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Air Pollution in Scotland 2019

RICARDO
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Introduction

This brochure has been produced as part of the Scottish Air Quality Database (SAQD) project on behalf of the Scottish Government. The 2019 brochure is the 13th in an annual series. It aims to provide a summary of the local air quality monitoring and associated work carried out by and on behalf of the Scottish Government and local authorities during 2019.

The SAQD project was developed as a comprehensive centralised resource to provide high-quality harmonised data and information. The quality assurance of the data generated by the Scottish network serves to improve research and analysis and supports the evaluation of air quality policy in Scotland. Since the initial development of the SAQD in 2006, it has grown year on year. The total number of automatic air quality monitoring sites in the SAQD during 2019 was 100. The increase in the number of monitoring sites included in the SAQD since 2006 is shown in Figure 1.1.

While air quality in most of Scotland is generally good, levels of some pollutants still exceed air quality objectives, particularly in urban areas. Therefore, continued efforts to reduce air pollution are vital, coupled with appropriate monitoring to assess progress. For more information on air quality in Scotland and, more specifically, your area, please visit the Air Quality in Scotland website (http://www.scottishairquality.scot/).

A more detailed Annual Report on the SAQD project is available on the Air Quality in Scotland website.

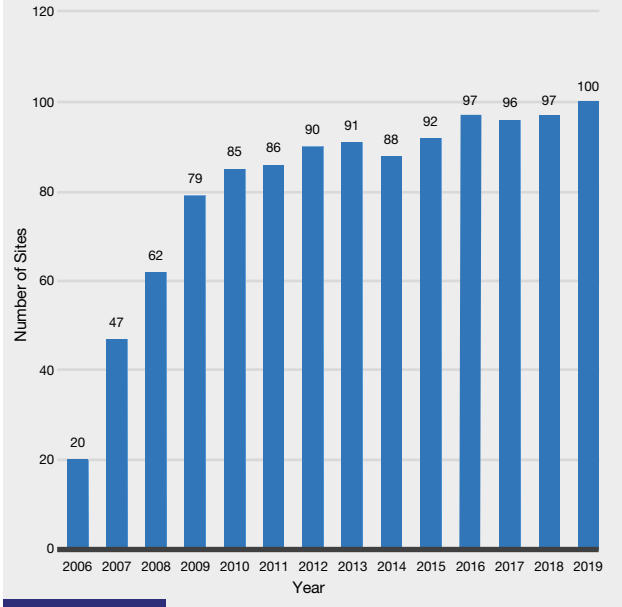

Figure 1.1

Growth in the number of monitoring sites included in the SAQD since 2006

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Legislation and Policy

Air quality management is shaped by statutory requirements from EU and UK legislation and policies that have been adopted by Scotland. The foundations of Scotland's air quality management system are based on the following air quality directives adopted by all EU Member States:

- Directive 2008/50/EC – on ambient air quality and cleaner air for Europe (the Air Quality Directive)
- Directive 2010/75/EC – on industrial emissions (integrated pollution prevention and control) (the Industrial Emissions Directive)

The Scottish Government has duly transposed these Directives into national law through the Air Quality Standards (Scotland) Regulations 2010 and the Pollution Prevention and Control (Scotland) Regulations 2012 (and subsequent amendments) respectively. A substantial review of the EU's air quality policy, including the Air Quality Directive, was undertaken in 2013 with the European Commission adopting a new Clean Air Policy Package, including a new Clean Air for Europe programme with measures to ensure that existing targets are met in the short term and new air quality objectives for the period up to 2030. The Package also includes support measures to help cut air pollution, with a focus on improving air quality in cities, supporting research and innovation, and promoting international cooperation.

Domestic air quality legislation is set under the Environment Act 1995 and associated regulations (see section 2.1 below).

2.1 Air Quality Standards and Objectives

A set of air quality standards and objectives have 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 practicable 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 (LAQM) 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. Scotland has adopted more stringent objectives for particulate matter up to 10 µm and 2.5 µm in diameter (PM_{10} and $PM_{2.5}$ respectively). A summary of the current Scottish air quality objectives is provided in Table 2.1.

Similar targets are set at EU level, where they are called limit and target values. These limit and target values are set out in the Air Quality Directive and transposed into Scottish legislation. It is the responsibility of EU Member States to achieve these values. EU air quality legislation will be part of retained EU law in the UK following EU exit.

Table 2.1 Summary of air quality in Scotland

Air Quality 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 (C_6H_6)	3.25 µg m^{-3}	Running annual mean	31.12.2010
1,3 Butadiene (C_4H_6)	2.25 µg m^{-3}	Running annual mean	31.12.2003
Carbon monoxide (CO)	10.0 mg m^{-3}	Running 8-Hour mean	31.12.2003
Lead (Pb)	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 that 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 is acknowledged in the CAFS strategy that, although progress has been made in Scotland, areas of poorer air quality still exist in towns and cities.

CAFS considers the impact of air quality on health and looks at the estimated costs and predicted premature deaths associated with poor air quality. It has been estimated that 2,000 premature deaths and around 22,500 lost life-years across the Scottish population are associated with fine particulate air pollution ($PM_{2.5}$)[1].

2.2.1 Cleaner Air for Scotland Objectives

The CAFS strategy sets out six main objectives and the actions required to achieve improvements in air quality. A summary of these objectives are set out below, more information on these objectives and the stated 40 actions can be accessed at http://www.gov.scot/publications/cleaner-air-scotland-road-healthier-future/pages/4/.

1. 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.

2. Health

A Scotland that protects its citizens from the harmful effects of air pollution and reduces health.

3. Legislation and policy

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

4. Placemaking

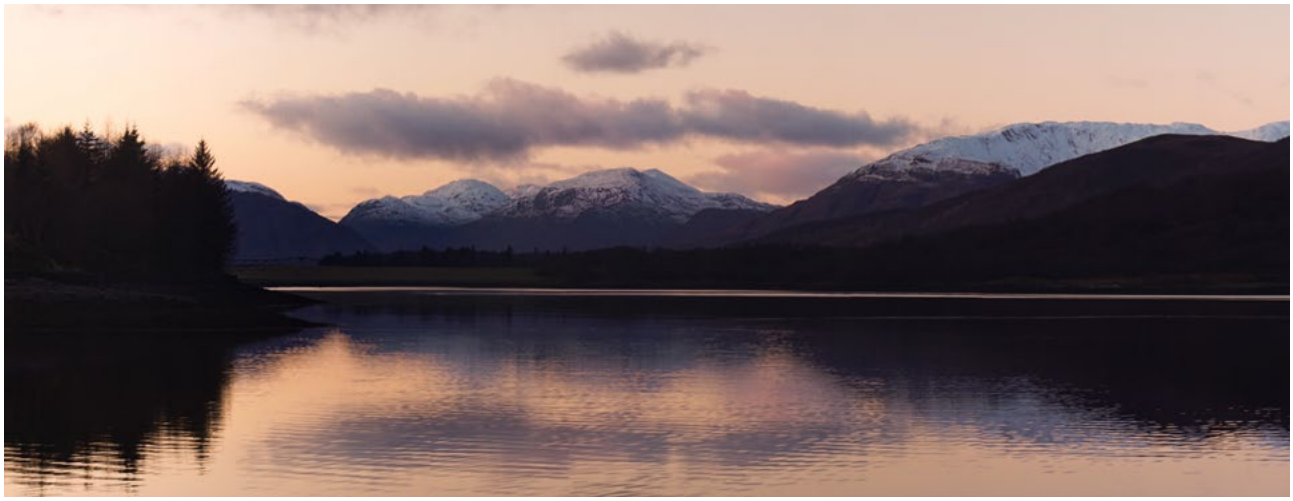
A Scotland where air quality is not compromised by new or existing development and where places are designed to minimise air pollution and its effects.

5. Communication

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

6. Climate change

Reducing greenhouse gas (GHG) emissions and achieving renewable energy targets while delivering co-benefits for air quality.



