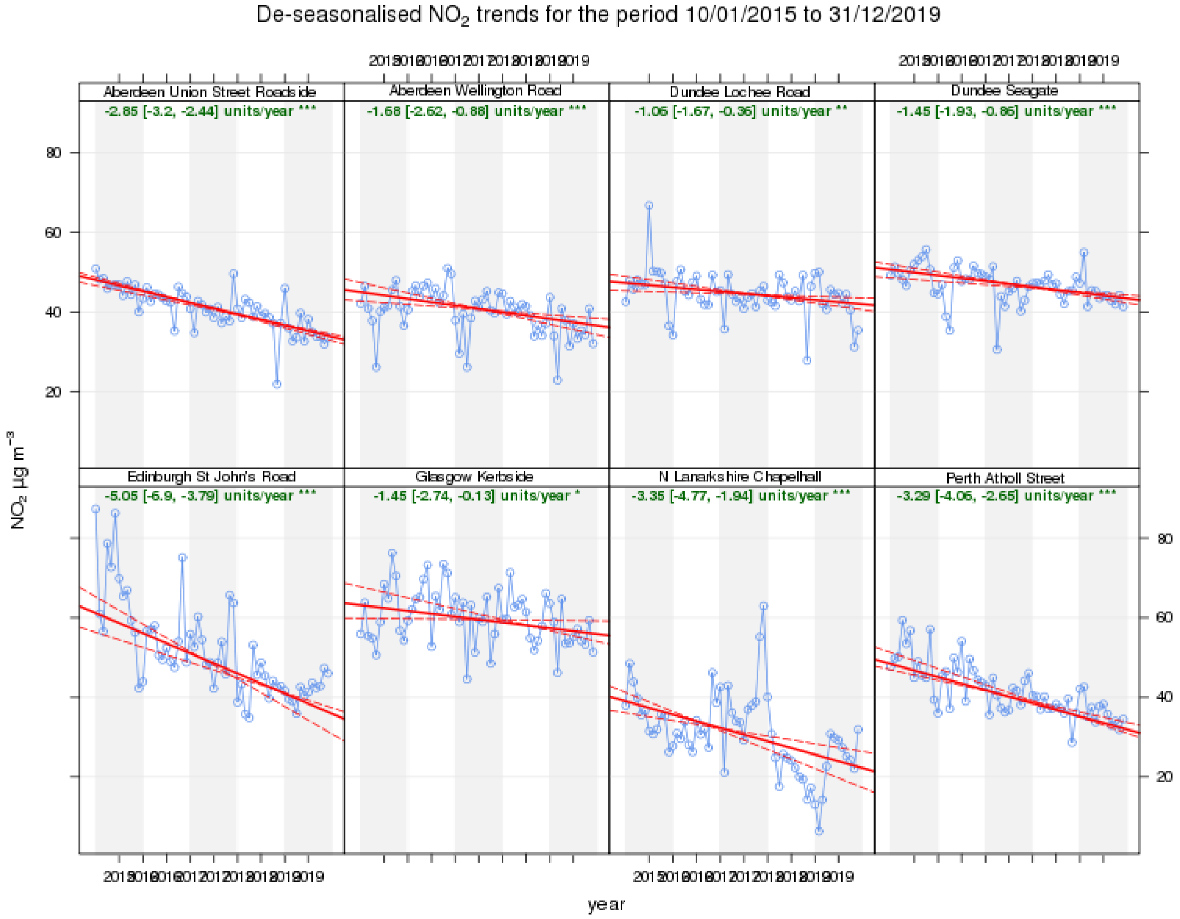


Figure 8-5 Recent Trends in NO_2 Concentration at Eight Long-running Urban Traffic Sites with Exceedances, 2015-2019



8.2 Particulate Matter

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.

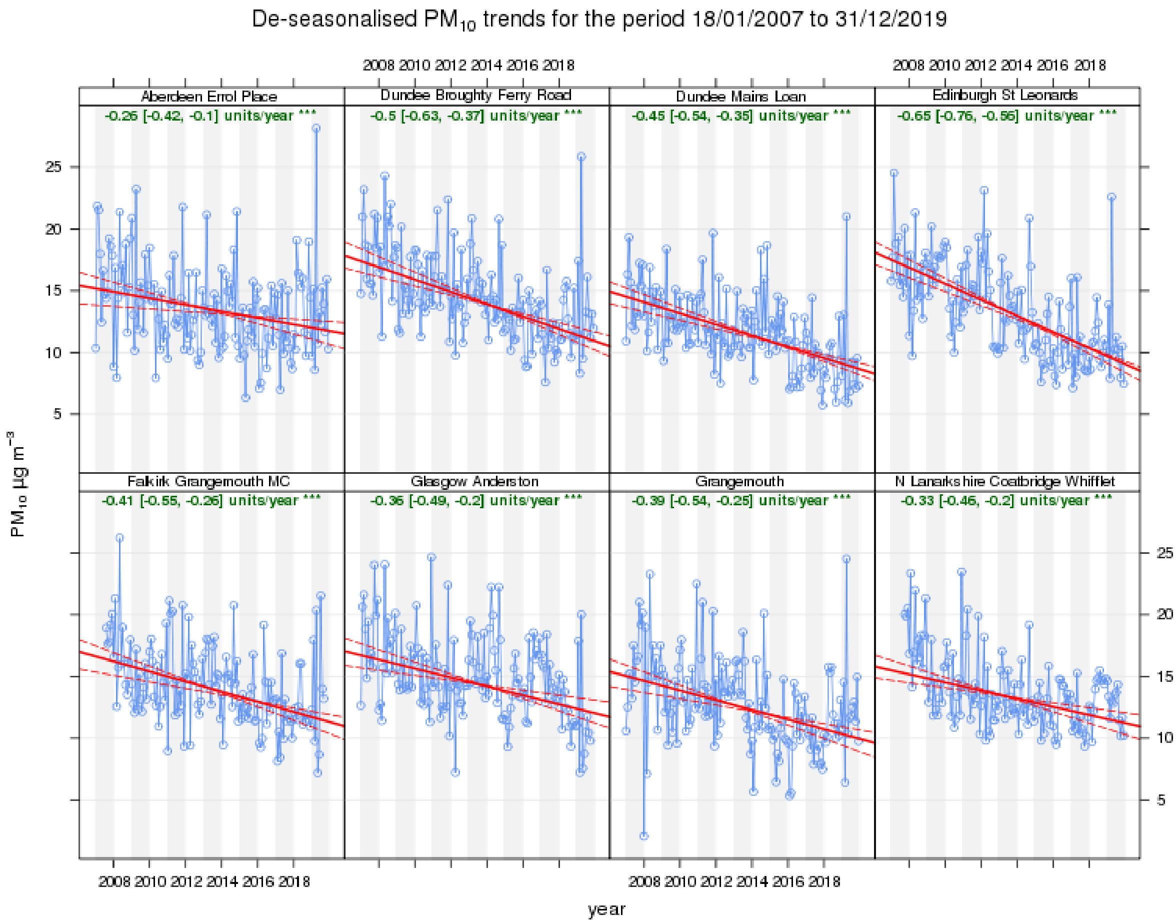
During the period covered by this trend analysis, many of Scotland's monitoring sites have used the Tapered Element Oscillating Microbalance (TEOM) to monitor PM_{10}. For the reasons discussed in Section 5 it is necessary to correct TEOM data for possible evaporation of the volatile component (due to 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), Dundee Broughty Ferry Road (TEOM, data VCM corrected), Dundee Mains Loan (TEOM, data VCM corrected, converted to Fidas in October 2017), Edinburgh St Leonards (FDMS since 2007), Glasgow Anderston (FDMS since 2011, changed to Fidas in November 2018), Grangemouth (FDMS since 2009, changed to BAMs June 2018), Falkirk Grangemouth MC, and North Lanarkshire Coatbridge Whifflet (TEOM). Dundee Broughty Ferry Road and Grangemouth are urban industrial; the rest are urban background.

Error! Reference source not found. 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) negative trend.

Figure 8-6 Trends in PM_{10} Concentration at Six Long-Running Urban Background and Urban Industrial Sites, 2007 – 2019



8.2.2 PM_{10} at Urban Traffic sites

There are 34 PM_{10} 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 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 8-7. The sites selected for this analysis are Aberdeen Wellington Road, East Dunbartonshire Bearsden, Edinburgh Salamander, Fife Cupar, Glasgow Abercromby Street, Glasgow Byres Road, Perth Crieff and West Lothian Broxburn. 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 downward trends (at the 0.001 level), with the exception of Glasgow Abercromby Street which was significant at 0.05 level. The trends indicate that PM_{10} over the past 10 years is decreasing year on year at these roadside sites. The exception to this however is Glasgow sites Abercromby Street and Byres Road where in recent years the trend appears to level off or even increase.

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 2015 – 2019, are shown in Figure 8-8. Figure 8-8 shows that PM_{10} concentrations over the past 5 years at Glasgow sites Abercromby Street and Byres Road have increased rather than decreased as with the 10 years analysis. In addition, statistical analysis of Edinburgh Queensferry road has also indicated an increase trend over the last five years. For the other sites analysed the decrease seen over the last five years is far less compared to 10 years. This shorter-term trend analysis highlights that the long-term downward trend has not continued everywhere over more recent years and concentrations may either be levelling off or increasing.

Figure 8-7 Trends in PM_{10} Concentration at Eight Long-Running Urban Traffic Sites, 2009 – 2019

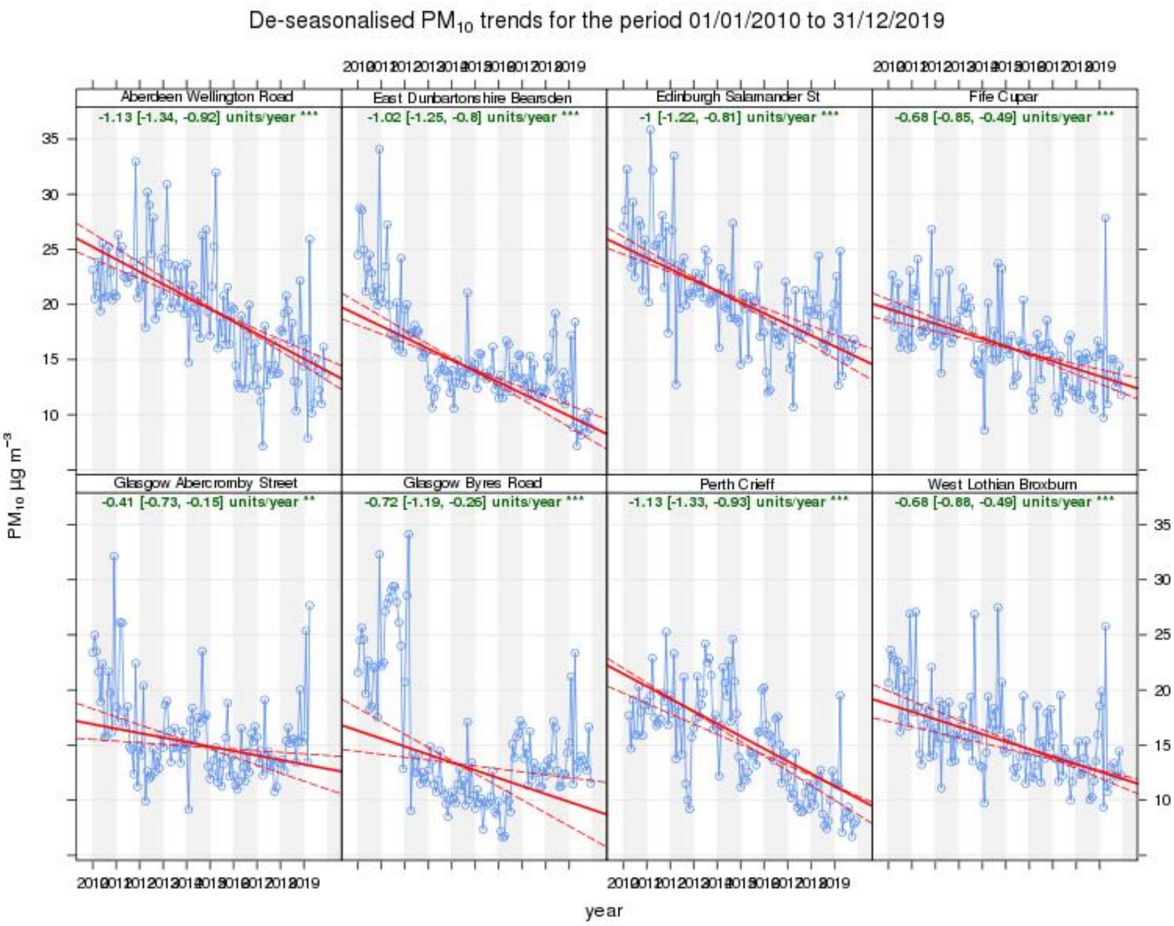
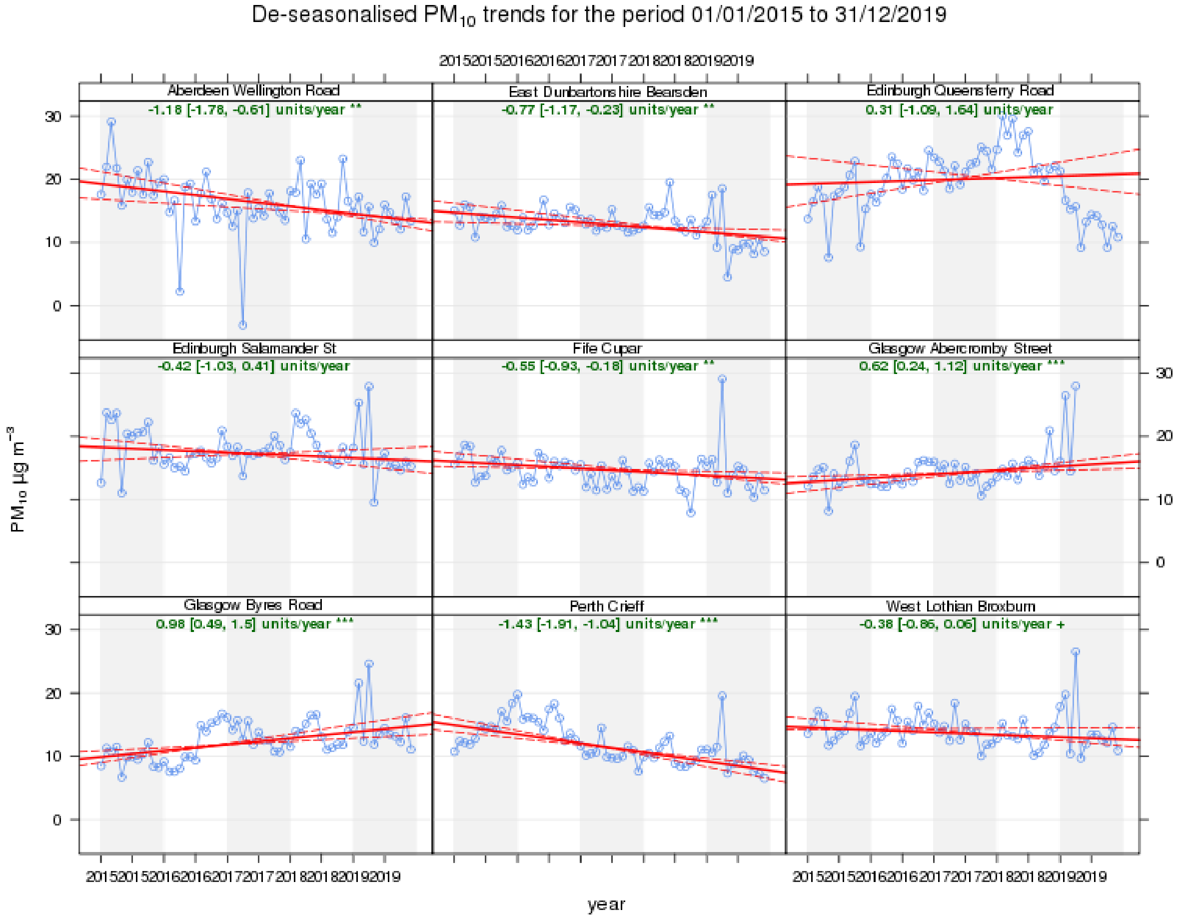


Figure 8-8 Trends in PM_{10} Concentration at Eight Long-Running Urban Traffic Sites, 2015 – 2019



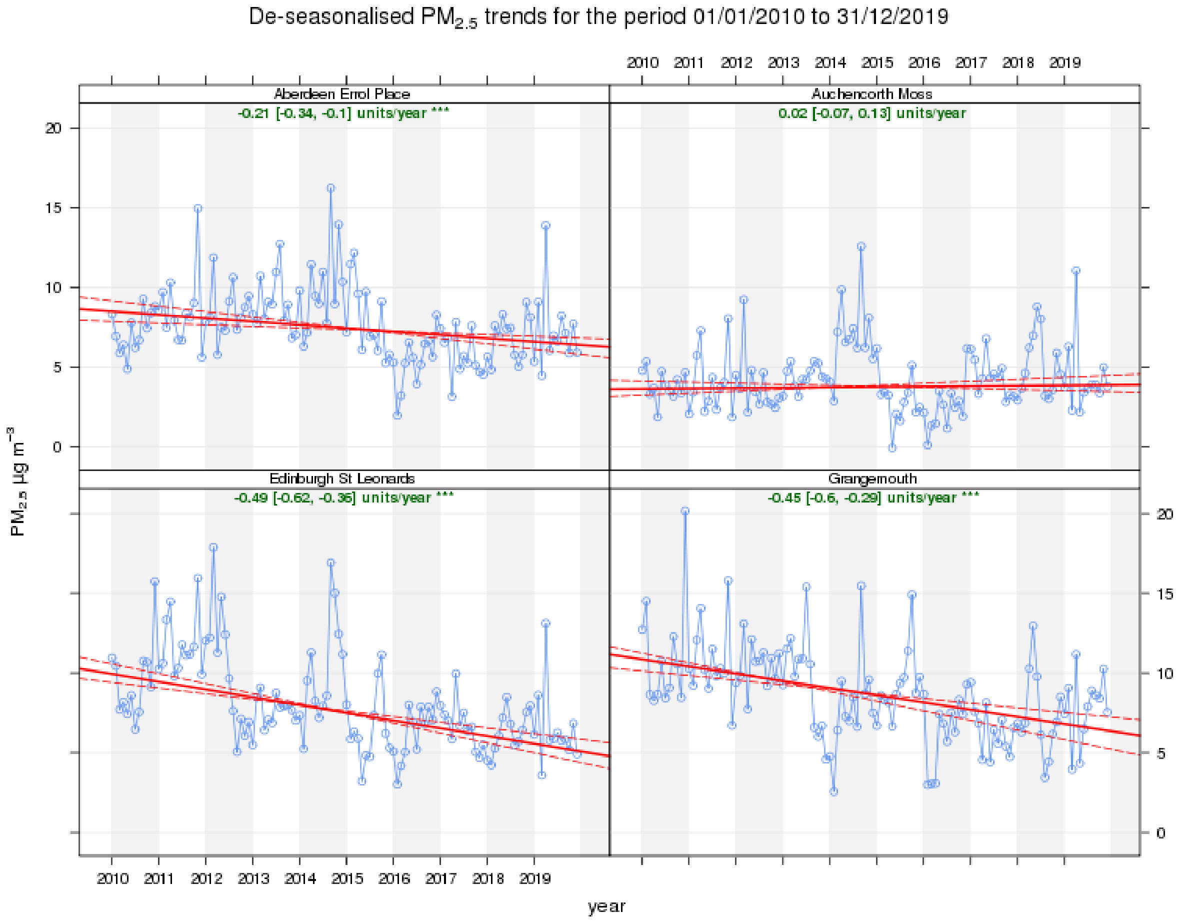
8.3 Particulate Matter as $PM_{2.5}$

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 69 sites monitoring $PM_{2.5}$ in Scotland. However, the vast majority of these sites started monitoring in the last three years with the introduction of the $PM_{2.5}$ objective and the requirement for local authorities to measure the pollutant. By the end of 2019 there were four sites with 10 consecutive years of $PM_{2.5}$ data. These sites are as follows: Aberdeen Errol Place (urban background), Auchencorth Moss (rural), Edinburgh St Leonards (urban background), and Grangemouth (urban industrial). The trend plot for these sites is shown in Figure 8-9. Previous reports in this series have provide trend analysis for daily $PM_{2.5}$ concentrations at the Inverness site, which used to monitor daily mean $PM_{2.5}$ concentrations using a Partisol gravimetric sampler. However, in July 2018 the Partisol was replaced by an automatic Fidas instrument, so Inverness now monitors $PM_{2.5}$ concentrations on an hourly basis.