[1] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/332854/PHE_CRCE_010.pdf

2.2.2 Independent CAFS Review

In 2018, the Scottish Government commenced an independent review of its air quality strategy 'Cleaner Air for Scotland – The Road to a Healthier Future' (CAFS) to set out the status of CAFS since its initial publication in late 2015. The review was a commitment in the 2018/19 Programme for Government and was launched by the Cabinet Secretary for the Environment, Climate Change and Land Reform on 6 November 2018. A Steering Group and a chair were appointed and tasked with reviewing the progress of the CAFS Strategy to date, assessing the current state of Scotland's air quality and possible future trajectories; identifying evidence and activity gaps and finally; providing advice and recommendations on priorities for further action. The Steering Group's final report, setting out its conclusions and recommendations, was published in August 2019. Later in 2019, the Scottish Government issued an online questionnaire to gather wider comment from stakeholders and the public. A new air quality strategy, taking into account the review recommendations, was issued for public consultation towards the end of 2020. The Cleaner Air for Scotland strategy independent review document can be accessed here: https://www.gov.scot/publications/cleaner-air-scotland-strategy-independent-review/pages/2/

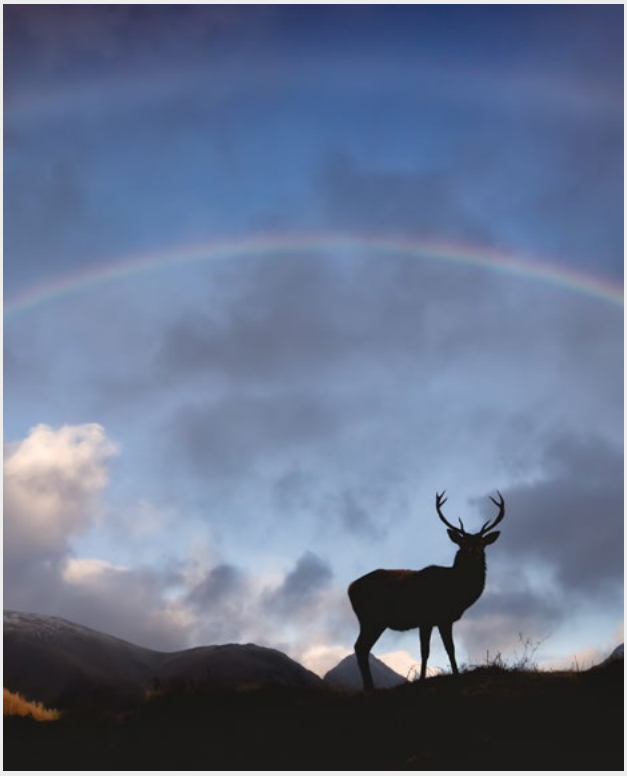
2.2.3 National Low Emissions Framework (NLEF)

The 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&id=588. The framework provides a methodology for local authorities to undertake air quality assessment to inform decisions on transport related actions.

The LAQM Annual Progress Report template for 2020 included the 'NLEF Stage 1 Screening Appraisal' for all local authorities with Air Quality Management Areas (AQMAs). The NLEF is directly linked to Air Quality Action Plan (AQAP) and this screening exercise will allow local authorities to carry out an assessment of their AQMAs to determine whether to proceed to Stage 2 Assessment; agreed by the Scottish Government and SEPA.

The Stage 2 Assessment main outcome is to determine whether to introduce a Low Emission Zone (LEZ) into the local authority or identify and consider actions that could lead to improved air quality and contribute to the revocation of the AQMA, again agreed by the Scottish Government and SEPA.



2.2.4 Low Emissions Zones

In Sept 2017, the Scottish 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 NLEF appraisal advocates such mitigation.

On 31 December 2018, the first Scottish LEZ was introduced into Glasgow city centre. Throughout 2019, Glasgow has been in its first phase of its LEZ and applies to local service buses only. However, Glasgow's LEZ development of future phases to incorporate all other vehicle types was delayed due to Covid-19. Plans to implement Edinburgh, Aberdeen and Dundee LEZ's were also delayed, but work has now re-commenced. More information is available here: https://www.lowemissionzones.scot/about

2.3 Local Air Quality Management

The LAQM process places an obligation on all local authorities to regularly review and assess air quality in their areas to determine if the air quality objectives are likely to be exceeded. Where an exceedance is considered likely, the local authority must:

- Declare an AQMA
- Assess and identify the reasons for the problem and develop an Air Quality Action Plan (AQAP) to help address the problem

In 2016, the Scottish Government produced and updated the technical guidance and policy guidance for the LAQM regime in the UK. The LAQM policy and technical guidance documents are available online (www.scottishairquality.co.uk/air-quality/legislation).

2.4 Air Quality Management Areas

In Scotland, there are 38 AQMAs declared across 14 of the Scottish local authorities. The AQMAs in Scotland are declared for either nitrogen dioxide (NO_2) and/or PM_{10} concentrations, with the exception of the Grangemouth AQMA for sulphur dioxide (SO_2). The adoption of the $PM_{2.5}$ objective of 10 µg m^{-3} has not resulted in any additional AQMAs being declared. However, $PM_{2.5}$ monitoring continues to increase. The AQMAs declared in Scotland are presented in Table 2.2.

Table 2.2 Current AQMAs in Scotland

Local authority	Pollutant (no of AQMAs)	Main Source	AQMAs
Aberdeen	NO_2 and PM_{10}	Roads	3
City of Edinburgh	NO_2 (5) and PM_{10} (1)	Roads	6
Dundee City	NO_2 and PM_{10}	Roads	1
East Dunbartonshire	NO_2 and PM_{10}	Roads	2
East Lothian	NO_2	Roads	1
Falkirk	SO_2 (1), NO_2 (1), PM_{10} (1), NO_2 and PM_{10} (1)	Industry and roads	4
Fife	NO_2 and PM_{10}	Roads	2
Glasgow City	NO_2 and PM_{10} (1), NO_2 (2)	Roads	3
Highland	NO_2	Roads	1
North Lanarkshire	PM_{10}	Industry and roads	4
Perth and Kinross	NO_2 and PM_{10}	Roads	2
Renfrewshire	NO_2 (2), NO_2 and PM_{10} (1)	Roads	3
South Lanarkshire	NO_2 (1) and PM_{10} (2)	Roads	3
West Lothian	NO_2 (2) and PM_{10} (1)	Roads	3

3

Networks and Data

3.1 Automatic monitoring in Scotland

Extensive air quality monitoring is carried out across Scotland. Some monitoring sites are run as part of UK-wide monitoring networks and others are operated by local authorities for LAQM purposes. The following AQS pollutants were monitored in Scotland during 2019:

- Benzene (C_6H_6)
- 1,3-butadiene (C_4H_6)
- Carbon monoxide (CO)
- Lead (Pb)
- Oxides of nitrogen (NOx), comprising nitric oxide (NO) and nitrogen dioxide (NO_2)
- Ozone (O_3)
- Particles (as PM_{10}, $PM_{2.5}$ and black carbon)
- Polycyclic aromatic hydrocarbons (PAH)
- Sulphur dioxide (SO_2)

Figure 3.1

Location of automatic monitoring stations

Figure 3.2

Scottish Automatic Monitoring Site

The locations of automatic monitoring stations are shown in Figure 3.1. These stations provide high-resolution, hourly information on a wide range of pollutants. Data from national network monitoring sites are updated hourly in near real time on the SAQD.

Data from local authority operated monitoring sites are updated hourly or daily depending on the station configuration. A typical automatic monitoring site is shown in Figure 3.2.

Scotland's automatic monitoring is supplemented by non-automatic monitoring techniques. For example, the pumped-tube samplers used to monitor benzene, the high-volume samplers used to measure PAH and the non-automatic techniques used to monitor nitrogen dioxide and metals (such as lead).

3.2 Passive monitoring in Scotland

In 2019, the Scottish local authority diffusion tube site map went live on the SAQD website (http://www.scottishairquality.scot/latest/diffusion-sites) (Figure 3.3). This network of over 1100 sites across the 32 local authorities provides published bias corrected annual mean diffusion tube data, site type information, location and historical data in a format that is easy to understand. Diffusion tubes are used:

- As a low-cost alternative to automatic monitoring at a greater amount of locations of concern for use within Local Air Quality Management.
- To give an indication of longer-term average NO_2 concentrations.
- For highlighting areas of high NO_2 concentrations where installation of an automatic analyser isn't feasible.

3.3 Key Results for 2019

This section provides a summary of results from automatic and non-automatic monitoring in Scotland in 2019 including compliance with AQS objectives. Further information is provided on the Air Quality in Scotland website (www.scottishairquality.co.uk). This will be supplemented by further information and data to be published in the full Annual Report later this year. Data from individual local authorities' NO_2 diffusion tube networks are not included.