Aberdeen Errol Place, Edinburgh St Leonards, and Grangemouth sites show slight but highly statistically significant (at the 0.001 level) downward trends for $PM_{2.5}$. Contrary to this, the rural site Auchencorth Moss shows a slight upward trend however it is not statistically significant.

Figure 8-9 Trends in $PM_{2.5}$ Concentration at Four Long-Running Monitoring Sites, 20010 – 2019



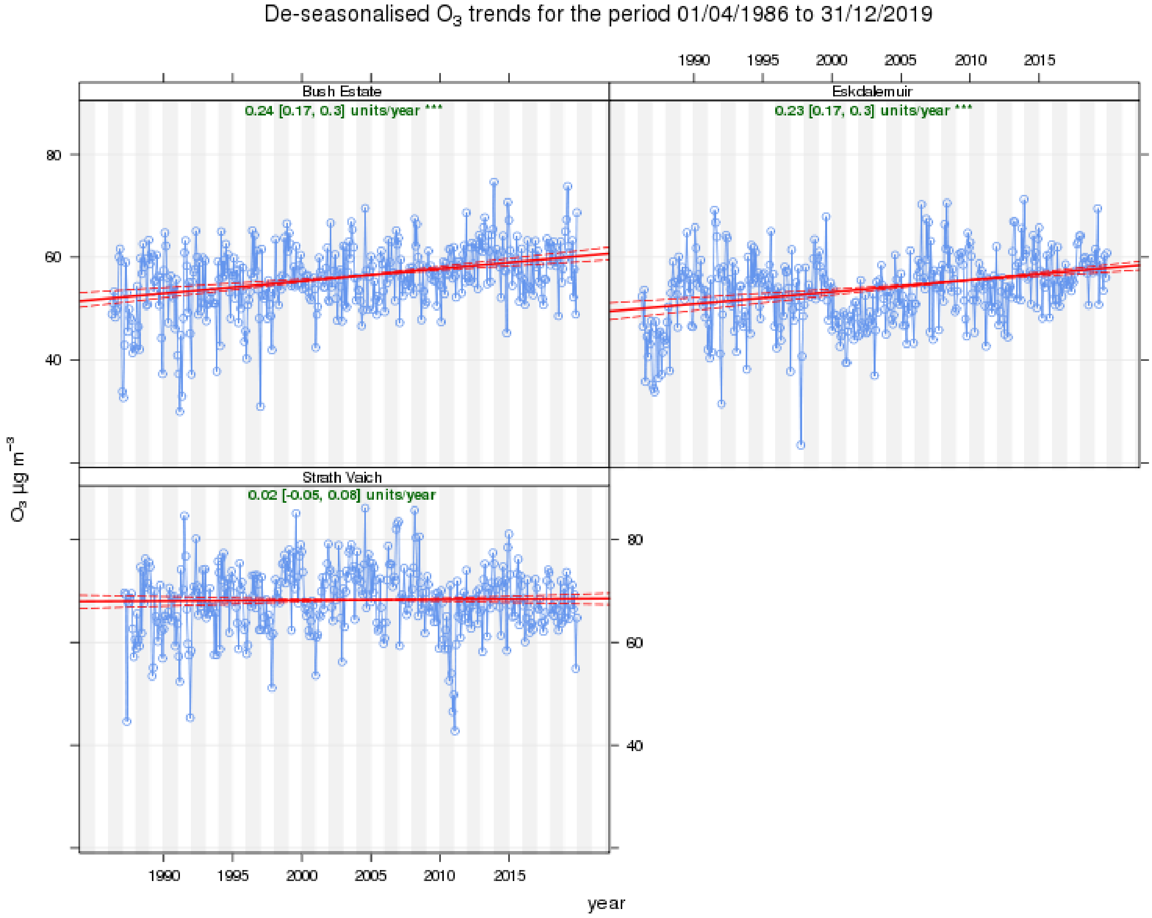
8.4 Ozone

8.4.1 Rural Ozone

Three of Scotland's rural air quality monitoring stations have been monitoring ozone for 31 years, 1986 – 2018. These are Bush Estate, Eskdalemuir and Strath Vaich. Figure 8-10 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 upward trend in monthly mean rural ozone concentrations over this period. For Bush Estate and Eskdalemuir this trend was highly statistically significant at the 0.001 level. For Strath Vaich the trend was smaller and was 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.[11]

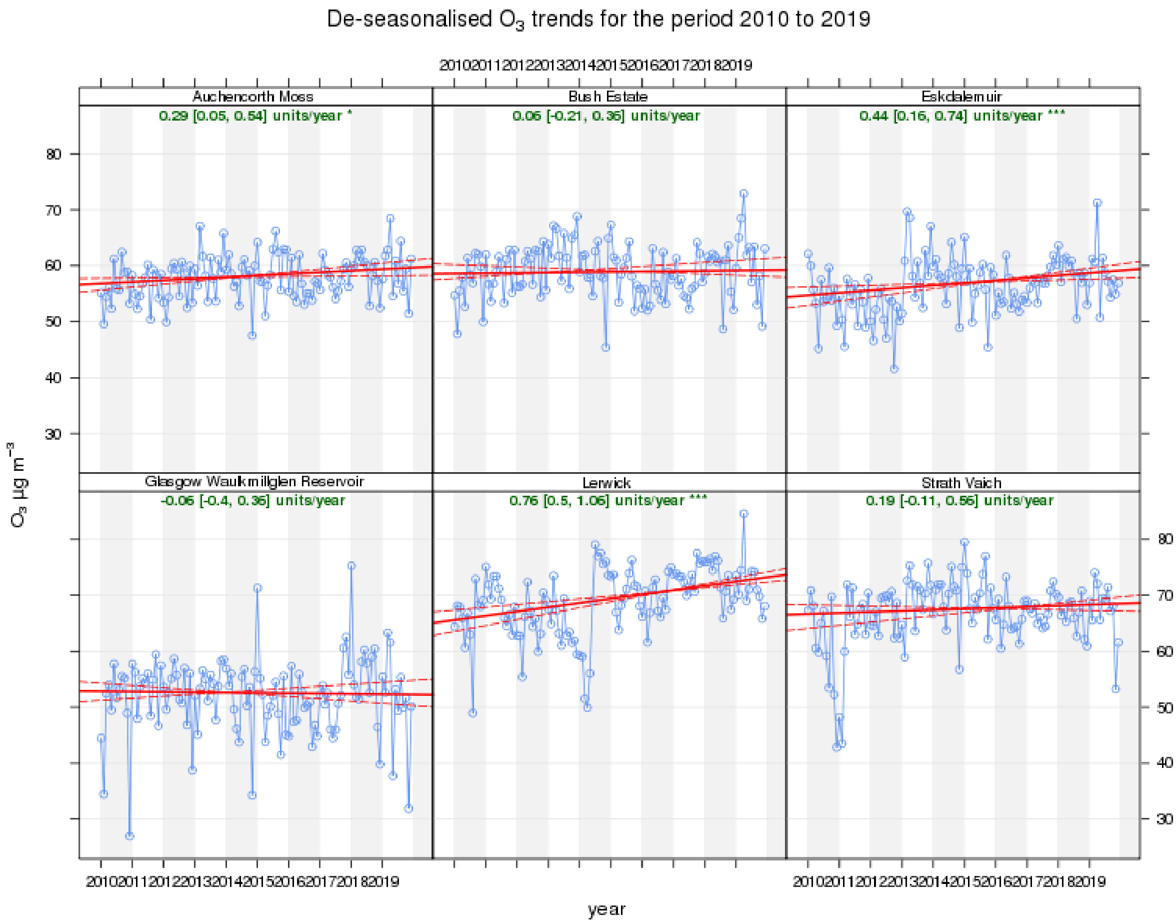
[11] See the APIS webpage "Ozone" at http://www.apis.ac.uk/overview/pollutants/overview_O3.htm

Figure 8-10 Trends in O_3 Concentrations at Long-Running Rural Sites, 1986 – 2019



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.

Figure 8-11 Trends in O_3 Concentrations at Six Long-Running Rural Sites, 2010 – 2019



8.4.2 Urban Background Ozone

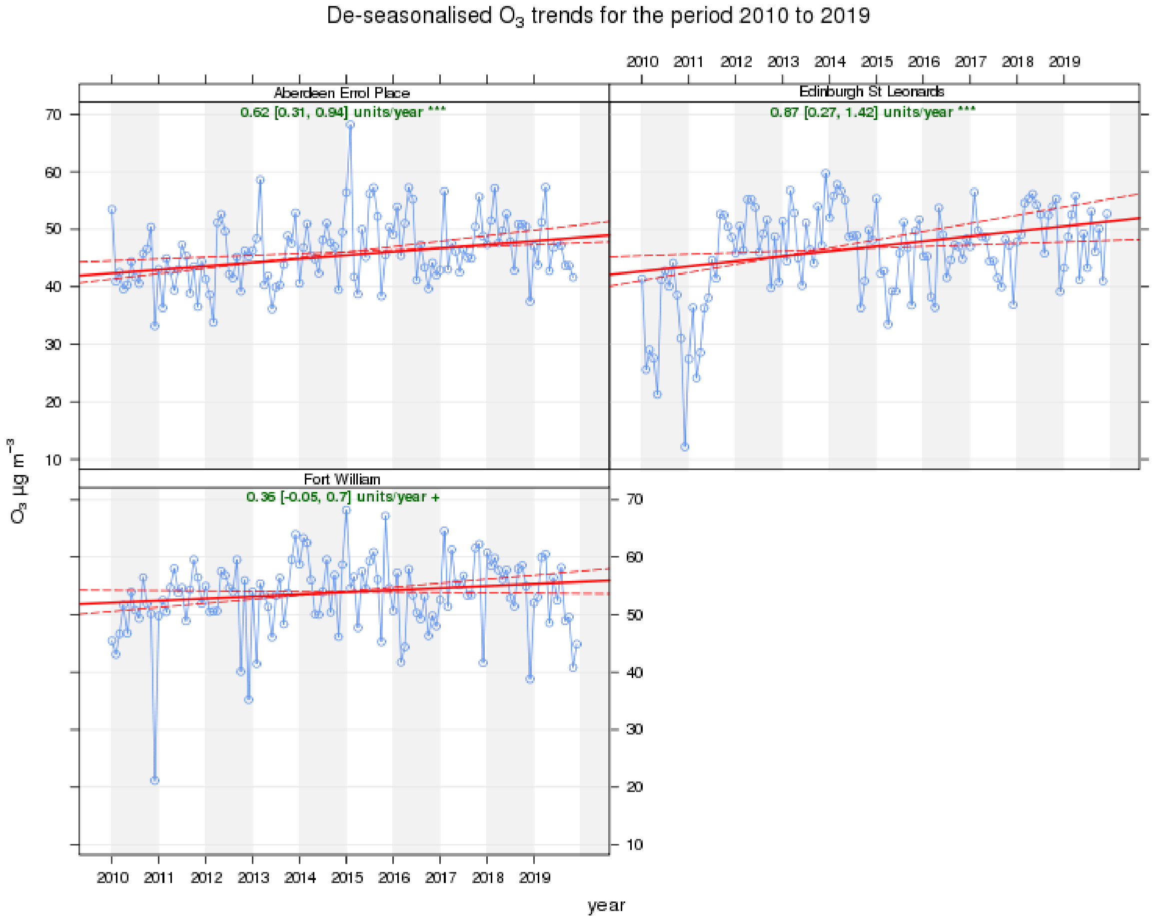
Figure 8-12 shows trends in de-seasonalised monthly mean ozone concentrations at the three Scottish urban background monitoring sites which have been monitoring ozone for the past 10 years, 2010-2019: Aberdeen Errol Place, Edinburgh St Leonards and Fort William.

There is again an upward 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) upwards 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 – 2019



8.5 Summary of trends

The Following trends have been observed in the measurements from Scottish air quality monitoring stations:

1. Trend analysis of nitrogen dioxide concentrations at Scotland's five long-running urban non-roadside (i.e. urban background and urban industrial) sites suggests that NO_2 concentrations are in general decreasing however not all at the same rate. It also indicates that NO_2 concentrations are decreasing at a greater rate in the larger urban areas where concentrations were higher. This is consistent with previous years analysis
2. Nitrogen dioxide concentrations at Scotland's three long-running rural sites showed decreasing trends. Bush Estate and Eskdalemuir showed small but highly significant downward trends. However, this was not the case for Glasgow Waukmillglen Reservoir, where concentrations were decreasing very slightly year-on-year, though the trend was not significant.
3. Scotland has a large number of urban traffic (roadside and kerbside) monitoring sites monitoring NO_2, of which 30 have now been operating for at least 10 years. This trend analysis therefore focussed on eight of these sites that have operated for 10 years and have reported exceedances of the AQS objective in recent years. All these sites showed significant downward trends.
4. Examination of trends at the same eight sites over the most recent five complete years (2015 to 2019) indicates that the patterns are mostly like the 10-year trends. The exceptions are that

Glasgow Kerbsides trend over the most recent five years is not as significant as the 10 years indicating that the downward trend is levelling off. In addition, Edinburgh St Leonards and N Lanarkshire Chapelhall's decreasing trends has become more significant in recent years.

5. PM_{10} particulate matter at Scotland's eight long-running urban background and Industrials sites showed highly significant downward trends over the last 10 years.
6. PM_{10} particulate matter at Scotland's nine long-running urban traffic (roadside and kerbside) sites showed highly statistically significant downward trends at all sites with the exception of Glasgow Abercromby Street.
7. Examination of trends in PM_{10} at the same nine sites over the most recent five complete years (2014 to 2018) indicates that, at some of these, the decreasing trends have continued but at others they have weakened, levelled off or switched to an increasing trend (e.g. Glasgow Byres Road and Glasgow Abercromby Street). For Edinburgh Queensferry Road analysis indicates an increasing trend. However, this may have been influenced by ongoing construction works close to the monitor location.
8. Only four sites in Scotland have 10 years or more $PM_{2.5}$ data. Aberdeen Errol Place, Edinburgh St Leonards, and Grangemouth sites show slight but highly statistically significant downward trends. Contrary to this, the rural site Auchencorth Moss shows a slight upward trend however it is not statistically significant.
9. Ozone has been measured at three rural sites in Scotland (Bush Estate, Eskdalemuir and Strath Vaich) for thirty years. All three sites showed small positive trends over this very long period; insignificant at Strath Vaich but highly statistically significant at the other two sites.
10. Ozone has been measured for the past 10 years at six rural sites. Over this more recent period five sites showed increasing trends at varying levels of statistical Significance and Glasgow Waukmillglen Reservoir showing a non-significant downward trend.
11. Ozone concentrations at the three urban background sites show upward trends over the past 10 years.

9 Emissions 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[12]. 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. 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, with permission from SEPA. The data provided is up to 2018, which is the most recent data available at the time of writing this report.

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).

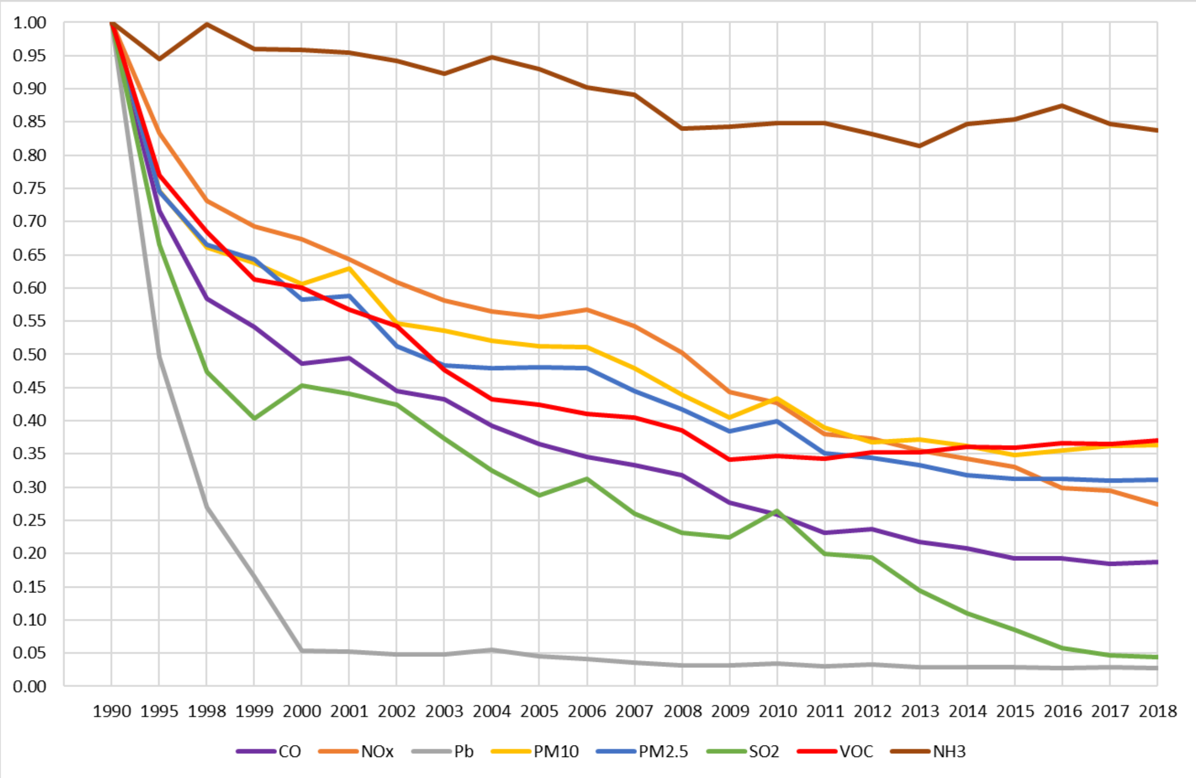
Since the 2017 report emissions data for $PM_{2.5}$ is included at the request of both the Scottish and Welsh Governments. It should be note however that the emissions dataset for $PM_{2.5}$ is very limited, and the inventory is heavily based on assumptions of $PM_{2.5}$ share of the PM_{10} for different emissions sources. In addition, in 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: 1990 – 2018*".

When comparing previously report emissions data you will see a slight difference in the figures stated. This is because the emissions dataset is recalculated each year from 1990 and a revision of historic time series is carried out if a more accurate and applicable data source becomes available.

Figure 9.1 illustrates the decline in emissions since 1990 of all eight pollutants normalised to provide a relative rate of decline. It shows that all pollutant emission levels have significantly declined, at a similar rate (with exception of ammonia (NH_3) and lead (Pb)), since 1990. However, this decline has levelled off and in some cases began to increase in recent years for a number of the pollutants. The higher rate of reduction in Pb between 1990 and 2000 coincides with the phasing out of leaded petrol in 1999.

[12] Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 1990 – 2016
http://naei.beis.gov.uk/reports/reports?report_id=970

Figure 9.1 Scotland normalised trends for all monitored pollutants



Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 1990 – 2018

9.1.1 Scotland NOx Inventory by NFR Sector 1990 – 2018

Table 9-1 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.

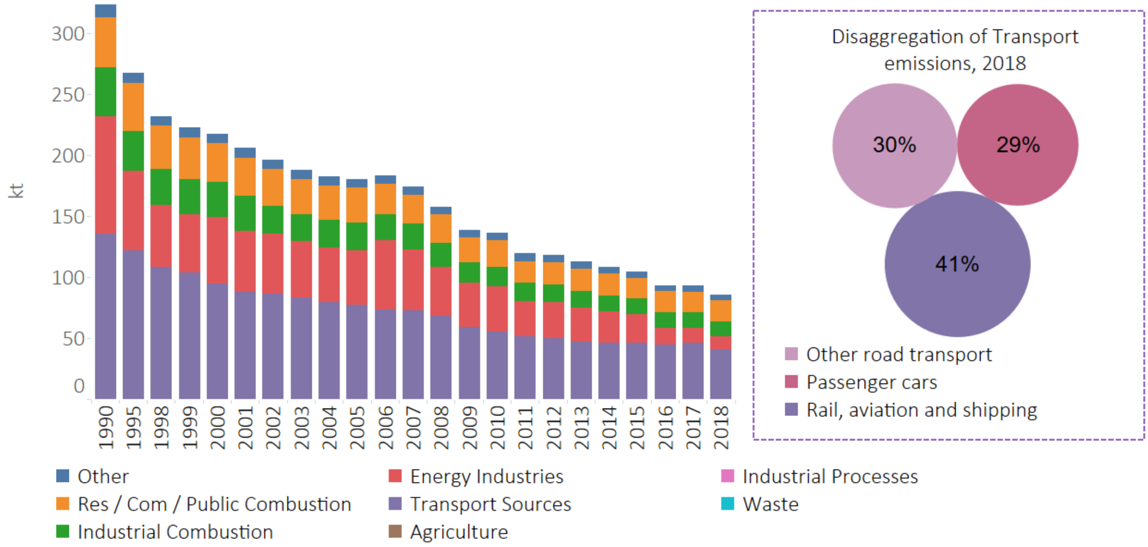
Table 9-1 Summary of NO_x emission estimates for Scotland (1990 – 2018)

Category	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006
Energy Industries	96.7	65.0	51.0	48.4	54.8	50.3	49.0	46.3	44.8	44.5	57.0
Industrial Combustion	39.9	32.8	29.8	28.6	28.5	28.3	23.0	22.2	22.7	22.5	20.9
Transport Sources	135.3	121.9	108.1	103.4	94.5	87.8	86.5	83.0	79.2	77.5	73.6
Other	24.8	22.3	23.1	19.5	17.7	19.6	17.2	16.0	15.6	15.0	15.2
Residential & other combustion	41.2	39.4	35.1	34.0	32.0	31.4	30.0	28.9	28.6	28.6	24.8
Total:	**337.8**	**281.5**	**247.1**	**234.0**	**227.4**	**217.4**	**205.6**	**196.2**	**191.0**	**188.2**	**191.5**

Category	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Energy Industries	50.1	40.2	35.8	37.1	28.9	30.1	27.9	26.2	24.0	14.4	11.7	10.9
Industrial Combustion	21.1	19.9	16.6	16.4	14.6	14.2	13.3	12.9	12.4	12.2	12.8	12.2
Transport Sources	72.5	68.1	59.4	55.2	51.6	49.7	47.3	46.0	45.9	44.3	46.5	40.9
Other	15.4	18.5	17.3	14.2	15.1	13.4	13.2	13.2	12.8	12.8	12.0	11.5
Residential & other combustion	23.9	23.3	20.9	21.5	18.1	18.5	18.2	17.8	16.7	17.5	16.8	16.9
Total:	**183.1**	**170.0**	**150.0**	**144.3**	**128.4**	**125.9**	**119.9**	**116.0**	**111.7**	**101.1**	**99.8**	**92.4**

Units: kilotonnes (kt) Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 1990 – 2017

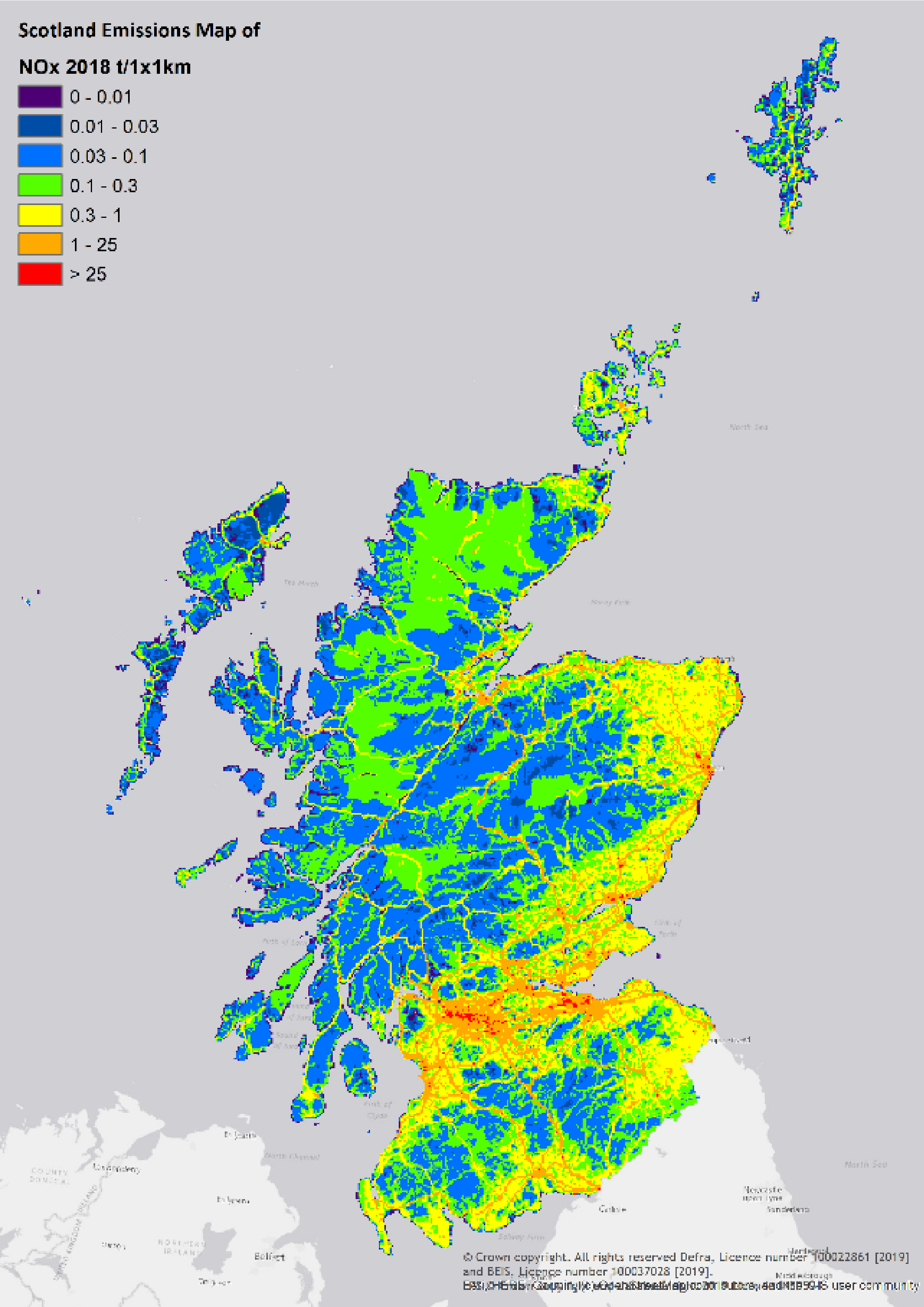
Figure 9.2 Time series of Scotland NO_x emissions 1990-2017



Scotland's NOx Emissions have declined by 73% since 1990 and were estimated to be 86kt in 2018 and representing 10% of 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, which is 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 (89% of 2018 passenger car emissions is due to diesel cars). The peak in NOx emissions in 2006 is due to an increase in emissions linked to the increased use of coal at power stations that year. The decline in NOx emissions since 2007 is also linked to the power sector, as Boosted Over-Fire Air (BOFA) abatement systems were fitted to all four of Longannet's units, to reduce NOx 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.

Figure 9.3 shows a map of Scotland's NOx emissions in 2018.

Figure 9.3 Map of NO_x Emissions in Scotland, 2018



Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 1990 – 2018

9.1.2 Scotland PM_{10} Inventory by NFR Sector 1990 – 2018

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 (1990 – 2018)

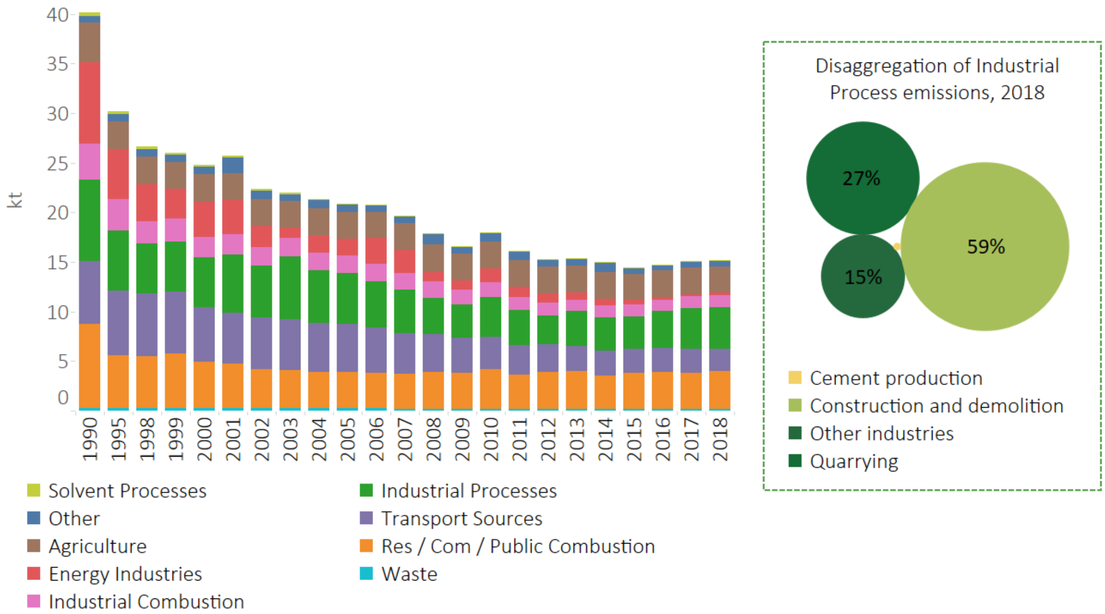
Category	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006
Agriculture	4.0	2.8	2.8	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Energy Industry	8.2	5.1	3.7	3.0	3.6	3.4	2.1	1.1	1.8	1.7	2.5
Industrial Combustion	3.7	3.2	2.3	2.3	2.1	2.0	1.9	1.8	1.8	1.8	1.8
Transport	8.2	7.7	7.5	7.0	6.1	5.8	5.8	5.6	5.4	5.5	5.2
Industrial Processes	8.2	6.0	5.0	5.1	5.0	5.8	5.3	6.4	5.3	5.1	4.7
Solvent Processes	0.4	0.3	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1
Residential & Other Combustion	9.0	5.8	5.8	6.0	5.2	5.8	4.4	4.4	4.1	4.1	4.0
Other	0.5	0.5	0.5	0.6	0.7	0.7	0.7	0.5	0.6	0.6	0.5
Total:	**41.6**	**30.9**	**27.3**	**26.2**	**24.9**	**25.8**	**22.3**	**22.0**	**21.3**	**20.9**	**21.0**

Category	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Agriculture	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.6	2.7	2.7	2.6
Energy Industry	2.3	1.0	1.0	1.4	1.0	1.0	0.7	0.6	0.5	0.3	0.2	0.2
Industrial Combustion	1.7	1.6	1.5	1.5	1.3	1.3	1.2	1.2	1.2	1.1	1.2	1.2
Transport	4.5	4.3	3.9	3.5	3.2	3.0	2.8	2.7	2.6	2.5	2.5	2.4
Industrial Processes	4.4	3.7	3.3	4.0	3.5	2.9	3.5	3.4	3.3	3.8	4.1	4.2
Solvent Processes	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Residential & Other Combustion	3.9	4.1	4.0	4.4	3.9	4.1	4.2	3.8	4.0	4.1	4.0	4.2
Other	0.5	0.9	0.5	0.7	0.7	0.4	0.6	0.8	0.4	0.4	0.4	0.4
Total:	**19.7**	**17.6**	**16.5**	**17.6**	**15.7**	**15.1**	**15.1**	**14.4**	**14.2**	**14.6**	**14.9**	**14.9**

Units: kilotonnes (kt)

Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 1990 – 2018

Figure 9.4 Time series of Scotland's PM_{10} emissions 1990-2018

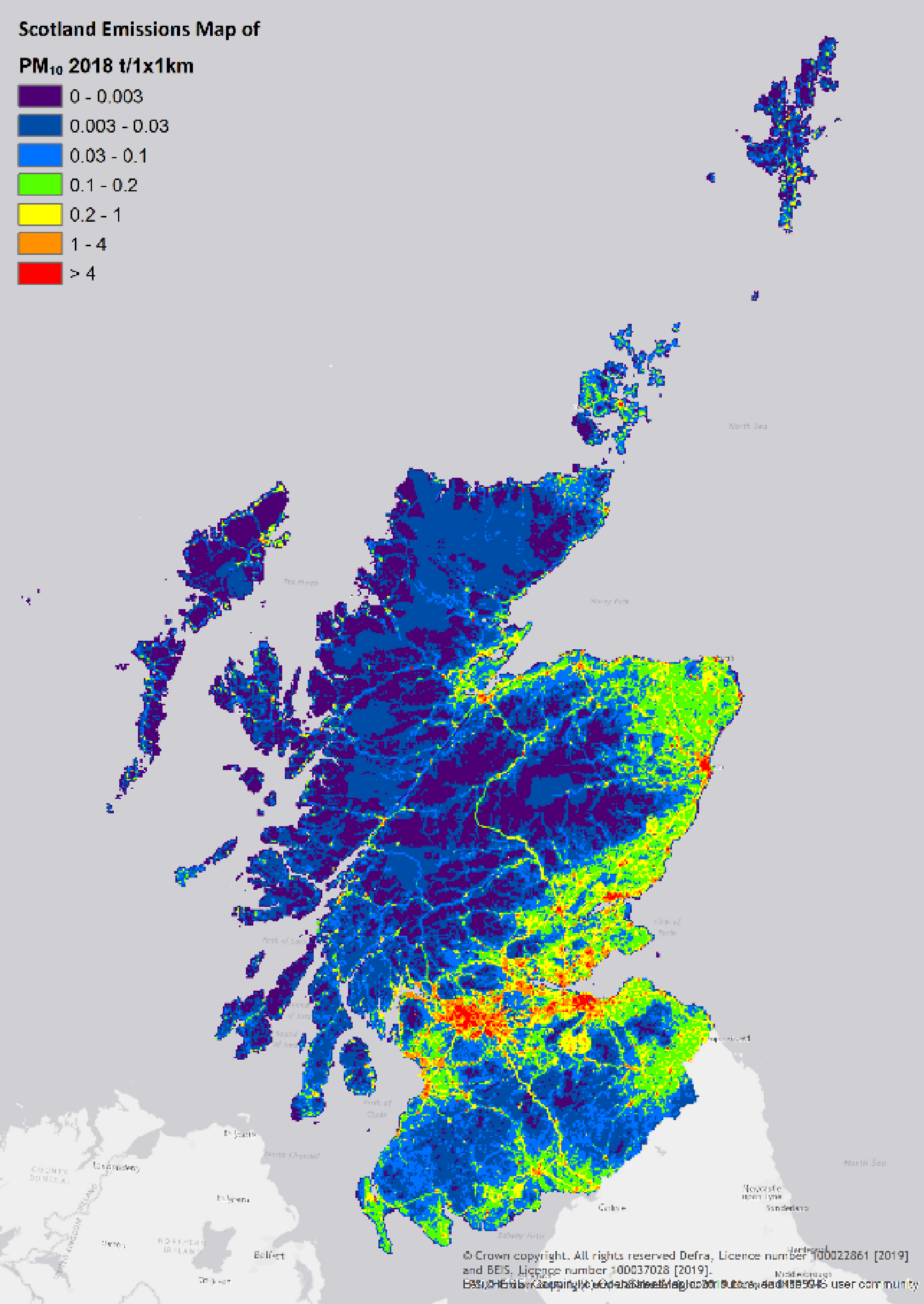


Emissions of PM_{10} have declined by 62% since 1990 and in 2018 and were estimated to be 15kt (9% of the UK total). Unlike most other pollutants, the emissions profile of PM_{10} is diverse: transport sources, residential and industrial processes each accounted for over 15% of total emissions in 2018. 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 gas in energy generation (which has negligible PM_{10} emissions) in place of coal. PM_{10} exhaust emissions from diesel vehicles have been decreasing due to the successive introduction of tighter emission standards over time. Increasingly, non-exhaust sources of PM_{10} (for example tyre wear) have become more important to consider as exhaust PM_{10} has reduced. In 2018, 79% of emissions from the road transport sector (75% in 2017) were related to non-exhaust sources.

The decline in PM_{10} emissions has basically stopped across all sectors over the past few years with some, such as Industrial Processes increasing. This has been attributed to an increased quantity of wood fuel use. Though PM_{10} emissions have reduced since 1990, overall, there has been no significant reduction in PM_{10} emissions since 2011.