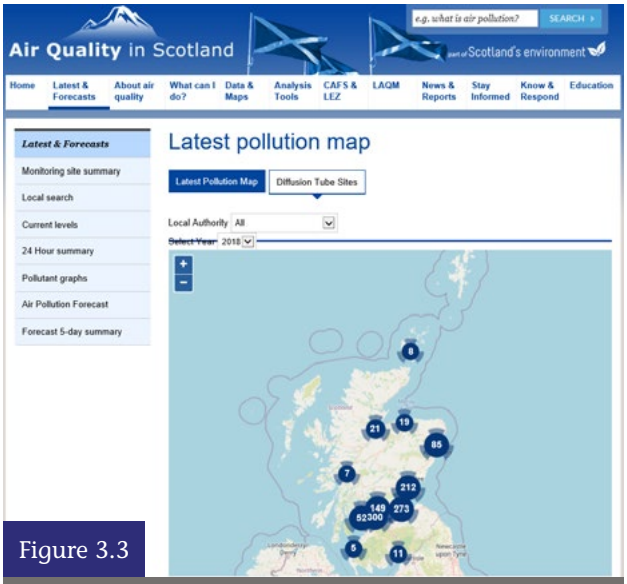


Figure 3.3

Diffusion Tube Site Map

Benzene

This hydrocarbon is a constituent of vehicle exhaust emissions. Benzene was monitored using a non-automatic pumped-tube sampler at two sites (Glasgow Kerbside and Grangemouth) as part of the UK Non-Automatic Hydrocarbon Network. Benzene was also measured using an automatic technique at the rural supersite at Auchencorth Moss. All sites had annual mean concentrations below the AQS objective for the running annual mean.

1,3-Butadiene

1,3-butadiene is also a constituent of vehicle exhaust emissions. This pollutant was monitored at one rural site (Auchencorth Moss in Midlothian) as part of the UK Automatic Hydrocarbon Network. There were no exceedances of the 1,3 butadiene objective in 2019.

Carbon monoxide

This gas is a product of incomplete combustion, with vehicle exhaust emissions being an important source. It was monitored at one site in Scotland in 2019 - Edinburgh St Leonards. Outdoor concentrations of CO were well within the AQS objective, as they have been for many years.

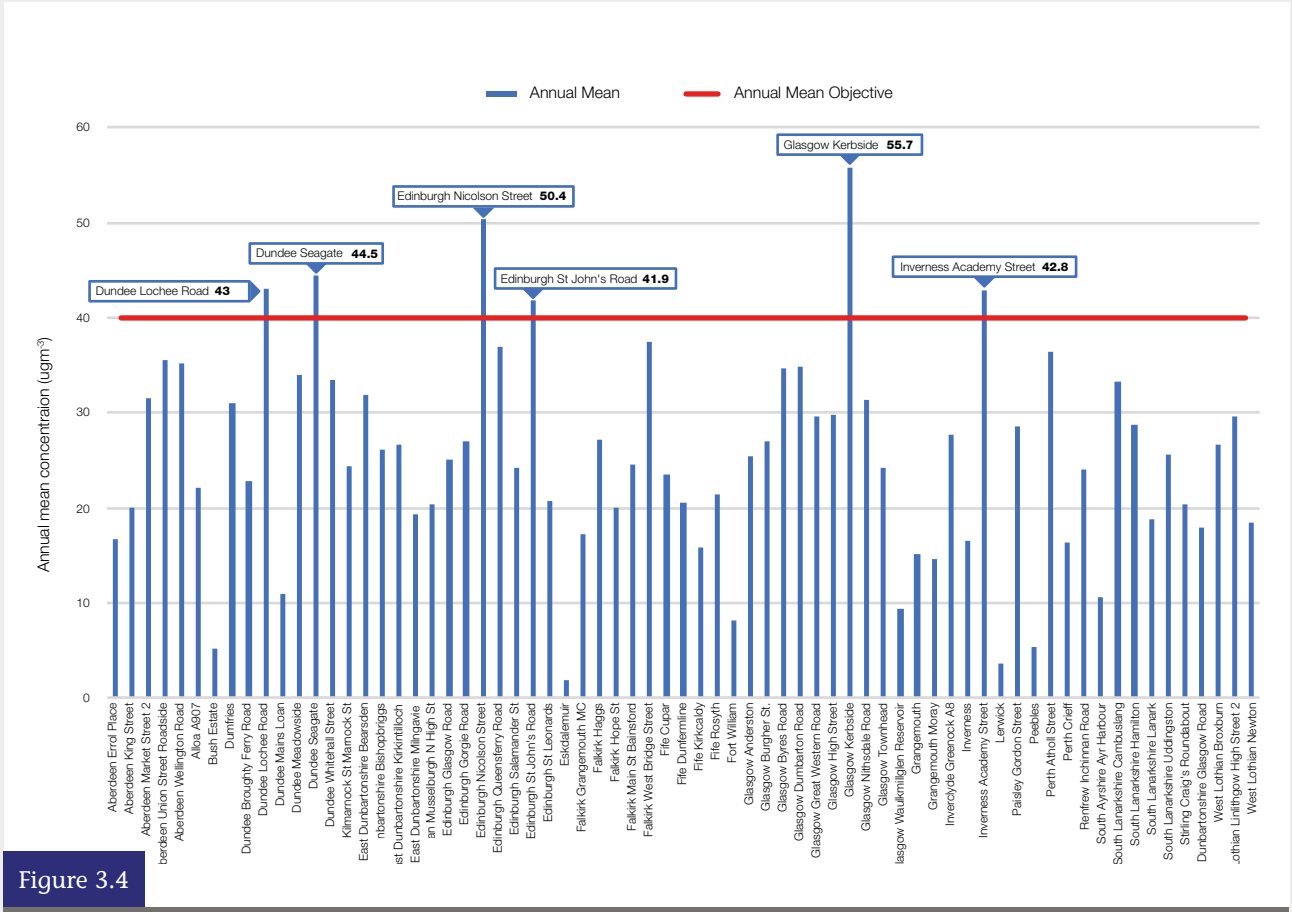


Figure 3.4

Annual mean NO_2 concentrations at sites with >75% data capture (2019)

No site exceeded the hourly AQS objective of 200 µg m-3 on more than the 18 permitted occasions.

Lead

This toxic metal is emitted from some industrial processes (although emissions are now strictly controlled). Lead is monitored at two non-automatic sites in Scotland (Auchencorth Moss and Eskdalemuir). The 2019 annual mean from both sites was well below the AQS objectives concentration of 0.25 µg m^{-3}.

Nitrogen dioxide – Automatic monitoring

This toxic gas is emitted from most combustion processes, including power generation, domestic heating and vehicle engines. It was monitored at 90 automatic sites in Scotland during 2019. Of these, 20 achieved less than the 75% data capture generally considered necessary to calculate a representative annual mean. This was because of instrument/sampling issues or the site starting up or closing down part way through the year.

Six sites had annual mean NO_2 concentrations greater than the AQS objective of 40 µg m^{-3}. The highest annual mean concentrations were measured at Glasgow Kerbside, located close to a busy road, which had a measured concentration of 55.7 µg m^{-3} (4.5 µg m^{-3} lower than in 2018). Figure 3.4 shows annual mean NO_2 concentrations at each site (with at least 75% data capture).

Nitrogen dioxide – Passive monitoring

At the time of writing this report data from only 471 sites (less than half the network) have been published for 2019. The missing data includes three out of the four major cities in Scotland. The delay in publishing the data has been attributed to the Covid-19 outbreak and associated restrictions. To identify which of these sites data are available for 2019 and all other historical data please go to http://www.scottishairquality.scot/latest/diffusion-sites.

Of the 471 sites 12 NO_2 diffusion tube monitoring sites exceeded the annual mean objective in 2019 and were located in Aberdeen City, Renfrewshire and Falkirk.

During 2018 there were 75 NO_2 diffusion tube monitoring sites that exceeded the annual mean objective. Most of these locations were in the city centre areas of the four major cities in Scotland (Aberdeen, Dundee, Edinburgh and Glasgow), however, other busy urban locations outside the centres also exceeded. Figure 3.5 shows the number of exceeding NO_2 diffusion tubes sites compared to the total number of sites monitoring over the past six years. Though the number of sites has significantly increased since 2013 the number of exceeding sites has decreased. However, this decreasing trend in exceedances has not been consistent.