Figure 9.5 shows a map of PM_{10} emission in Scotland for 2018.

Figure 9.5 Map of PM_{10} Emissions in Scotland, 2018



Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 1990 – 2018

9.1.3 Scotland $PM_{2.5}$ Inventory by NFR Sector 1990 – 2018

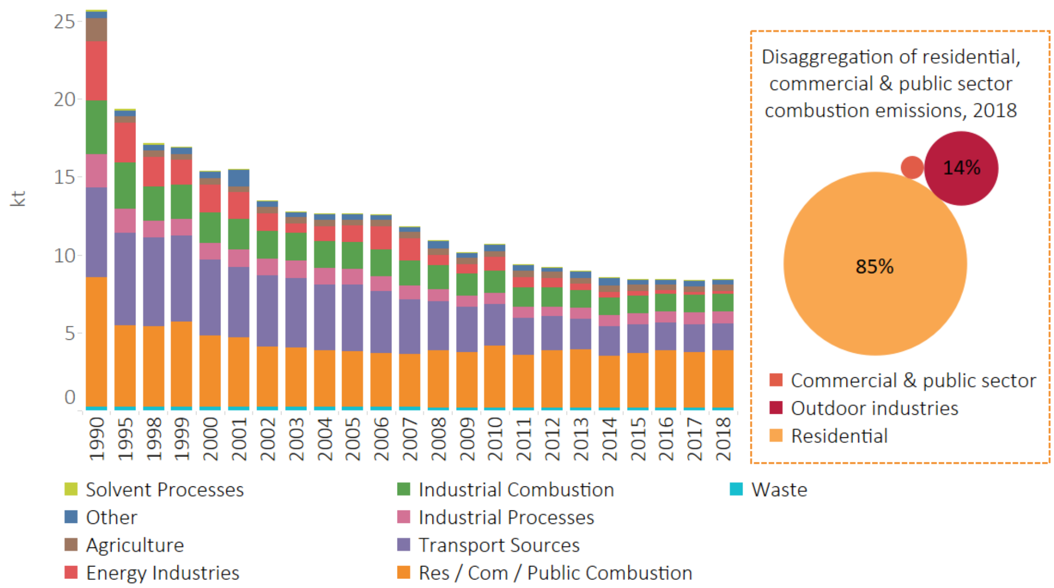
Table 9-3 and figure 9.6 provides a summary of $PM_{2.5}$ emission estimates for Scotland by category. The detailed data are available in the report and website citied in the introduction to this chapter.

Table 9-3 Summary of $PM_{2.5}$ emission estimates for Scotland (1990 – 2018)

Category	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006
Agriculture	1.48	0.42	0.42	0.41	0.41	0.40	0.40	0.40	0.41	0.40	0.40
Energy Industry	3.84	2.51	1.92	1.58	1.79	1.72	1.12	0.60	0.97	1.02	1.47
Industrial Combustion	3.44	3.03	2.17	2.18	1.99	1.95	1.78	1.74	1.70	1.76	1.75
Transport	7.45	7.04	6.77	6.30	5.47	5.15	5.12	4.89	4.74	4.77	4.52
Industrial Processes	2.15	1.51	1.11	1.07	1.03	1.11	1.05	1.18	1.06	1.03	0.95
Solvent Processes	0.13	0.11	0.09	0.07	0.06	0.05	0.05	0.04	0.03	0.03	0.03
Residential & Other Combustion	8.79	5.67	5.62	5.88	5.02	5.54	4.30	4.25	4.04	4.00	3.87
Other	0.19	0.18	0.17	0.20	0.22	0.21	0.24	0.18	0.22	0.20	0.17
Total:	**27.3**	**20.3**	**18.1**	**17.5**	**15.8**	**15.9**	**13.8**	**13.1**	**13.0**	**13.0**	**13.0**

Category	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Agriculture	0.40	0.40	0.39	0.39	0.39	0.39	0.39	0.39	0.38	0.38	0.38	0.38
Energy Industry	1.41	0.63	0.63	0.84	0.63	0.60	0.43	0.37	0.31	0.23	0.17	0.20
Industrial Combustion	1.64	1.58	1.41	1.43	1.28	1.21	1.11	1.13	1.15	1.08	1.14	1.14
Transport	3.87	3.66	3.31	2.90	2.57	2.38	2.18	2.06	1.97	1.92	1.90	1.80
Industrial Processes	0.88	0.77	0.68	0.76	0.71	0.63	0.68	0.72	0.68	0.75	0.77	0.77
Solvent Processes	0.03	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Residential & Other Combustion	3.81	4.02	3.94	4.32	3.76	4.02	4.08	3.67	3.87	4.01	3.91	4.05
Other	0.17	0.37	0.18	0.28	0.28	0.17	0.25	0.35	0.20	0.17	0.19	0.19
Total:	**12.0**	**11.1**	**10.4**	**10.7**	**9.4**	**9.3**	**8.9**	**8.4**	**8.4**	**8.4**	**8.3**	**8.4**

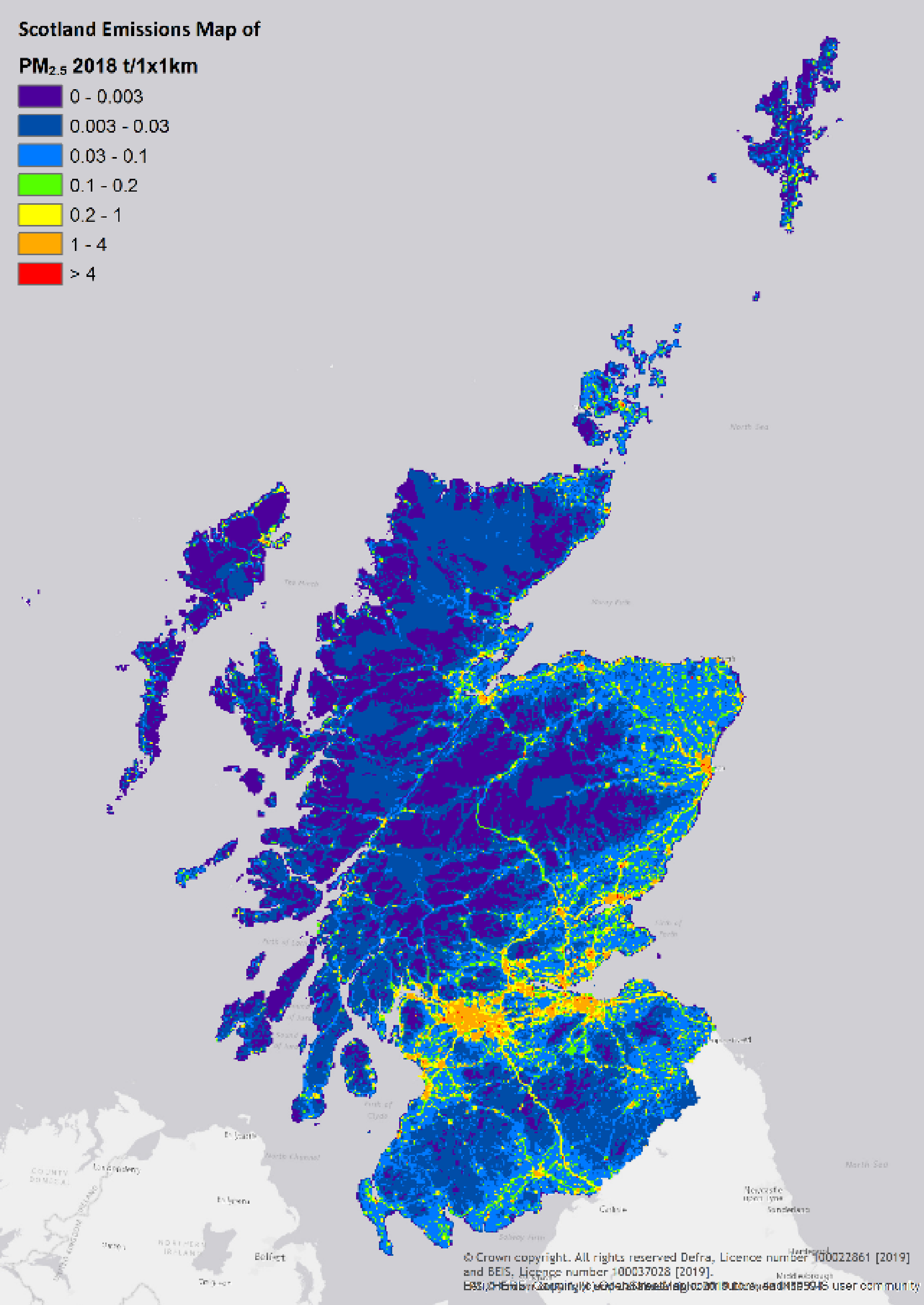
Figure 9.6 Time series of Scotland's $PM_{2.5}$ emissions 1990-2018



Emissions of $PM_{2.5}$ have declined by 67% since 1990 and in 2017 were estimated to be 8kt (8% of the UK total). As with PM10, PM2.5 emissions have a large number of significant sources. Process emissions tend to produce coarser PM fractions and as such combustion emission are of greater importance for $PM_{2.5}$ compared to PM_{10} emissions. For $PM_{2.5}$, the residential, commercial and public sector combustion category accounts for 44% of 2018 emissions. The decline in emission since 1990 has primarily been attributed to the switch in the fuel mix use in electricity generation away from coal and towards natural gas, especially in the early time series. Later year reductions in emissions is attributed to the Transport sector, mainly due to the introduction of more stringent emissions standards through time. As can be seen in table 9-3 and figure 9.5 the decline in emissions has significantly reduced over the past few years with no significant decrease since 2013. 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.

Figure 9.7 shows a map of $PM_{2.5}$ emissions in Scotland for 2018.

Figure 9.7 Map of $PM_{2.5}$ Emissions in Scotland, 2018



Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 1990 – 2018

9.1.4 Scotland Ammonia (NH_3) Inventory by NFR Sector 1990 – 2018

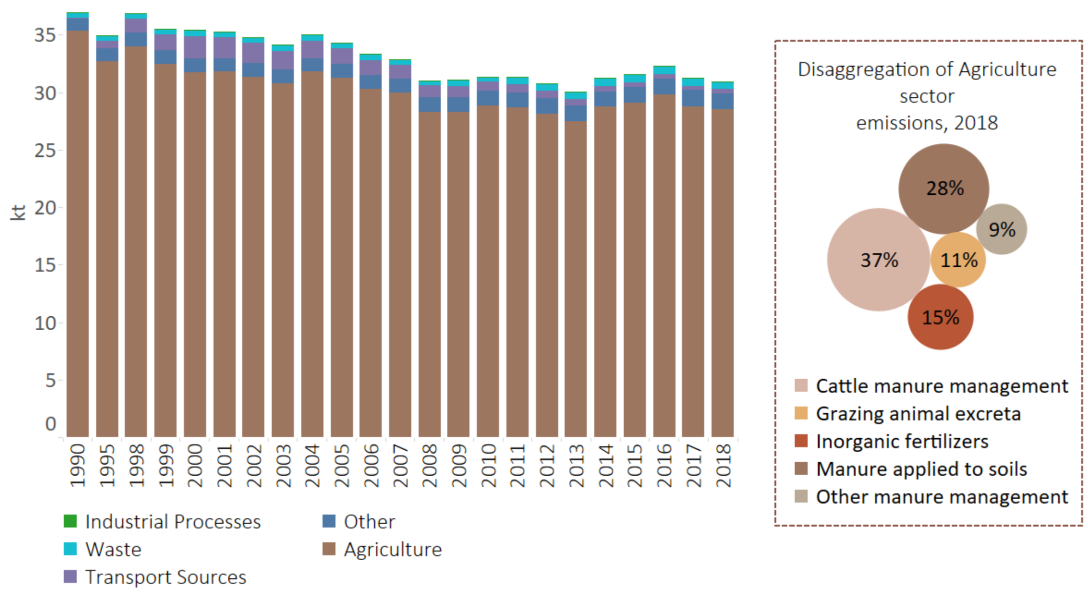
Table 9-4 and figure 9.8 provides a summary of Ammonia emission estimates for Scotland by category. The detailed data are available in the report and website citied in the introduction to this chapter.

Table 9-4 Summary of Ammonia emission estimates for Scotland (1990 – 2018)

Category	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006
Agriculture	35.32	32.71	33.99	32.48	31.77	31.78	31.36	30.79	31.80	31.22	30.30
Industrial Processes	0.09	0.09	0.08	0.07	0.08	0.08	0.07	0.07	0.08	0.07	0.06
Transport	0.08	0.62	1.18	1.34	1.97	1.84	1.75	1.60	1.49	1.36	1.28
Waste	0.36	0.39	0.41	0.41	0.41	0.42	0.46	0.47	0.48	0.46	0.47
Other	1.21	1.21	1.29	1.28	1.27	1.27	1.27	1.29	1.28	1.32	1.31
Total:	**37.06**	**35.03**	**36.95**	**35.58**	**35.50**	**35.39**	**34.90**	**34.22**	**35.14**	**34.43**	**33.42**

Category	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Agriculture	29.98	28.28	28.28	28.82	28.66	28.14	27.50	28.74	29.08	29.83	28.80	28.48
Industrial Processes	0.07	0.06	0.06	0.07	0.07	0.07	0.05	0.05	0.05	0.05	0.05	0.06
Transport	1.17	1.04	0.99	0.86	0.74	0.65	0.55	0.48	0.43	0.41	0.38	0.37
Waste	0.48	0.40	0.53	0.32	0.55	0.55	0.59	0.66	0.64	0.66	0.68	0.63
Other	1.30	1.36	1.36	1.38	1.40	1.44	1.48	1.43	1.44	1.45	1.49	1.51
Total:	**33.00**	**31.14**	**31.22**	**31.46**	**31.43**	**30.85**	**30.17**	**31.36**	**31.64**	**32.40**	**31.39**	**31.05**

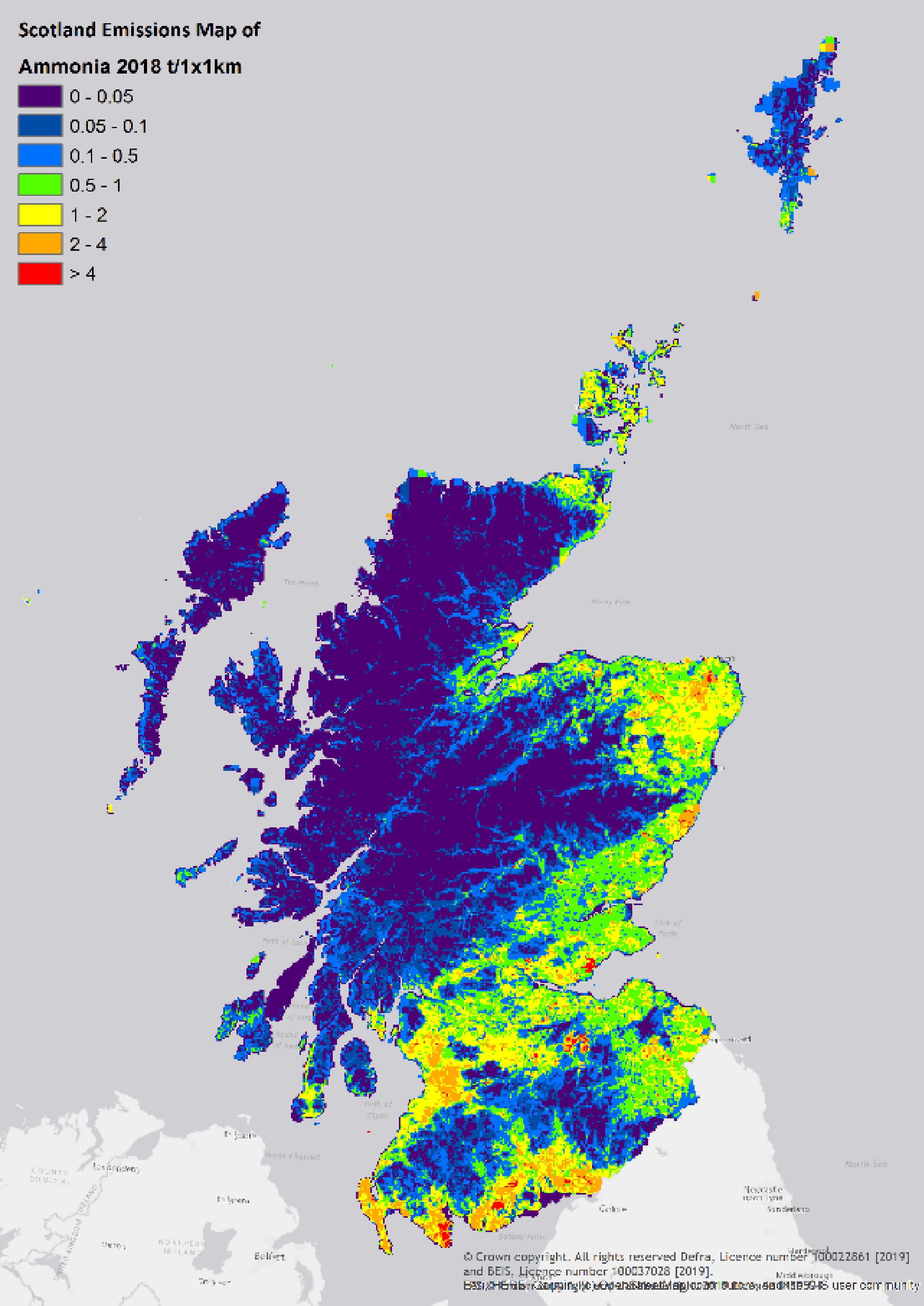
Figure 9.8 Time series of Scotland's Ammonia emissions 1990-2018



Emissions of ammonia were estimated to be 31kt in 2018. These emissions have declined by 16% since 1990 and accounted for 11% of the UK total in 2018. Agriculture sources have dominated the inventory throughout the time-series, with cattle manure management accounting for at least 30% of the emissions from this sector across the entire time-series. The trend in NH_3 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. However, an increased use of urea-based fertilisers, which are associated with higher NH_3 emission factors, has had the opposite effect in recent years. The result is a plateauing of emissions since 2008, with an observed increase between 2013 and 2016. The land-spreading of non-manure digestates have caused additional increases over this period. Increases in the 1990s in Transport are linked to the introduction of three-way catalytic converters, although subsequent technological advancements mean that emissions have been declining since 2000.

Figure 9.9 shows a map of Ammonia emissions in Scotland for 2018.

Figure 9.9 Map of Ammonia Emissions in Scotland, 2018



Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 1990 – 2018

9.1.5 Scotland NMVOC Inventory by NFR Sector 1990 – 2018

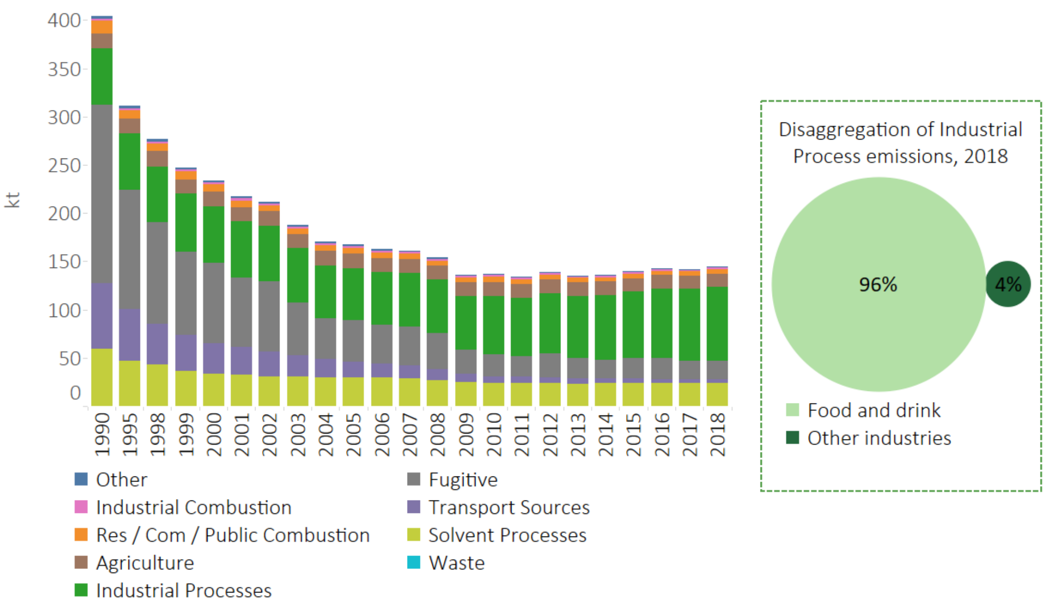
Table 9-5 and figure 9.10 provides a summary of Non Methane Volatile Organic Compounds (VOC) emission estimates for Scotland by category. The detailed data are available in the report and website citied in the introduction to this chapter.

Table 9-5 Summary of Ammonia NMVOC estimates for Scotland (1990 – 2018)

Category	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006
Agriculture	15.6	15.4	15.4	14.8	15.2	15.0	15.0	15.0	15.2	15.0	14.6
Fugitive	185.4	124.3	105.8	87.1	83.0	72.6	73.0	54.9	41.8	42.9	40.3
Industrial Combustion	2.6	2.3	2.4	2.4	2.3	2.4	2.3	2.2	2.3	2.2	2.2
Industrial Processes	58.3	58.2	57.8	59.6	59.1	57.9	57.3	56.0	55.0	54.3	54.4
Residential, Commercial & Public Sector Combustion	12.7	8.0	8.0	8.3	7.0	6.6	5.9	5.7	5.5	5.3	5.1
Solvent Processes	59.1	46.6	43.1	36.3	33.6	32.0	30.8	30.3	30.0	29.2	29.5
Transport	67.9	53.4	41.6	36.9	31.4	28.6	25.3	21.9	19.0	16.5	14.7
Other	3.5	3.5	3.2	2.8	11.8	14.6	10.3	6.7	6.1	6.1	5.3
Total:	**405.1**	**311.8**	**277.3**	**248.0**	**243.4**	**229.7**	**219.9**	**192.8**	**174.9**	**171.6**	**166.1**

Category	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Agriculture	14.7	14.3	14.0	14.3	14.1	14.1	13.7	13.8	13.6	13.7	13.6	13.4
Fugitive	40.0	36.6	24.5	22.4	20.9	25.1	21.1	19.2	21.3	21.2	18.8	19.4
Industrial Combustion	2.3	2.3	1.9	1.9	1.8	1.8	1.4	1.5	1.7	1.5	1.7	1.6
Industrial Processes	56.0	55.6	56.3	60.8	61.0	62.5	65.0	67.3	69.2	72.5	74.6	76.7
Residential, Commercial & Public Sector Combustion	5.0	5.1	4.9	5.2	4.6	4.8	4.7	4.3	4.4	4.6	4.5	4.7
Solvent Processes	28.9	27.0	25.1	23.7	24.3	23.7	23.3	24.1	24.2	24.0	23.9	23.8
Transport	12.9	11.6	8.4	7.3	6.2	5.5	4.9	4.5	4.3	4.1	4.1	3.9
Other	4.1	3.6	3.3	5.2	6.2	5.2	8.8	11.4	6.9	6.8	6.8	6.8
Total:	**163.9**	**156.0**	**138.2**	**140.8**	**139.1**	**142.7**	**142.9**	**146.1**	**145.6**	**148.4**	**147.9**	**150.2**

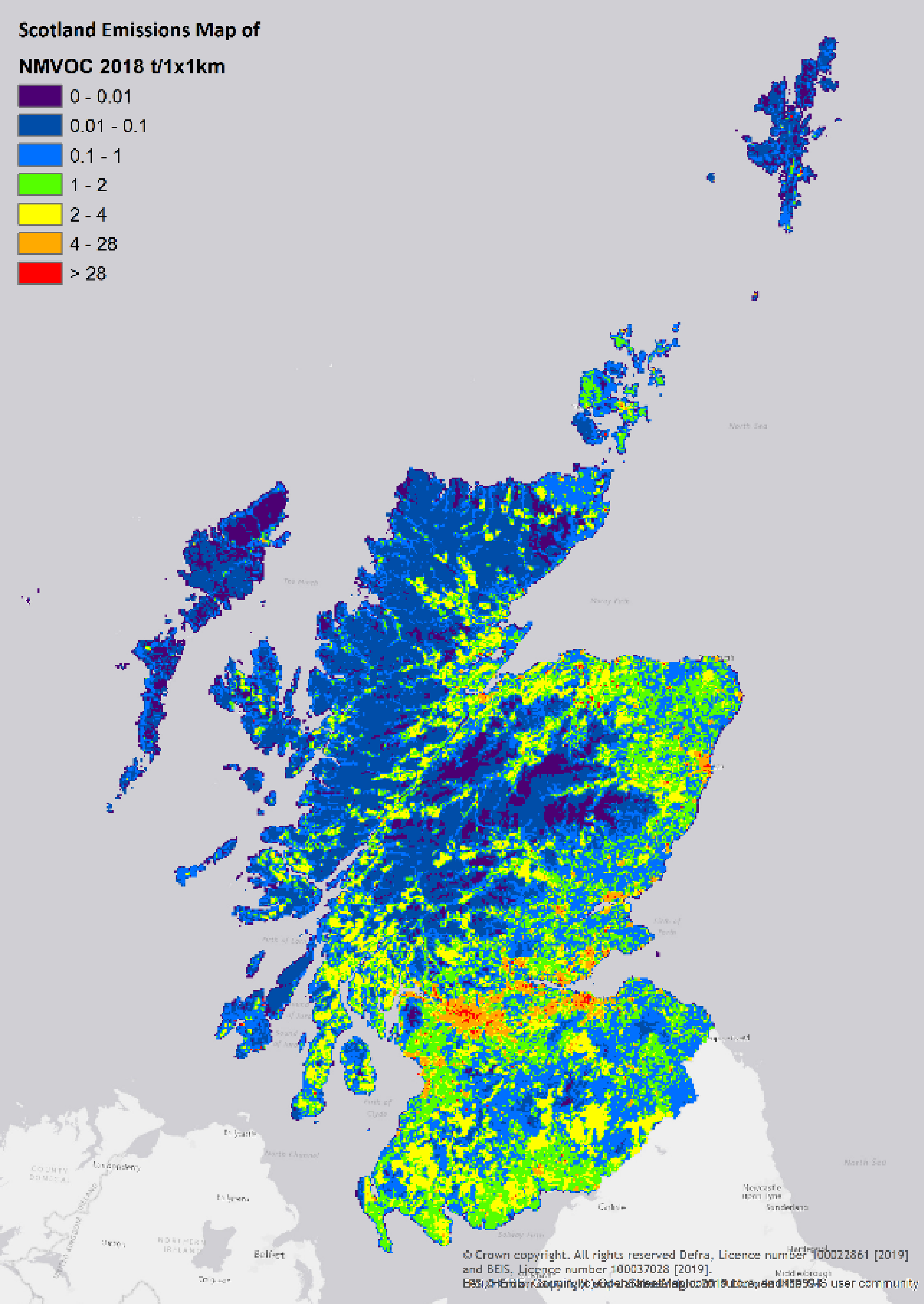
Figure 9.10 Time series of Scotland's NMVOC emissions 1990-2018



Emissions of non-methane volatile organic compounds were estimated to be 144kt in 2018, representing 18% of the UK total. Emissions have declined by 64% since 1990. This reduction has been dominated by the 90% decrease in fugitive emissions since 1990. This is primarily 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 (around 86% of industrial processes emissions in 2018) have increased since 2009 due to the increased production and storage of whisky, contributing approximately 51% of NMVOC emissions in Scotland in 2018. Emissions from road transport sources, including evaporative losses of fuel vapour from petrol vehicles have also declined over time due to emission control technologies 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 2018

Figure 9.11 Map of NMVOC Emissions in Scotland, 2018



Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 1990 – 2018

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

The Covid-19 lockdown measures (Phase 1 in late 23rd March 2020 – Phase 3rd July 2020) put in place to control the spread of the Covid-19 pandemic, created a downturn in vehicle emissions in Scotland's cities and urban areas and provided a unique opportunity to assess how such an event affects air quality. The restrictions also gave an opportunity to see how much air quality could improve if there was a significant change in the source (i.e. petrol and diesel vehicles). It is well established that road traffic is the main source of oxides of nitrogen (NOx) within urban areas in Scotland and the data verified this with measured concentration decreasing significantly compared to previous years and also Business As Usual (BAU) model results. For BAU modelled comparison and more in-depth analysis go to the Air Quality in Scotland Website (http://www.scottishairquality.scot/news/reports?view=technical).

In addition to nitrogen dioxide (NO_2), particulate matter (PM_{10} and $PM_{2.5}$) is of great interest. Analysis on the affect the Covid-19 restrictions had on PM is more difficult due to the secondary nature where particles are formed, through chemical reactions of other pollutants; and transboundary nature, where PM forms and travels over long distances. As a result, both the weather e.g. where the air mass originated from, and emissions from elsewhere (e.g. Europe) can have a much greater impact on local concentrations.

10.1 Nitrogen Dioxide Data Analysis

Figure 10.1 highlights the daily concentration time series of NO_X (purple line) and NO_2 (orange line) for Glasgow Kerbside (Hope Street) between March 2020 – May 2020. The pink shade indicates the period when social distancing was introduced, and the green shade indicates the lockdown enforcement. As can be seen from Figure 10.1 both NOx and NO_2 concentrations significant decrease when lockdown was enforced on the 23rd March resulting in the removal of the vast majority of traffic from the roads especially in the city centre areas.

Similar decreases in concentrations were seen across Scotland's other busy urban areas, see Figures 10.2.

Figure 10.1 Glasgow Kerbside (Hope Street) analysis (March 2020 – May 2020)

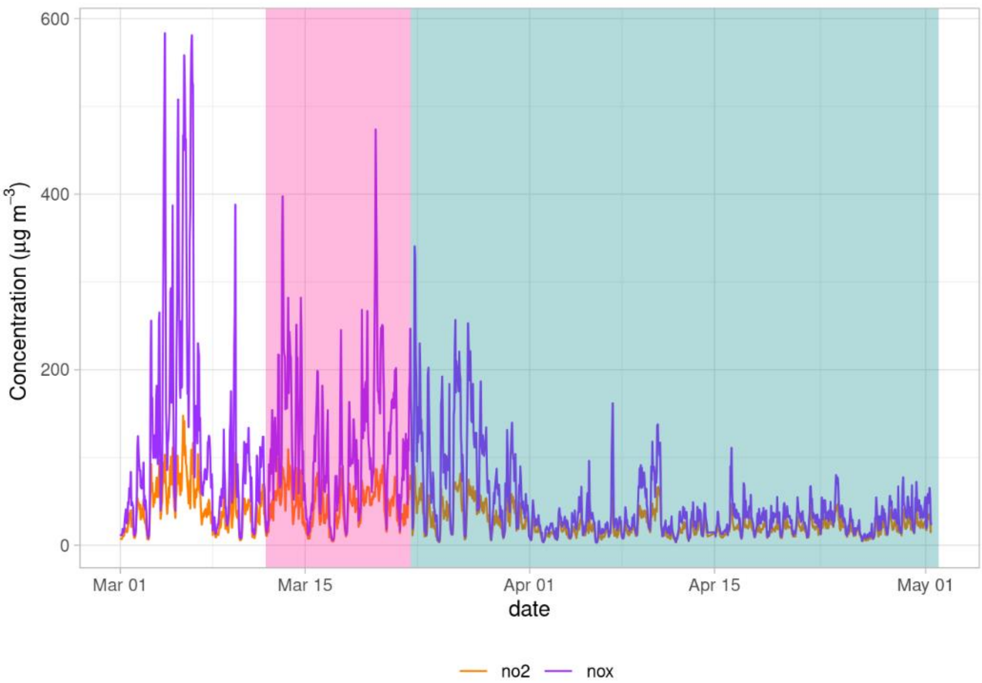


Figure 10.2 Scottish Busy Urban Areas analysis (March 2020 – May 2020)

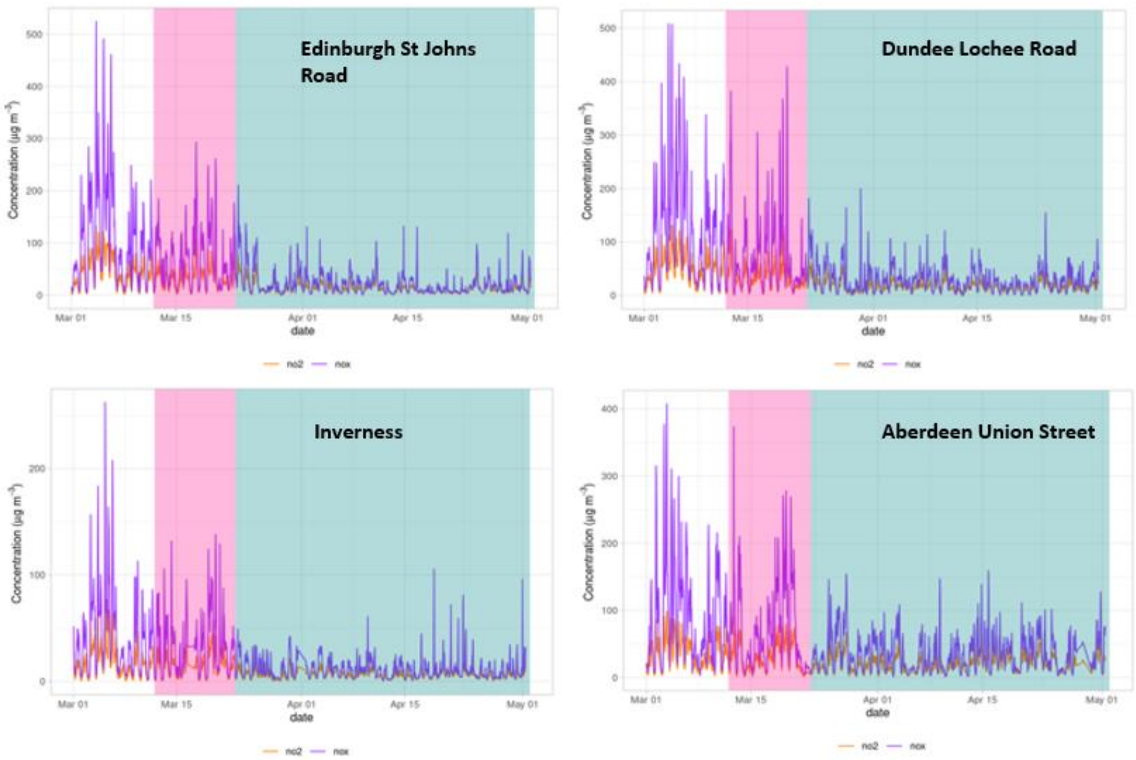
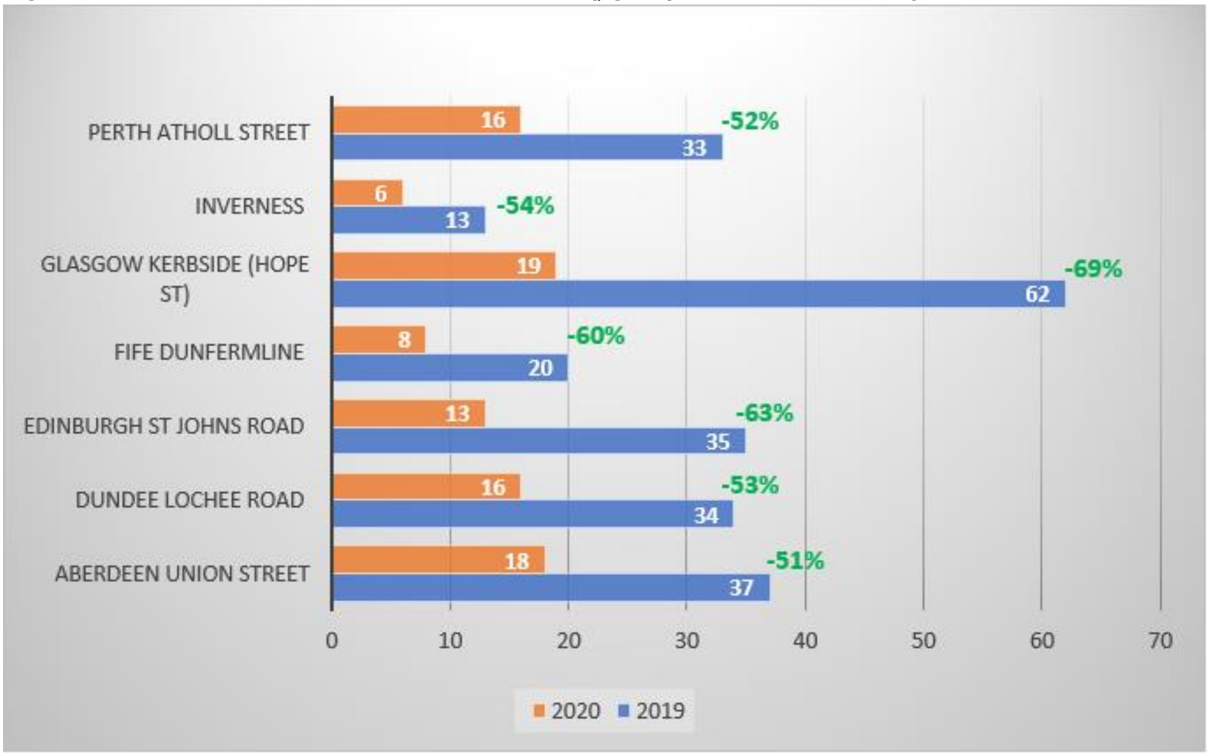


Figure 10.3 provides a direct comparison between NO_2 concentrations measure in 2019 and 2020 for the period 23rd March to 26th May. It illustrates the significant difference between 2019 and 2020 and also provides (in green) the decrease as a percentage . For more in-depth analysis, go to the Air Quality in Scotland website (http://www.scottishairquality.scot/news/).