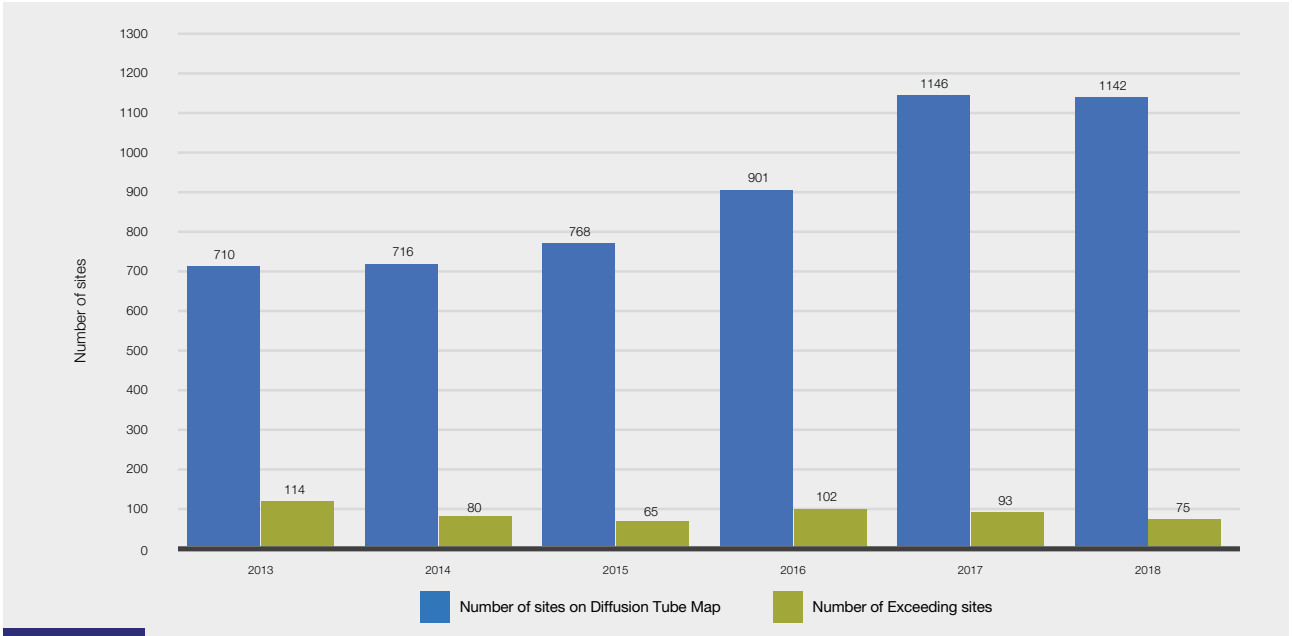


Figure 3.5

Annual diffusion tube NO_2 concentrations (2013 – 2018)

Sulphur dioxide

This gas is emitted when fuels containing small amounts of sulphur (such as oil and coal) are burned. This pollutant was monitored at eight sites in 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.

Particulate matter as PM_{10}

Particulate matter arises from many sources. It can be directly emitted from combustion processes or formed from chemical reactions involving other pollutants. Natural sources (e.g. wind-blown dust and sea salt) also contribute.

PM_{10} was monitored at 82 Scottish sites in 2019 sites using automatic monitoring.

The Scottish annual mean objective of 18 μgm^{-3} was not exceeded at any sites in 2019. This is the first time in the last 10 years that no sites have exceeded the annual mean objective in Scotland. Figure 3.6 provides annual mean PM_{10} concentrations for all sites in Scotland with 75% or more data capture.

The Scottish Objective for the 24-hour mean PM_{10} concentration of 50 μgm^{-3}, not to be exceeded 7 days per year, was however exceeded at one site. The site in question was Renfrewshire Johnston with 14 exceedances.

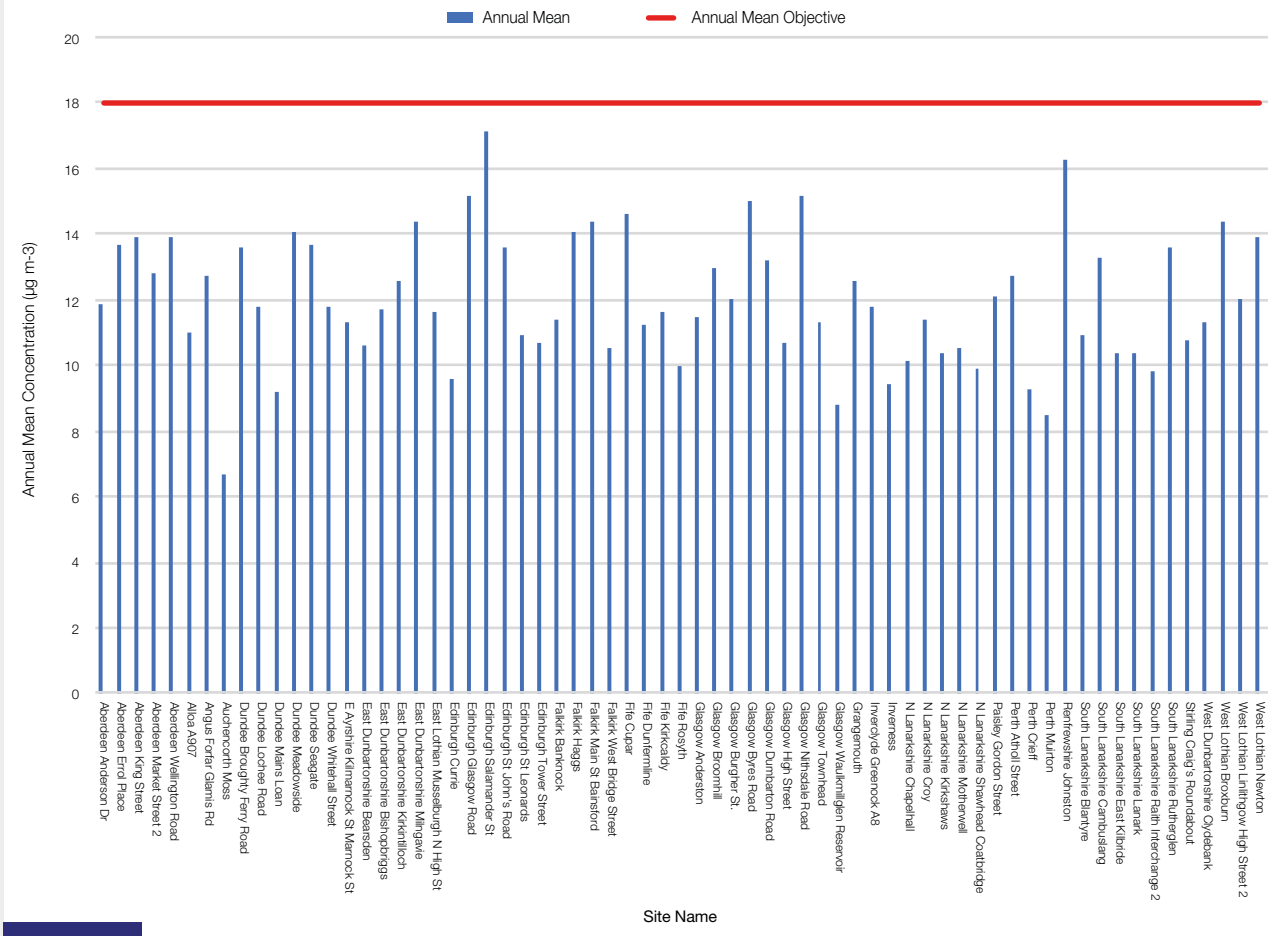


Figure 3.6

Annual mean PM_{10} concentrations at sites with >75% data capture (2019)

Particulate matter as $PM_{2.5}$

During 2019, the finer particle fraction, $PM_{2.5}$ was monitored at 58 Scottish sites, an increase by 13 automatic analysers from 2018. Of these, 10 achieved less than the 75% data capture generally considered necessary to calculate a representative annual mean. This was because of instrument/ site faults or instrument installations during the year.

The Scottish AQS annual mean objective of 10 µg m^{-3} was not exceeded at any sites in 2019. See Figure 3.7 for annual mean concentrations at all sites (with a data capture of 75% or more) compared to the annual mean objective.