Figure 10.3 Difference in mean NO_2 concentrations ($\mu g\ m^{-3}$) 23rd March – 26th May 2019 and 2020



Time Variation analysis was also carried out to identify the affect the lockdown period had on air pollution compared to years going back to 2015. Time variation plots created using the Openair analysis tool (available on the Air Quality in Scotland Website http://www.scottishairquality.scot/data/openair) shows the pollutant concentrations by day of the week, mean hour of the day and a combined hour of the day, day of the week, and monthly plots. Also shown on the plots is the 95% confidence interval in the mean which can be helpful when determining whether there is a significant difference between comparison years. Figures 10.4 to 10.7 provides time variation plot analysis for NO_2 at a selected site from each of the four major cities in Scotland (Aberdeen, Dundee, Edinburgh, and Glasgow). Additional analysis was carried out at other urban locations in Scotland and can be found on the Air Quality in Scotland website (http://www.scottishairquality.scot/news/reports?view=technical&id=632). The analysis again illustrates the significant drop in concentration compared to previous years especially around the rush hour period and working day. It also shows that again the decreases in NO_2 concentrations were seen at all of the major cities. It is expected that the decrease in NO_2 would have been greater in city centre areas compared to more urban and rural locations as it is assumed that traffic numbers decreased more here.

Figure 10.6 NO_2 concentrations between 23rd March and 26th May in the years 2015 to 2020 at Aberdeen Union Street (µg m^{-3})

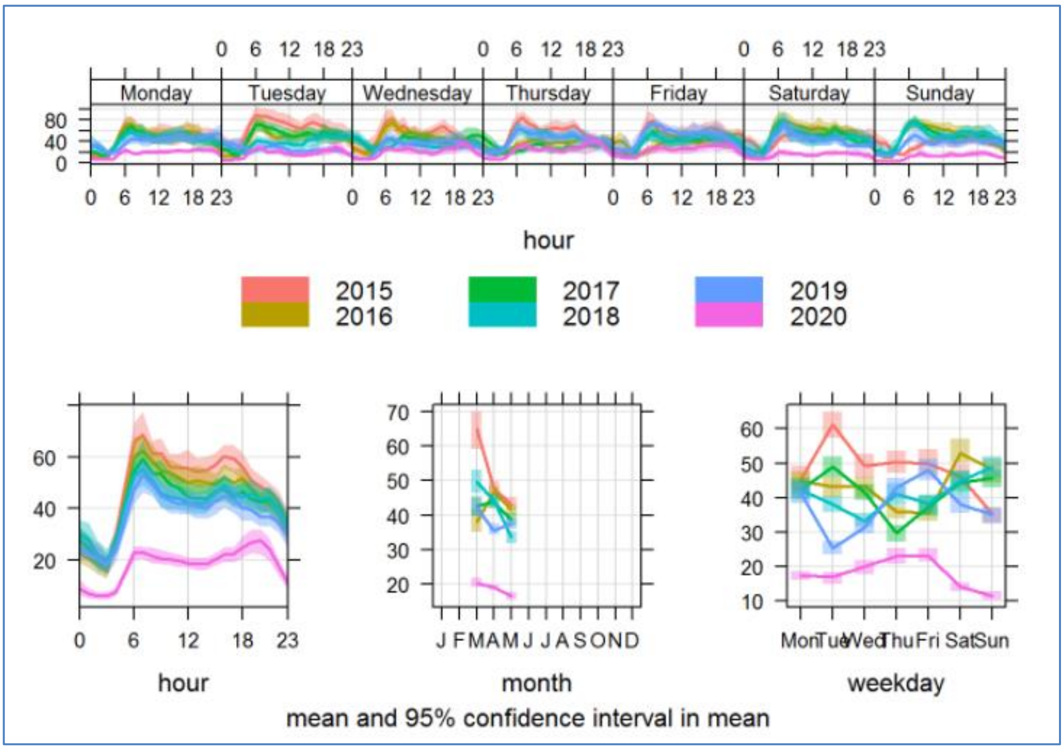


Figure 10.7 NO_2 concentrations between 23rd March and 26th May in the years 2015 to 2020 at Dundee Lochee Road (µg m^{-3})

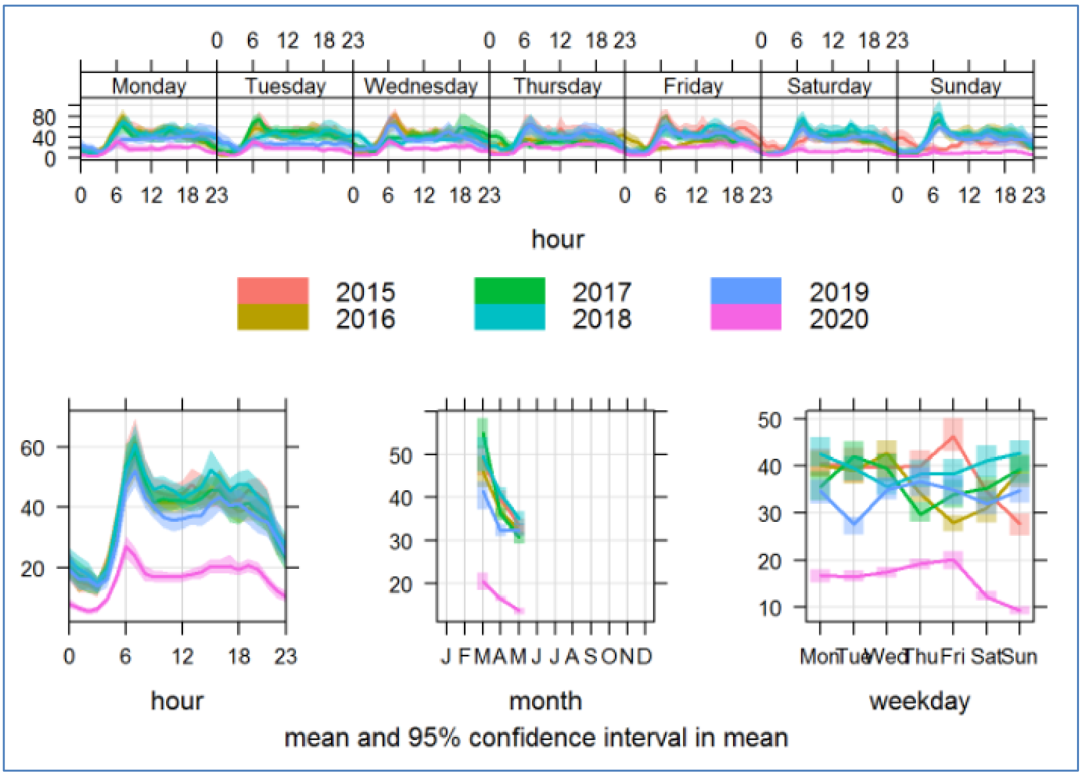


Figure 10.8 NO_2 concentrations between 23rd March and 26th May in the years 2015 to 2020 at Edinburgh St Johns Road (µg m^{-3})

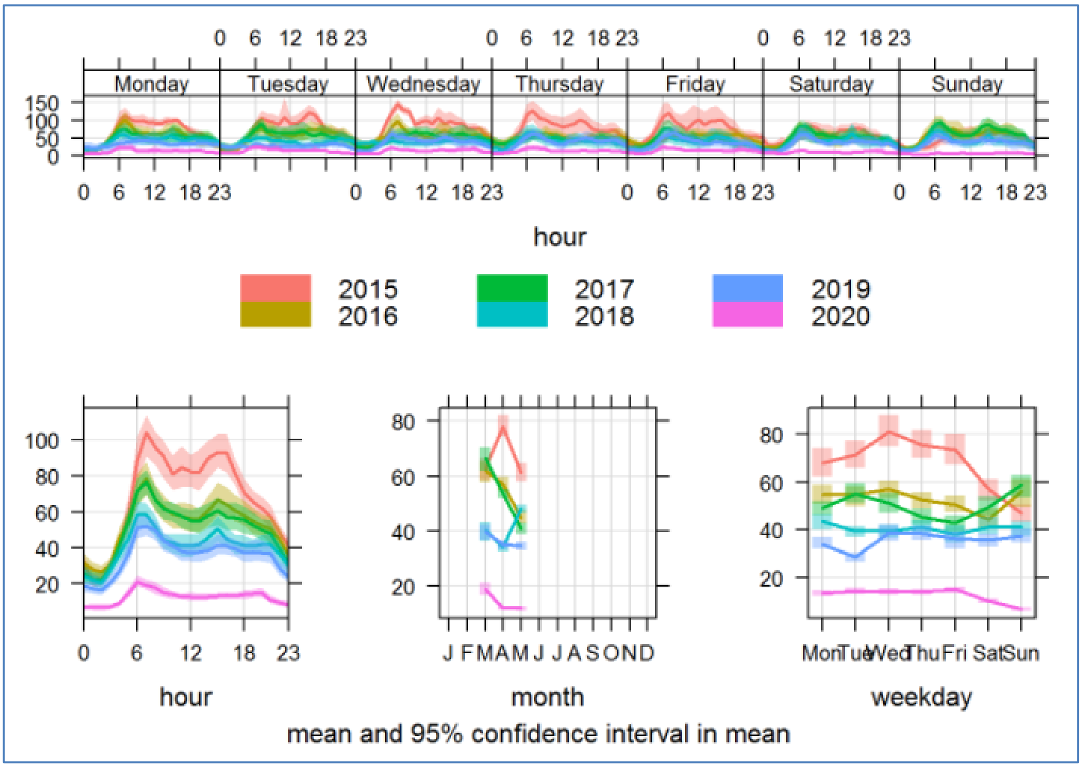
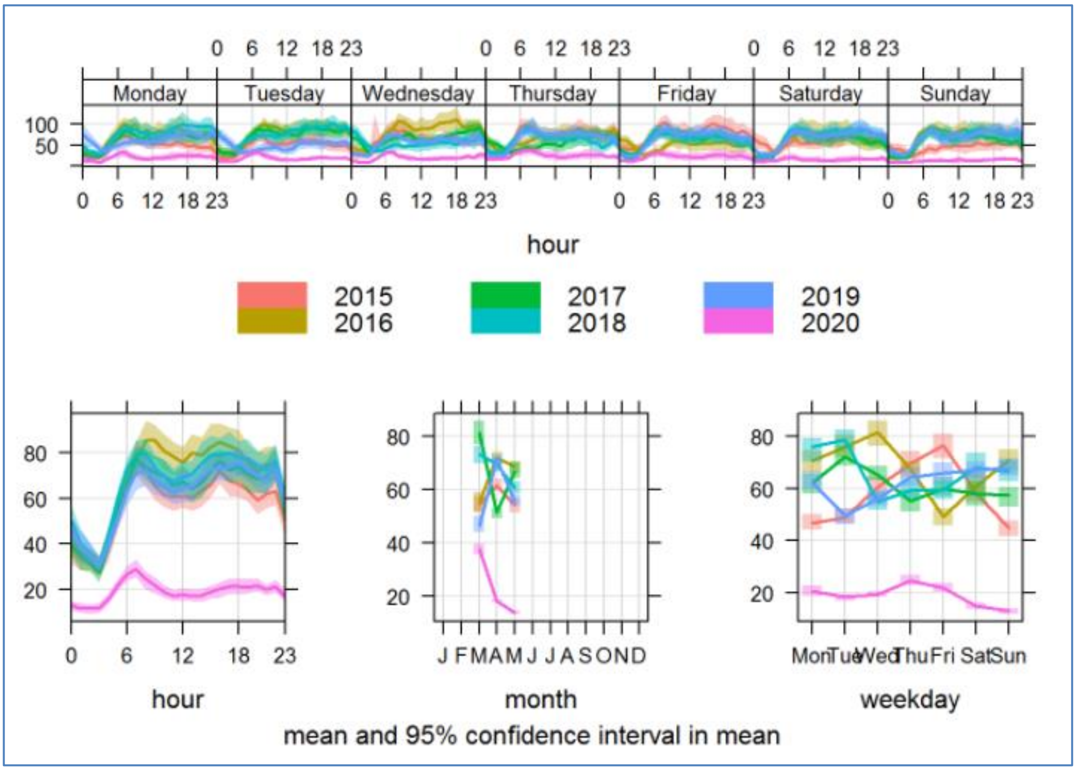


Figure 10.9 NO_2 concentrations between 23rd March and 26th May in the years 2015 to 2020 at Glasgow Kerbside (Hope Street) (µg m^{-3})



10.2 Particulate Matter

Figures 10.10 and 10.11 compares PM_{10} and $PM_{2.5}$ concentrations between 2019 and 2020 for the lockdown period for a selection of urban sites across Scotland. Also provided (in green) is the concentration percentage difference.

Significant decreases in concentration were also seen for Particulate Matter (PM_{10} and $PM_{2.5}$) but not to the same extent as NO_2. The lockdown influence on PM concentrations is less clear - when directly compared to years back to 2015, with decreases in concentrations varying from between 9% and 53% across the stated sites. This more detailed analysis can be found here http://www.scottishairquality.scot/news/index?id=626.

The reason for this is most likely due to the multiple sources of PM that affect concentrations in Scotland and also the transboundary nature of the pollutant. Where with NOx the main emission source is vehicle traffic in urban areas, for PM this is not the case (as described in section 9 of this report). However, more in-depth analysis of the lockdown data could help identify the contribution vehicles have to particulate matter concentrations at urban locations. It should be noted that it is not clear how the lockdown restrictions have affected other sources of PM and how that may have also contributed to the change in concentrations measured.

Figure 10.10 Difference in mean PM_{10} concentrations ($\mu g\ m^{-3}$) 23rd March – 26th May 2019 and 2020

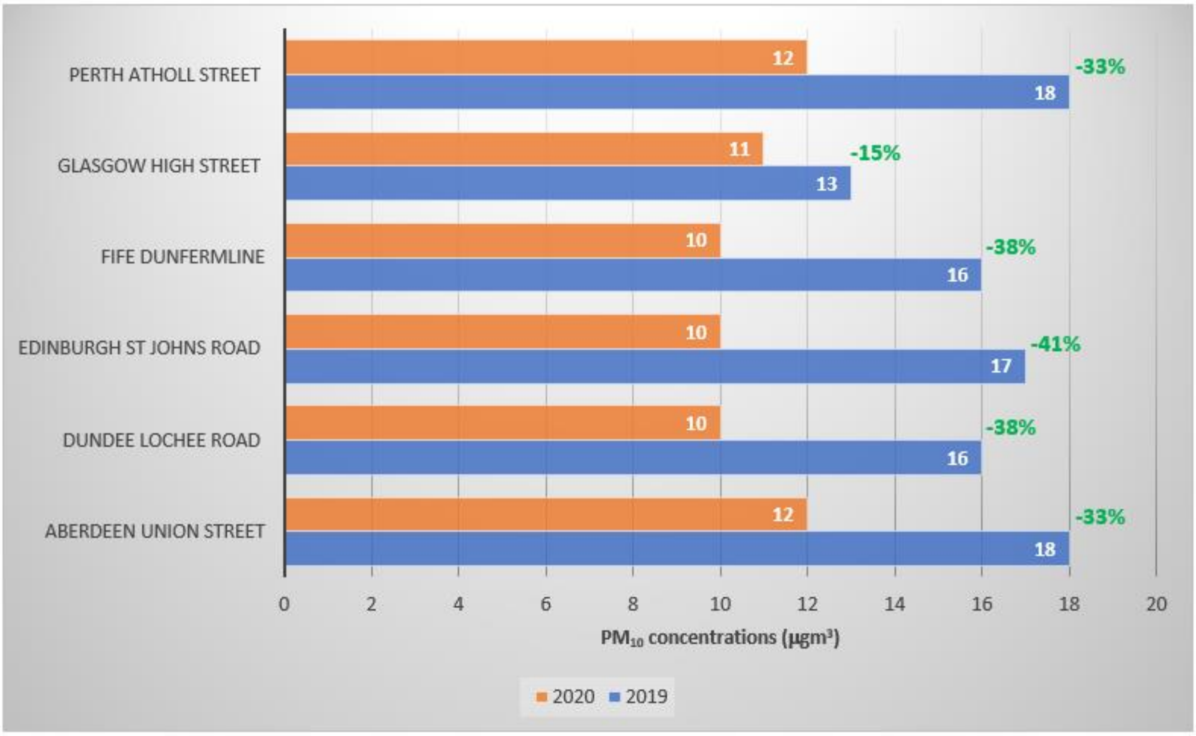
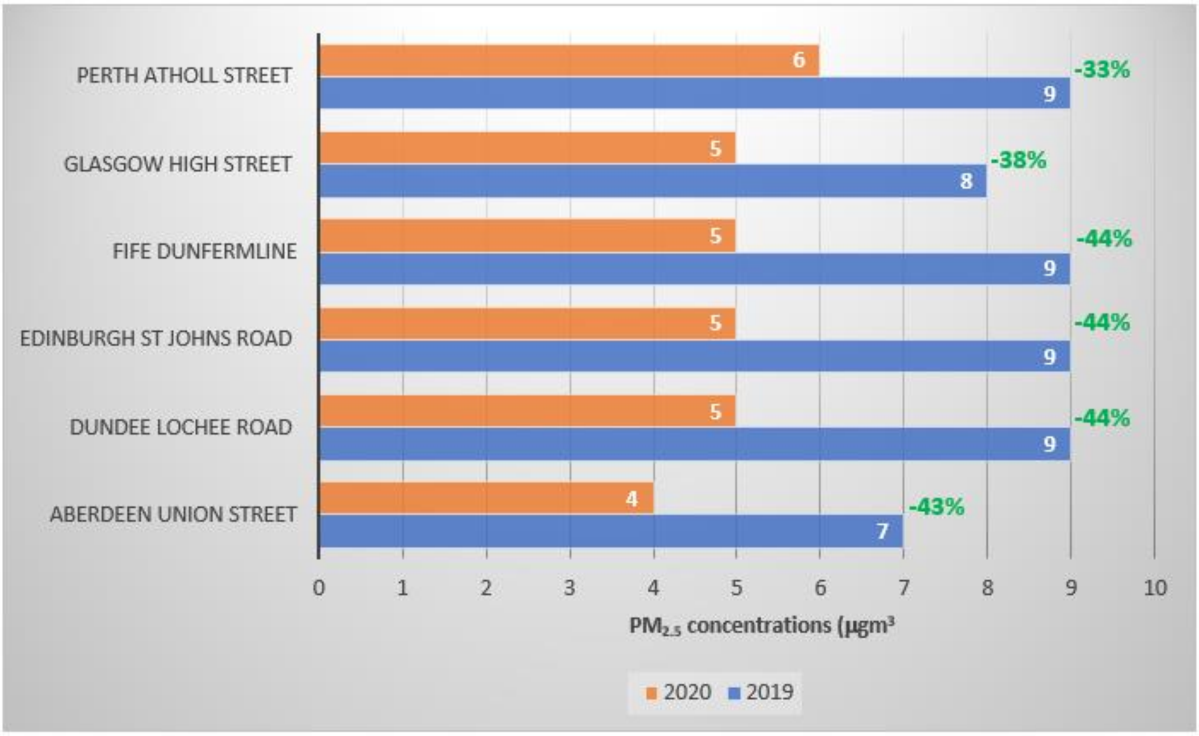


Figure 10.11 Difference in mean $PM_{2.5}$ concentrations ($\mu g\ m^{-3}$) 23rd March – 26th May 2019 and 2020



Figures 10.12 to 10.19 show time variation plots for PM_{10} and $PM_{2.5}$ at a selected site at each of the 4 major cities in Scotland. This analysis shows that though concentrations were lower they were as prevalent as with NO_2.

Figure 10.12 PM$_{10}$ concentrations between 23rd March and 26th May in the years 2015 to 2020 at Aberdeen Union Street (µg m^{-3})

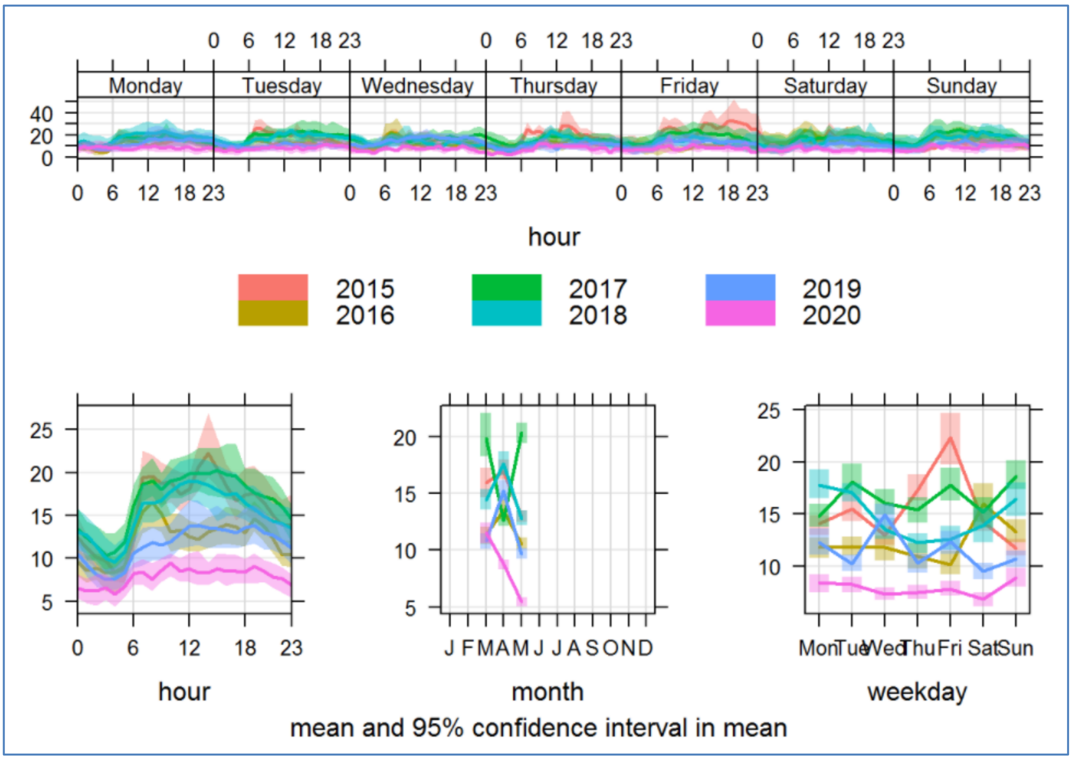


Figure 10.13 PM$_{10}$ concentrations between 23rd March and 26th May in the years 2015 to 2020 at Dundee Lochee Road (µg m^{-3})

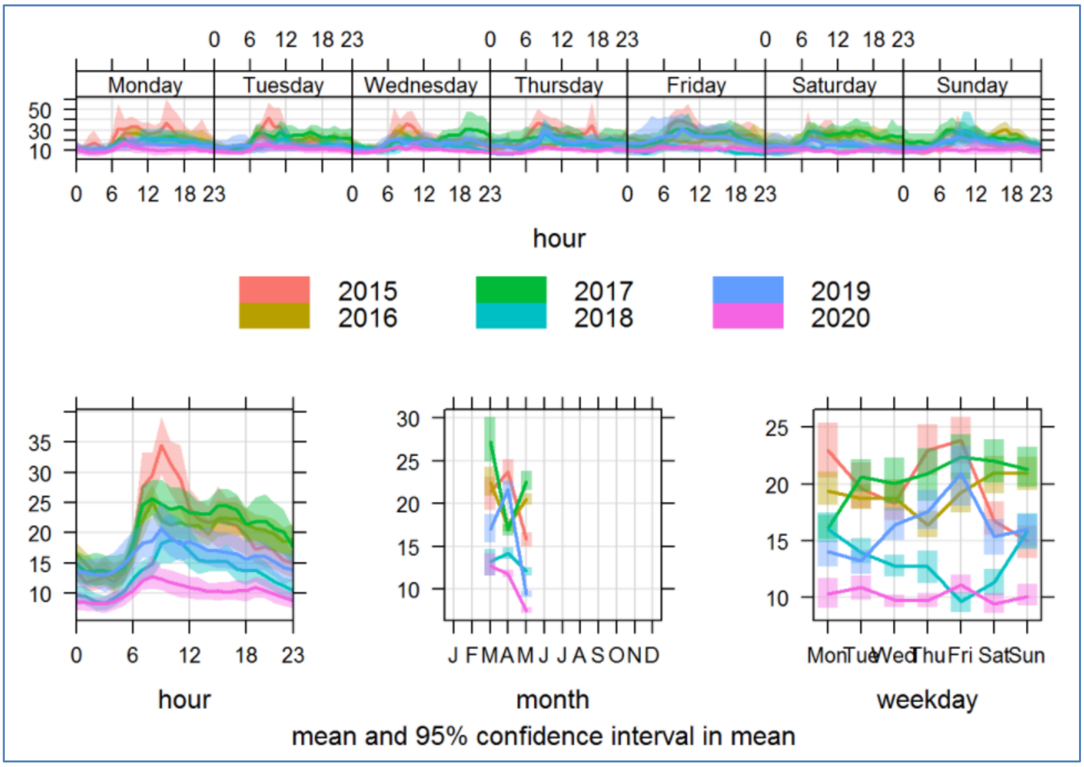


Figure 10.14 PM$_{10}$ concentrations between 23rd March and 26th May in the years 2015 to 2020 at Edinburgh St Johns Road (µg m^{-3})

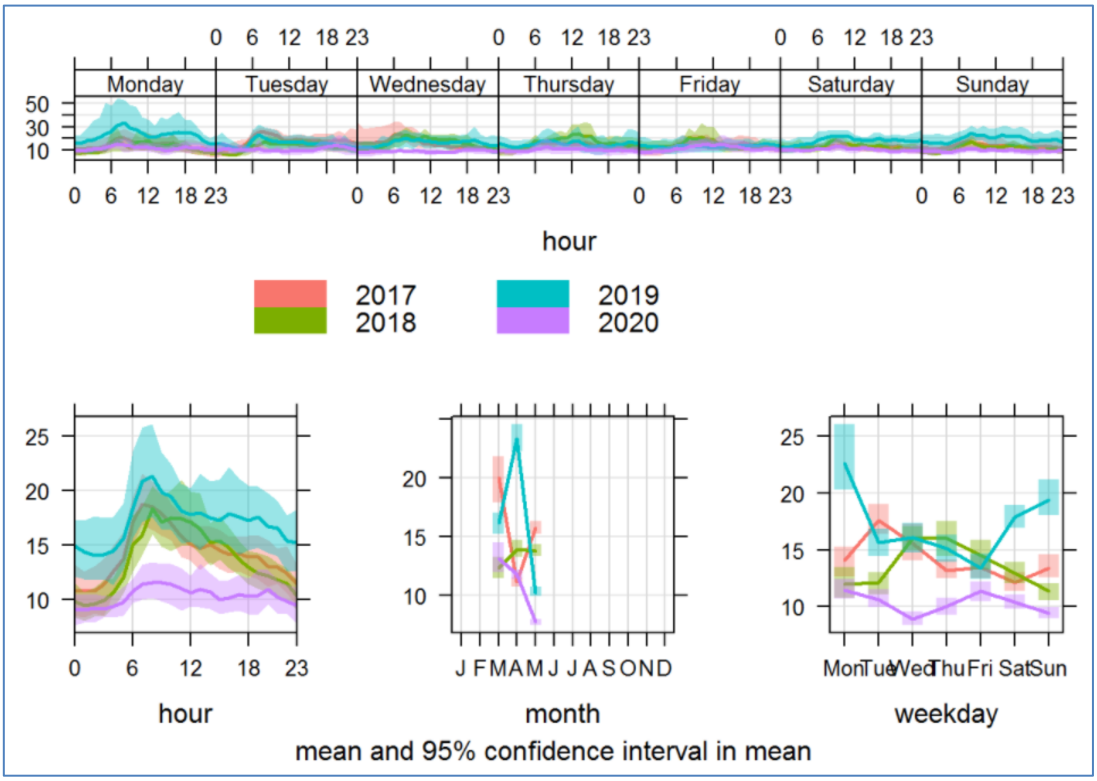


Figure 10.15 PM$_{10}$ concentrations between 23rd March and 26th May in the years 2015 to 2020 at Glasgow High Street (µg m^{-3})

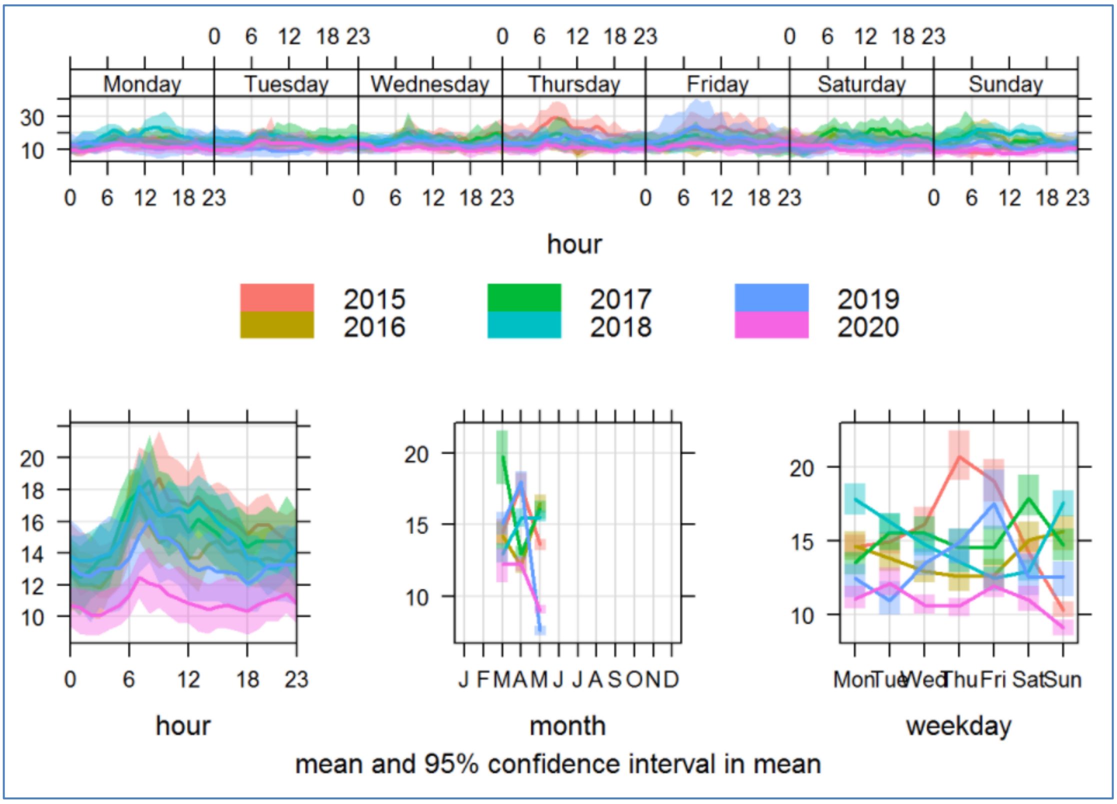


Figure 10.16 PM$_{2.5}$ concentrations between 23rd March and 26th May in the years 2015 to 2020 at Aberdeen Union Street (µg m^{-3})

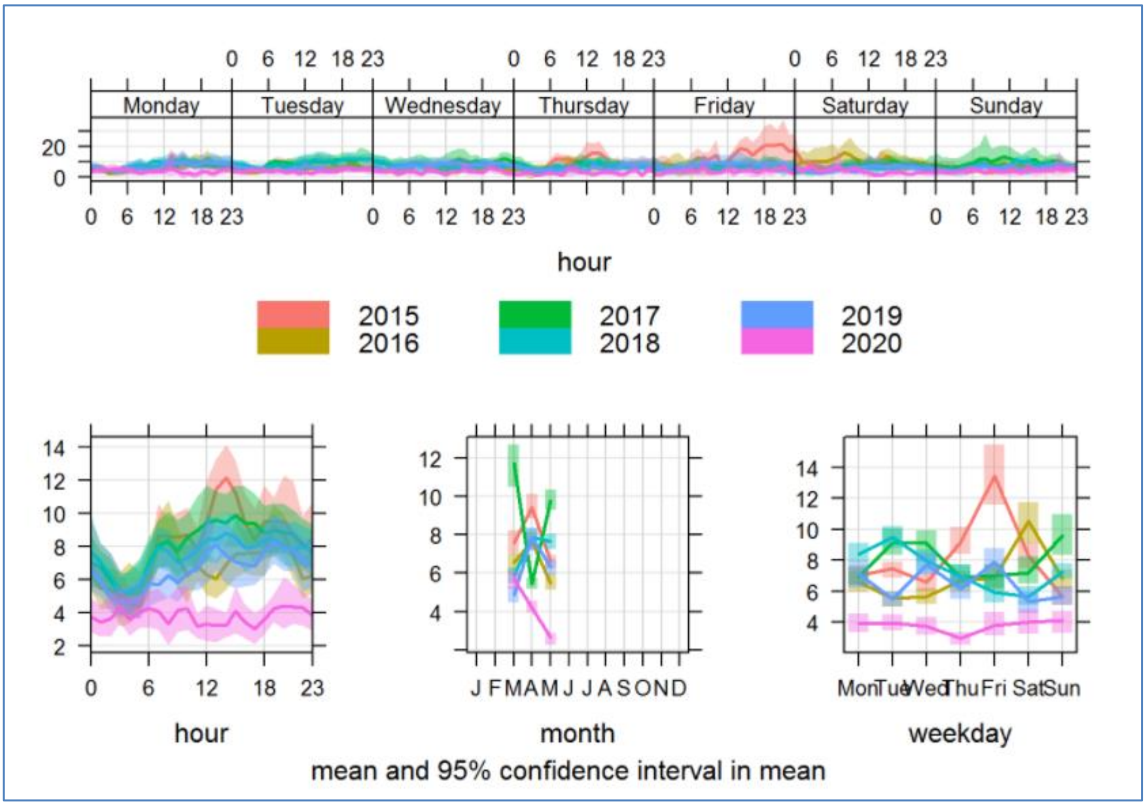


Figure 10.17 PM$_{2.5}$ concentrations between 23rd March and 26th May in the years 2015 to 2020 at Dundee Lochee Road (µg m^{-3})

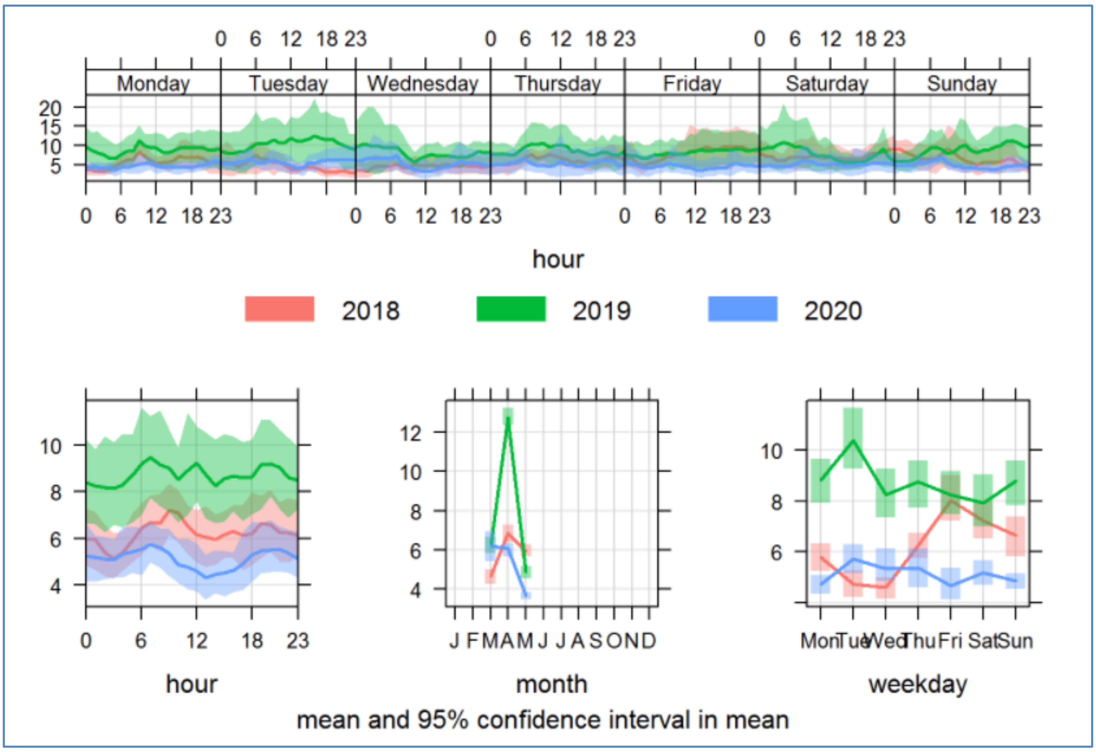


Figure 10.18 PM$_{2.5}$ concentrations between 23rd March and 26th May in the years 2015 to 2020 at Edinburgh St Johns Road (µg m^{-3})