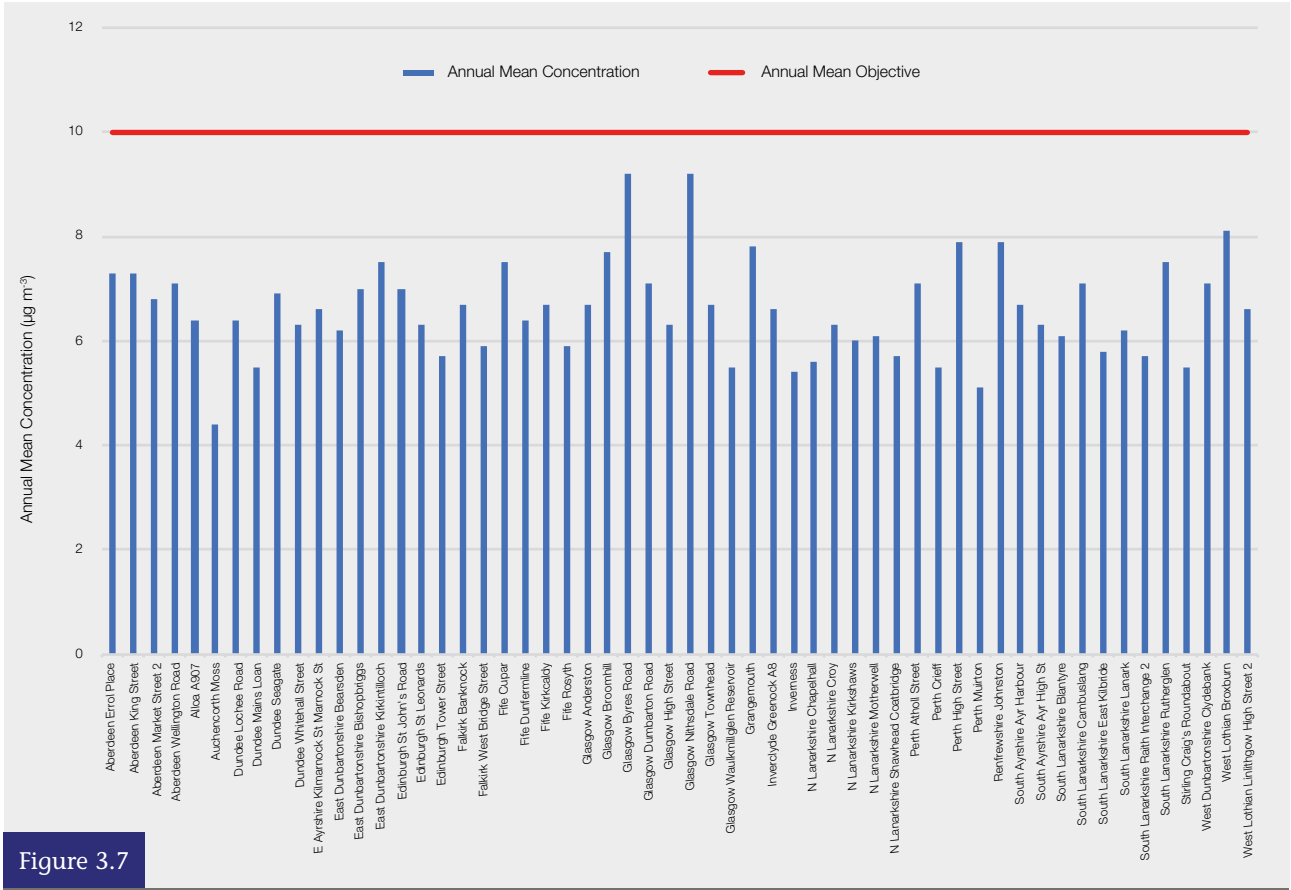


Figure 3.7

Annual mean PM2.5 concentrations at sites with >75% data capture (2019)

Polycyclic aromatic hydrocarbons
This group of pollutants is monitored at four sites in Scotland (Kinlochleven, Glasgow Townhead, Edinburgh St Leonards and Auchencorth Moss). The AQS objective of 0.25 ng m^{-3} for benzo[a]pyrene was exceeded at one site in 2019 – Kinlochleven, with a measured annual mean concentration of 0.29 ng m^{-3}.

Ozone
This is a secondary pollutant that is formed by reactions involving other pollutant gases in the presence of sunlight and over several hours. Once formed, it may persist for several days and be transported over long distances. This makes it difficult to control by local action. It was monitored at 11 sites in Scotland during 2019. Of these, the AQS objective of 100 µg m^{-3} as an 8-hour running mean not to be exceeded more than 10 days was exceeded at seven sites in 2019 (see Figure 3.8).

The AQS objective is not included in regulations. This is in recognition of the fact that it is transboundary in nature and that local authorities have very little control over concentrations in their areas.

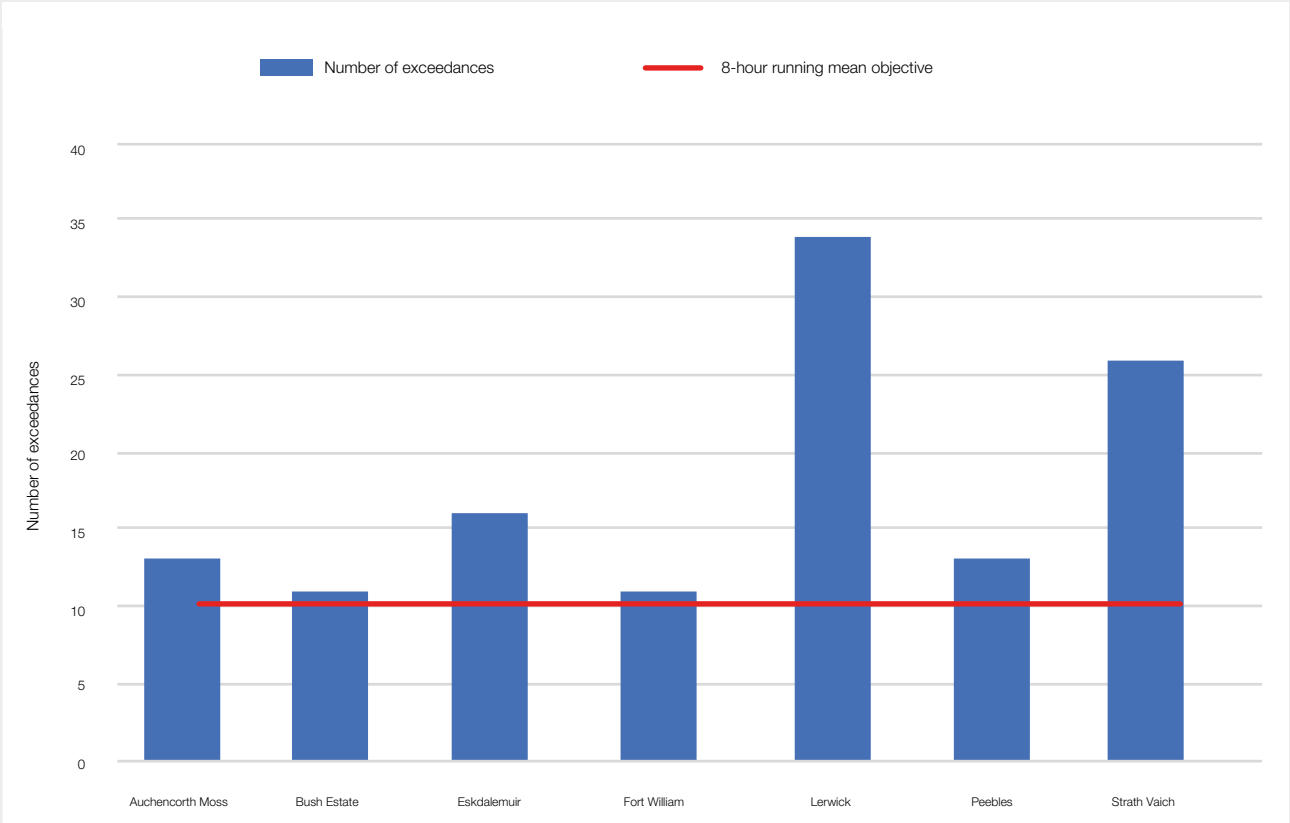


Figure 3.8

Exceedances of the 8-hour running AQS objective for ozone (2019)

4

Air Quality Trends

This section summarises how air quality in Scotland has changed over recent years. As with previous years, the pollutants of interest are NO_2, PM_{10}, $PM_{2.5}$ and Ozone.

Automatic monitoring of NO_x has been routinely carried out in Scotland since 1987. However, until 2000, there were relatively few automatic monitoring sites. Subsequent years have seen the number of monitoring sites in the SAQD increase from 20 (in 2000) to the current total of 100 (in 2019). The data produced by these monitoring sites has 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 seen 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, for this report, investigation of trends has been based on subsets of long-running sites.

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 to assess long-term trends at a monitoring site. In most cases, it is now possible to do trend analysis for longer periods (e.g. 10 years).

The trend analysis presented in this section has been carried out using Openair; the air pollution analytical tool available via the Air Quality in Scotland website[2].

The trend analyses were carried out 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 in this section.

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:

* indicating that the trend is statistically significant at the 0.05 level

** indicating significance at the 0.01 level

*** indicating significance at the 0.001 level

The + symbol indicates that the trend is significant at the 0.1 level.