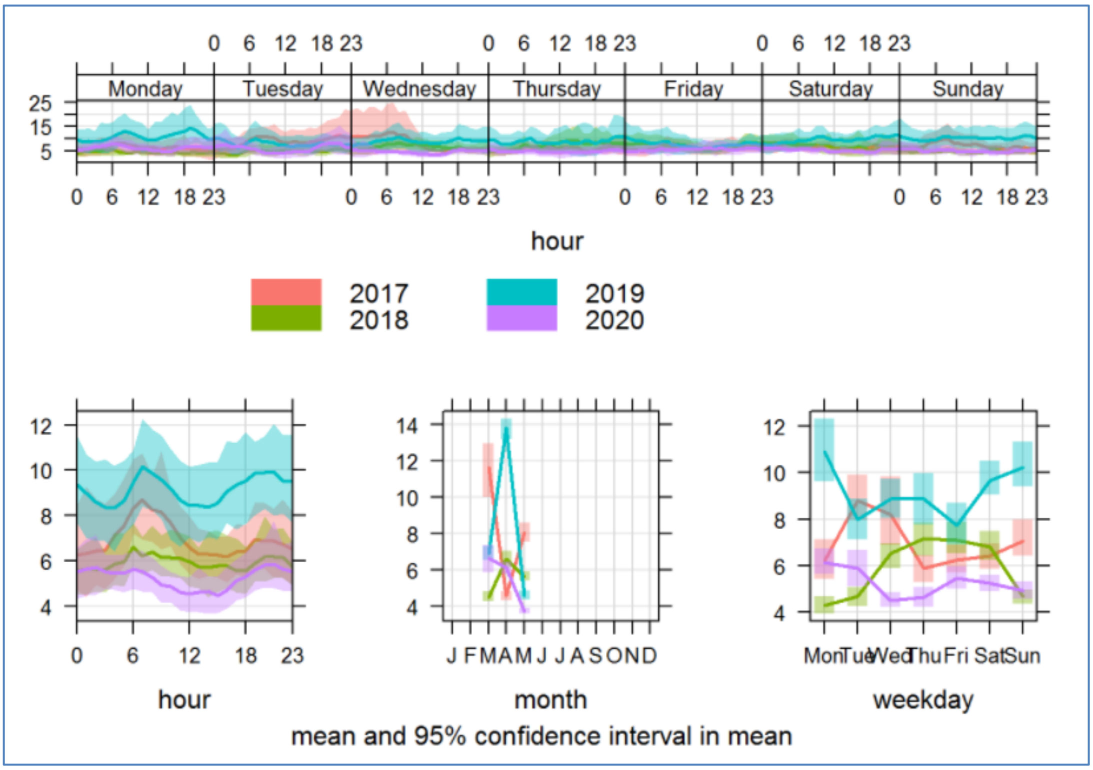
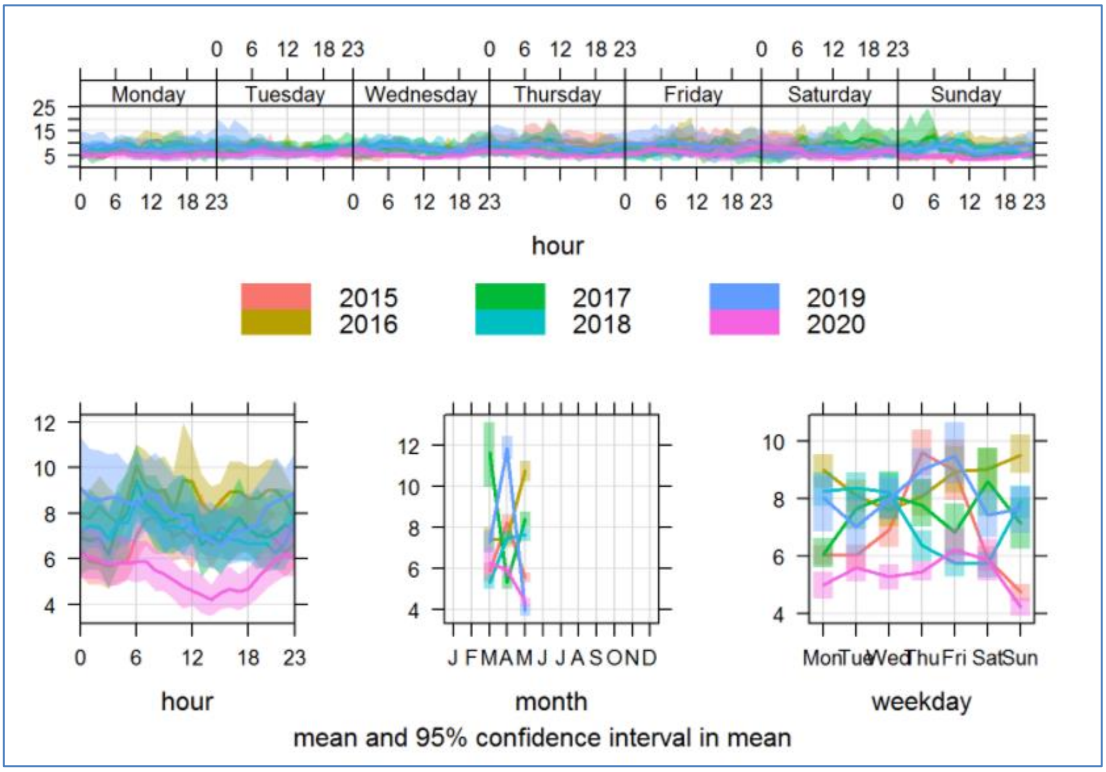


Figure 10.19 PM$_{2.5}$ concentrations between 23rd March and 26th May in the years 2015 to 2020 at Glasgow High Street (µg m^{-3})



10.3 Modelled data analysis

Figure 10.20 and 10.21 provide a visual representation of how concentrations of NO_2 changed across the central belt of Scotland before and after the introduction of Covid-19 restrictions were implemented. These figures were generated using RapidAir®, an air quality dispersion modelling software that uses optimised methodologies to visualise air quality at high resolution, so as to test the impact of development or mitigation scenarios. Again, the figures illustrate the definite decrease in NO_2 across central Scotland brought on by the Covid-19 restrictions. It is especially evident on the motorways and in city centres.

Figure 10.20 Rapid Air image depicting NO_2 concentrations across the central belt of Scotland before Covid-19 restrictions ($\mu g\ m^{-3}$)

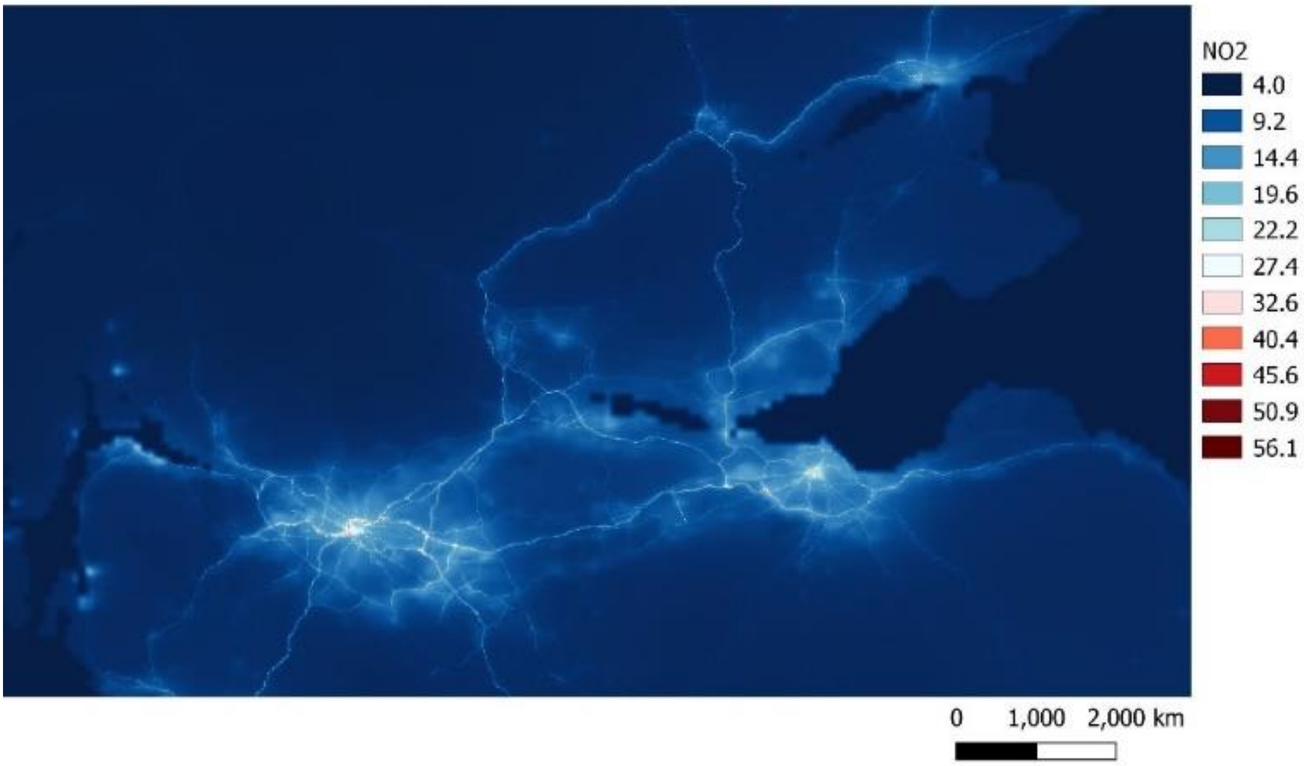
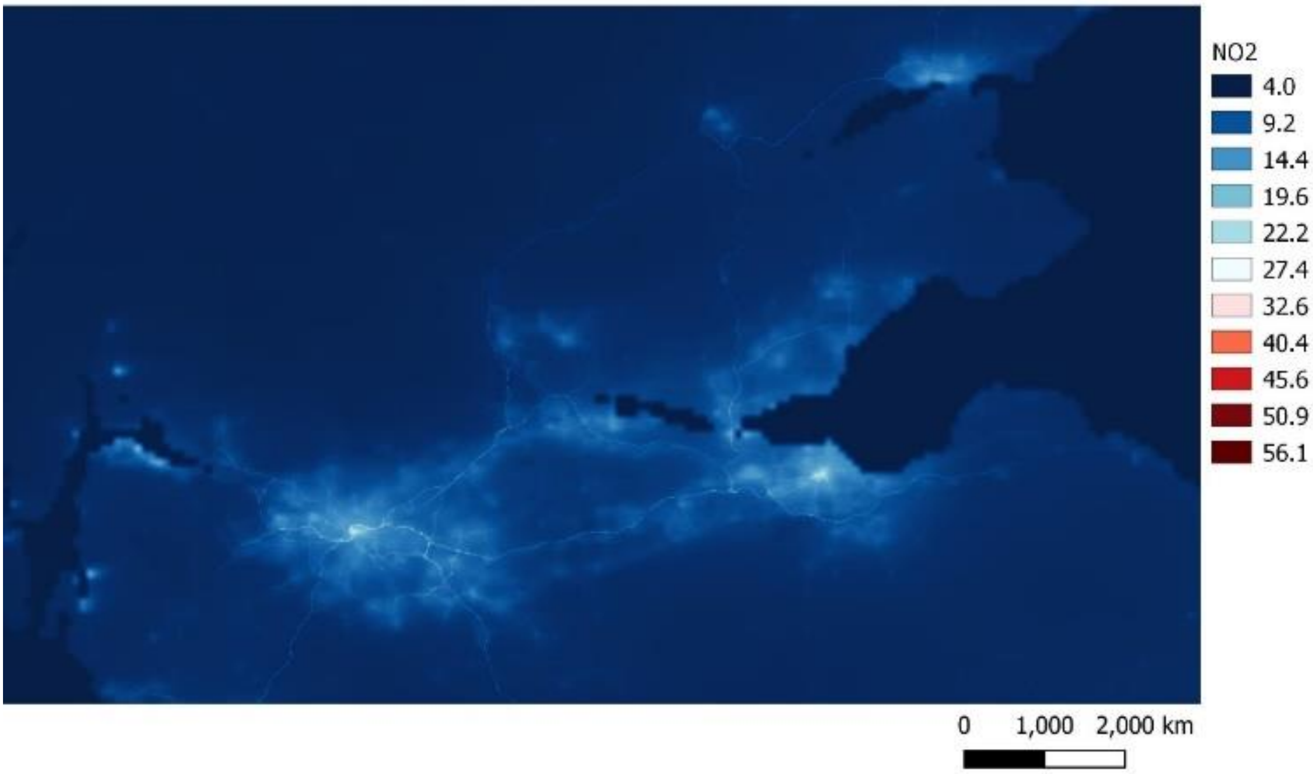


Figure 10.21 Rapid Air image depicting NO_2 concentrations across the central belt of Scotland during Covid-19 restrictions ($\mu g\ m^{-3}$)



11 Summary and Conclusions

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 recent years, with the latest contract running from 2019-2022.

This report brings together all the Scottish Air Quality Database data for calendar year 2019 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 Covid-19 pandemic on air quality in Scotland.

Legislation and Policy

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 is 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 as soon as possible. CAFS outlines the contribution that better air quality can make to sustainable development whilst improving health and the natural environment and reducing health inequalities for the citizens of Scotland.

In addition to the six main objectives, CAFS outlines new initiatives to be implemented to compliment the objectives set; these initiatives include a National Modelling Framework and National Low Emissions Framework. CAFS outlines further changes such as the adoption of the WHO annual mean guideline value for $PM_{2.5}$ of 10ug m^{-3}; this was incorporated into domestic legislation by the Air Quality Scotland Amendment Regulations 2016.

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 2019 five automatic monitoring sites exceeded the annual mean objective for NO_2. At the time of writing this report not all diffusion tube data for 2019 had been published due to delays caused by the covid-19 pandemic. Due to this the full number of NO2 diffusion tube data has not been reported for 2019. In 2018, 74 diffusion tube sites exceeded the NO2 annual mean objective.

In 2019, no sites exceeded the PM_{10} annual objective for PM_{10}. One site exceeded the daily mean objective of 50 µg m^{-3} not to be exceeded more than seven times in a year.

The pattern of measured concentrations is similar to previous years in that where exceedances of the Scottish air quality objectives occur, these are in areas where the relevant local authority has already declared or is in the process of declaring an Air Quality Management Area (AQMA).

In 2019, the Air Quality Strategy Objective for ozone (not more than 10 days with a maximum eight hour running mean greater than 100 µg m^{-3}) was exceeded at seven out of the 11 sites measuring the pollutant in Scotland.

In 2019, 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.

Air Quality Mapping of Scotland

Ricardo 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). This report provides maps modelled using 2018 data, the most recent year for which inventory data is available.

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 42 road links (85.7 km of road) in the Glasgow Urban Area and at 18 road links (41.2 km of road) in Central Scotland. In the Edinburgh Urban Area seven road links (9.2 km of road) exceedances were modelled and in the North East Scotland zone only two roads had an exceedance (4.8 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 some 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 downward trends

Examination of trends at the same nine sites over the most recent five complete years (2015 to 2019) indicates that the patterns are mostly very similar to the 10-year trends but with varying statistical significance.

PM_{10}

PM_{10} at Scotland's eight long-running urban non-roadside sites showed a significant or highly significant negative trend. PM_{10} at Scotland's nine long-running urban traffic (roadside and kerbside) sites showed statistically significant downward trends at all sites (at the 0.001 level in all but one case).
Examination of trends in PM_{10} at the same nine sites over the most recent five years indicates that, at some of these, the decreasing trends have continued but at others they have weakened, levelled off or switched to an increasing trend.

$PM_{2.5}$

At the time of writing this report there are 66 sites monitoring $PM_{2.5}$ in Scotland. However, the vast majority of these sites started monitoring in the last 3 years with the introduction of the $PM_{2.5}$ objective and the requirement for local authorities to measure the pollutant. By the end of 2018 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 downward trends for $PM_{2.5.}$ Contrary to this, the rural site Auchencorth Moss shows a slight upward trend however not statistically significant.

Ozone

Ozone has been measured at three rural sites in Scotland for 30 years. All three sites showed small positive trends over this very long period, 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 a not statistically significant decreasing trend.
10 year trend analysis of ozone concentrations showed increasing trends (at vary statistical significance) at all three Scottish urban background sites.

Emissions of Pollution Species

Scotland NOx emissions have declined by 73% since 1990 and were estimated to be 86kt in 2018 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 2017 passenger car emissions is due to diesel cars).

Emissions of PM_{10} have declined by 62% since 1990 and in 2018 and were estimated to be 15kt (9% of the UK total). PM_{10} exhaust emissions from diesel vehicles have been decreasing due to the successive introduction of tighter emission standards over time. The decline in $PM1_{0}$ emissions has basically stopped across all sectors over the past few years with some, such as Industrial Processes increasing. This has been attributed to an increased quantity of wood fuel use. In addition, almost all other emissions sources have remained stable since 2011. Though PM_{10} emissions have reduced since 1990, overall there has been no significant reduction in PM10 emissions since 2011.

Emissions of PM2.5 have declined by 67% since 1990 and in 2018 were estimated to be 8kt (8% of the UK total). For PM2.5, the residential, commercial and public sector combustion category accounts for 44% of 2018 emissions. The decline in emissions has significantly reduced over the past few years with no significant decrease since 2013. 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 of ammonia have declined by only 16% since 1990 and were estimated to be 31kt (11% 0f the UK total) in 2018. 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. However, an increased use of urea-based fertilisers, which are associated with higher NH3 emission factors, has had the opposite effect in recent years. The land-spreading of non-manure digestates have caused additional increases.

Emissions of Non-Methane Volatile Organic Compounds have declined 64% since 1990 and were estimated to be 144kt in 2018 (18% of the UK total). This reduction has been dominated by the 90% decrease in fugitive emissions since 1990. This is primarily due to the decrease in emissions from the exploration, production, and transport of oil, specifically emissions from the onshore loading of oil. There has been an upward 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 (51% of emissions in 2018).

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

Initial analysis indicates that the Covid-19 lockdown resulted in a significant drop in NO_2, PM_{10} and $PM_{2.5}$ concentrations levels in Scottish busy urban areas and especially in city centres. This is attributed to the huge decrease in vehicle traffic. More in-depth analysis may also help identify vehicle traffic contribution to particulate matter in Scotland.

Appendices

Appendix 1 – National Monitoring Networks in Scotland 2019

Table A1.1. AURN Measurement Sites in Scotland 2019

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 NOx	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 NOx	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 A1.2 Automatic Hydrocarbon Network Sites in Scotland 2019

Auchencorth Moss	RURAL	Benzene and 1,3-butadiene and 24 other ozone precursor hydrocarbon species*	322167, 656123

Table A1.3 Non-Automatic Hydrocarbon Network Sites in Scotland 2019

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 A1.3 PAH Monitoring Sites in Scotland 2019

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 A1.4 Heavy Metals Monitoring Network Sites in Scotland 2019

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 A1.6 Rural Metal Deposition Monitoring sites in Scotland 2019

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 A1.7 The Precipitation Network (PrecipNet) Sites in Scotland 2019

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

Table A1.8 Acid Gas and Aerosol Network (AGANet) and Ammonia Network (NAMN) Sites in Scotland 2019

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	✓	

Appendix 2 - Ratification Procedures

A2.1 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).

A2.1.1 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.

A2.1.2 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.

A2.1.3 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.

A2.1.4 Ozone Photometers

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

A2.2 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.

A2.2.1 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.

A2.3 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.

A2.3.1 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.

A2.3.2 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.

The Gemini Building
Fermi Avenue
Harwell
Didcot
Oxfordshire
OX11 0QR
United Kingdom
t: +44 (0)1235 753000
e: enquiry@ricardo.com

ee.ricardo.com