[2] Visit http://www.scottishairquality.scot/data/openair for more information on the Openair tools that are available and how to use them.

4.1 Nitrogen Dioxide

In Scotland (as elsewhere in the UK), the largest number of AQMAs have been declared in response to exceedances of the NO_2 objectives. This is also reflected in the number of monitoring stations reporting exceedances for this pollutant (see Section 3.3 of this report). In particular, the objective of 40 µg m^{-3} for annual mean NO_2 concentration is the most widely exceeded. Therefore, it is important to understand how concentrations of this pollutant vary with time.

4.1.1 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'.

All sites shown in Figure 4.1 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 4.2 takes into consideration analysis from all urban background site in Scotland over the past five years, which includes the 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 4.1. 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.

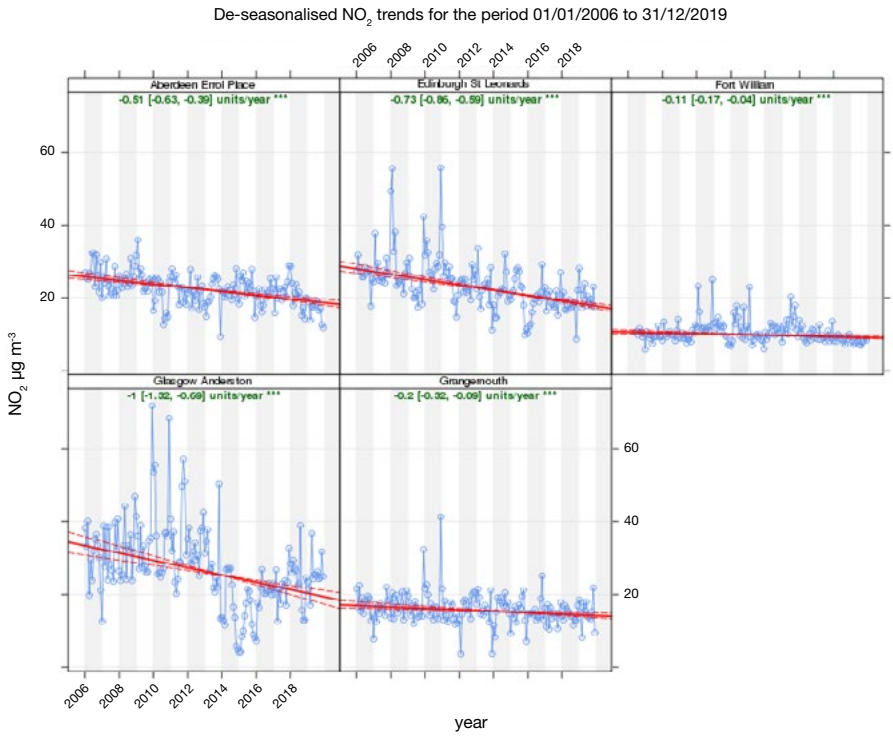


Figure 4.1

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

4.1.2 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. To identify where these sites are, please got to http://www.scottishairquality.scot/latest/.

This is a large number of sites, so for the purposes of this brochure we have selected eight sites from the list of long-running sites. These are:

- Aberdeen Union Street
- Aberdeen Wellington
- Dundee Lochee Road
- Dundee Seagate
- Edinburgh St Johns
- Glasgow Kerbside (Hope Street)
- North Lanarkshire Chapelhall
- Perth Atholl Street

Figure 4.3 shows the trend plots. As with the previous years (the 2018 edition), all eight sites show highly significant downward trends (at the 0.001 level).

Trends over the most recent five complete years, 2015 – 2019, have also been examined for these sites. These are shown in Figure 4.4. 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.

Further information on air quality trends for a range of pollutants is reported in more detail within the SAQD Annual Report.

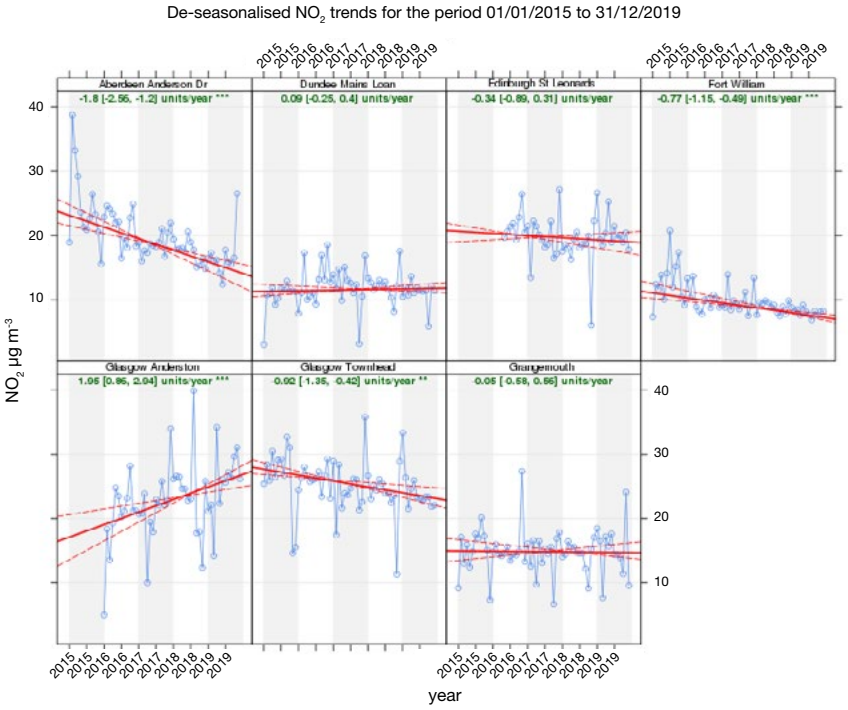


Figure 4.2

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

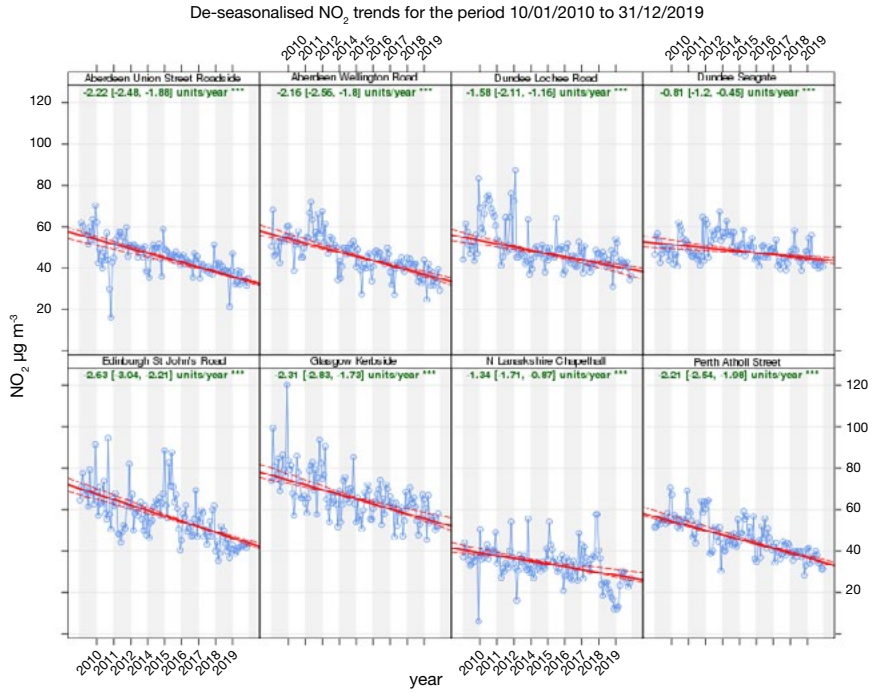


Figure 4.3

Trends in NO_2 concentrations at eight long-running urban traffic sites with exceedances (2010-2019)

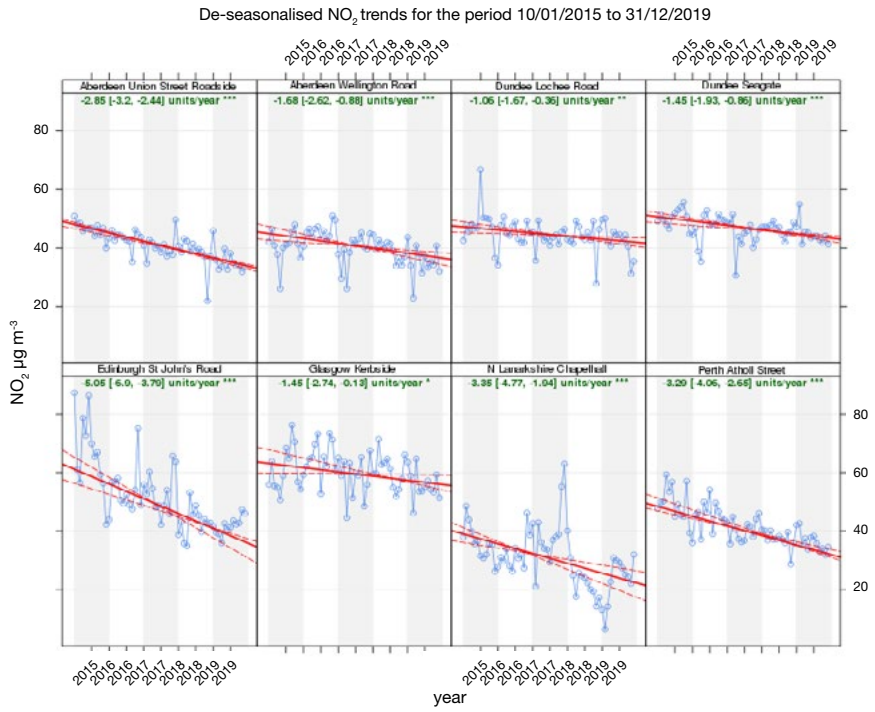


Figure 4.4

Recent trends in NO_2 concentration at nine long-running urban traffic sites (2015-2019)

4.2 Particulate Matter (PM_{10} and $PM_{2.5}$)

This pollutant is of 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.
- There is increasing evidence of the effects on health of $PM_{2.5}$ at progressively lower concentrations
- 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.

4.2.1 PM_{10} at Urban Traffic Sites

There are 34 PM_{10} monitoring sites in Scotland that have been monitoring for over 10 years. Trends in de-seasonalised monthly mean PM_{10} concentrations for eight traffic-related sites in operation since 2010 or earlier are shown in Figure 4.5. The sites selected for this analysis are Aberdeen Wellington Road, East Dunbartonshire Bearsden, Edinburgh Salamander Street, 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.

Trends in PM_{10} concentrations for the same eight sites (plus Edinburgh Queensferry Road), for the most recent five years 2015 – 2019, are shown in Figure 4.6. Figure 4.6 shows that PM_{10} concentrations over the past five years at Glasgow sites Abercromby Street and Byres Road have increased rather than decreased. In addition, statistical analysis of Edinburgh Queensferry road has also indicated an increase over the last five years. For the other sites analysed, the decrease seen over the 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.

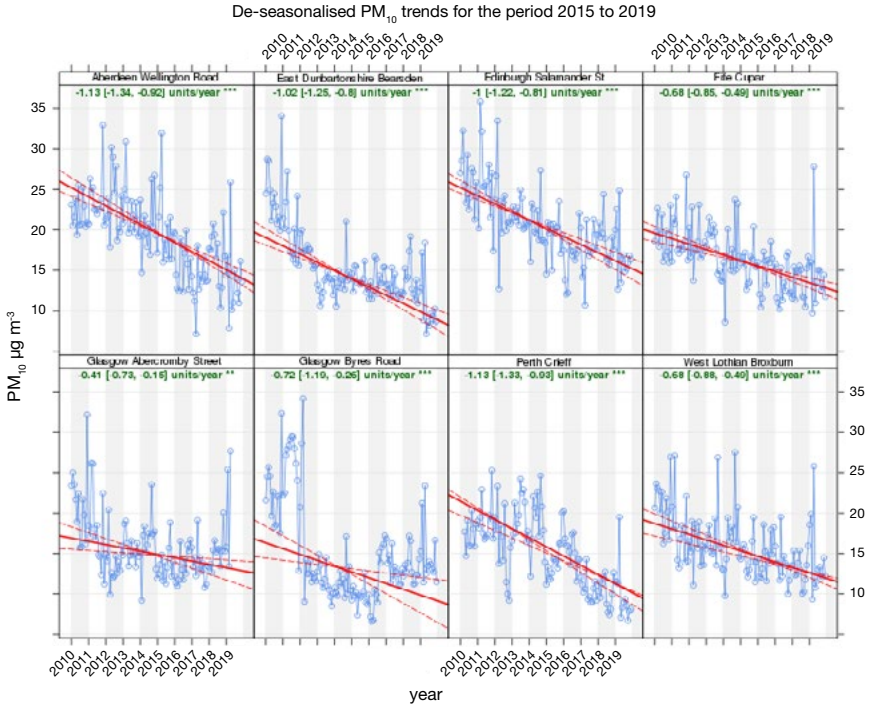


Figure 4.5

Trends in PM_{10} concentration at eight long-running urban traffic sites, 2009 – 2019

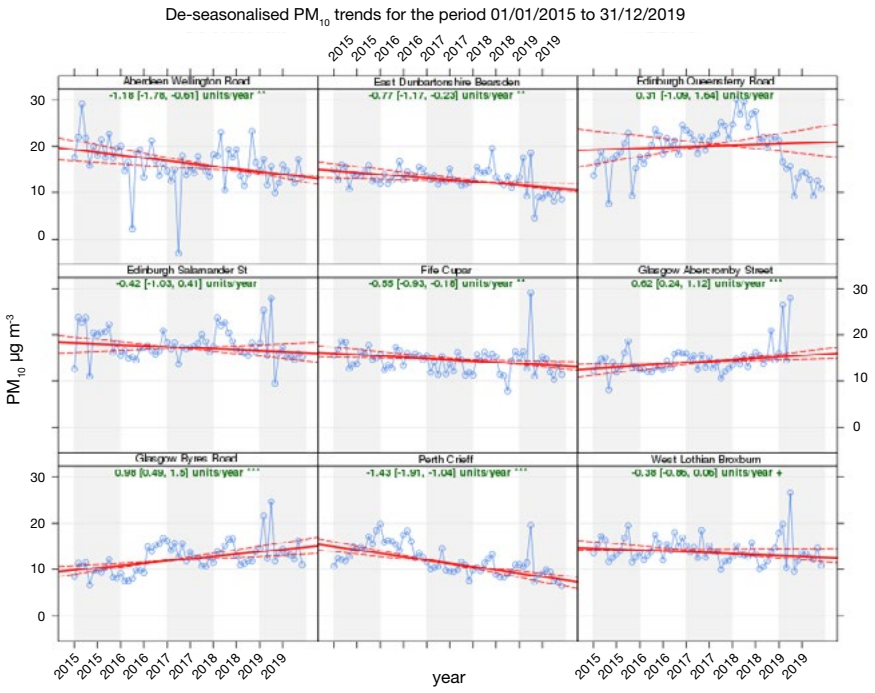


Figure 4.6

Recent trends in PM_{10} concentrations at eight urban traffic sites 2015 – 2019

4.2.2 Particulate Matter ($PM_{2.5}$)

At the time of writing this report there are 78 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 4.7.

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.

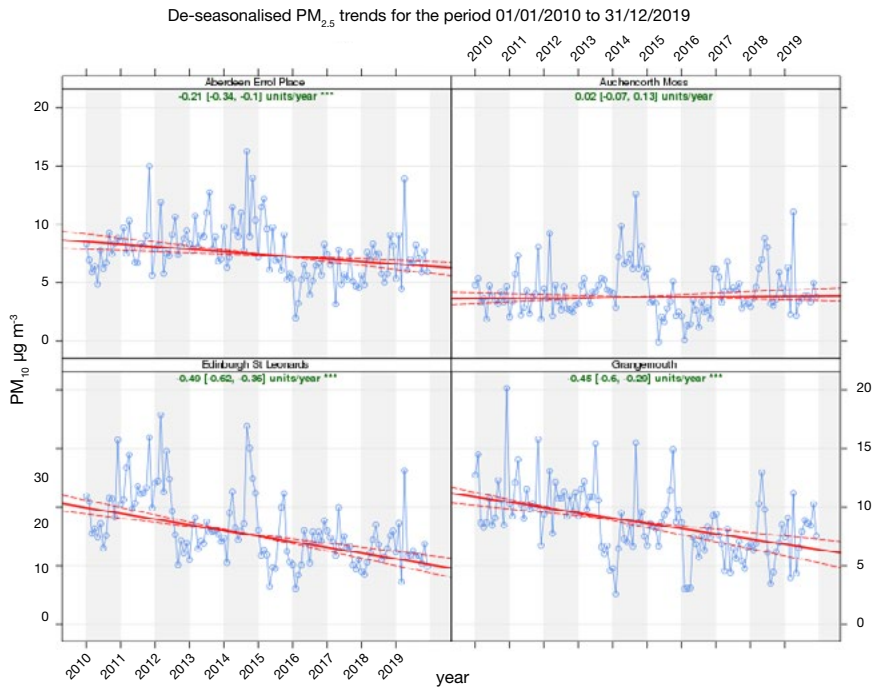


Figure 4.7

Recent trends in $PM_{2.5}$ concentrations at four urban background sites 2010 – 2019

4.3 Ozone (O_3)

Ozone has been included within this year's trend analysis due to the fact that during 2019 seven out of 11 sites in Scotland exceeded the running eight hour mean objective not to be exceed 10 times per year. Trend analysis will identify whether this is unusual or part of a long-term trend.

4.3.1 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 4.8 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.[3]

Six sites have been in operation for over 10 years. These are the aforementioned three sites, plus Auchencorth Moss, Glasgow Waulkmillglen Reservoir and Lerwick. Trends in ozone concentration at these six sites are shown in Figure 4.9. In contrast to the thirty-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.

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

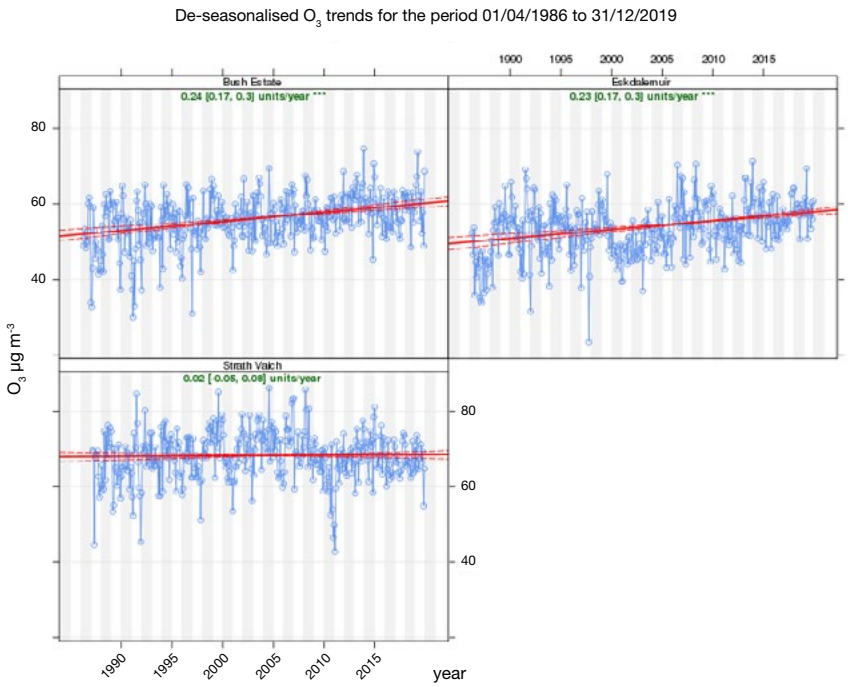


Figure 4.8

Trends in ozone concentrations at long running rural sites, 1986 – 2019

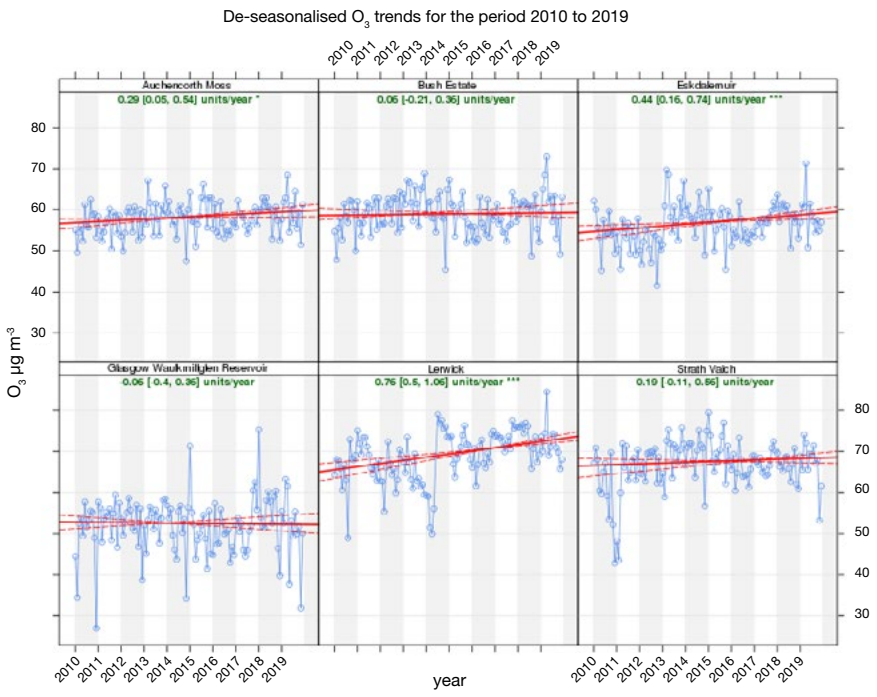


Figure 4.9

Trends in ozone concentrations at six long running rural sites 2010 – 2019

4.4 Regional Pollution Episodes 2019

During 2019, there were two moderate regional pollution events relating to the pollutant ozone on the following dates:

- 14th May 2019
- 25th – 26th July 2019

There was one moderate regional PM episode on the following date:

- 25th – 27th February 2019

There was one significant moderate to very high pollution event between 15th – 24th April 2019, relating to the pollutant Particulate Matter (mainly PM_{10}), during which time there was also moderate ozone (O_3) concentrations.

Figure 4.10 illustrates the elevated concentrations as seen on the Air Quality in Scotland website for the 15th – 24th April 2019 episode (www.scottishairquality.scot).

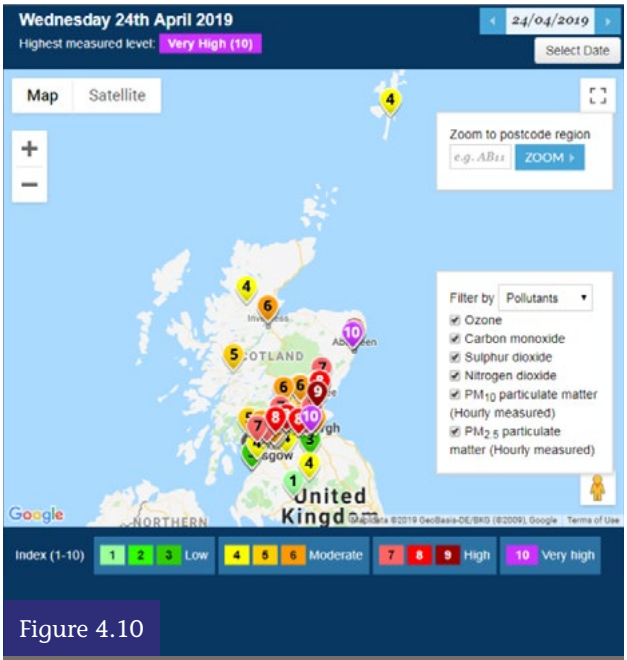


Figure 4.10

Air Quality in Scotland website 24th April 2019

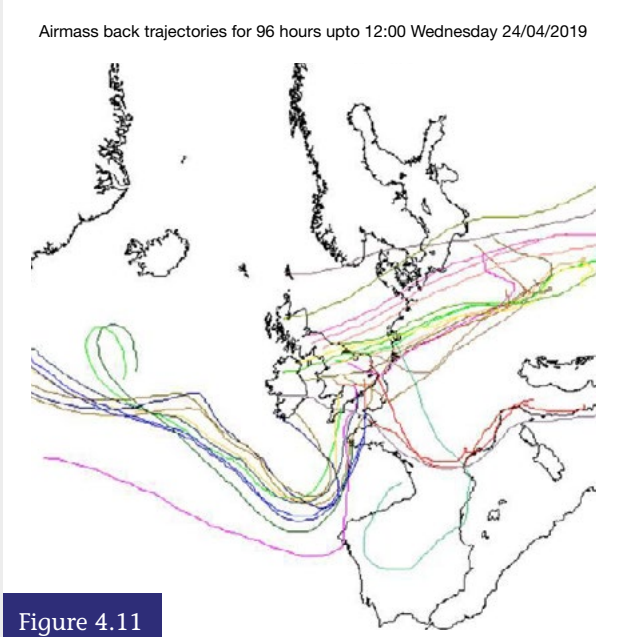


Figure 4.11

Air Quality in Scotland website 24th April 2019

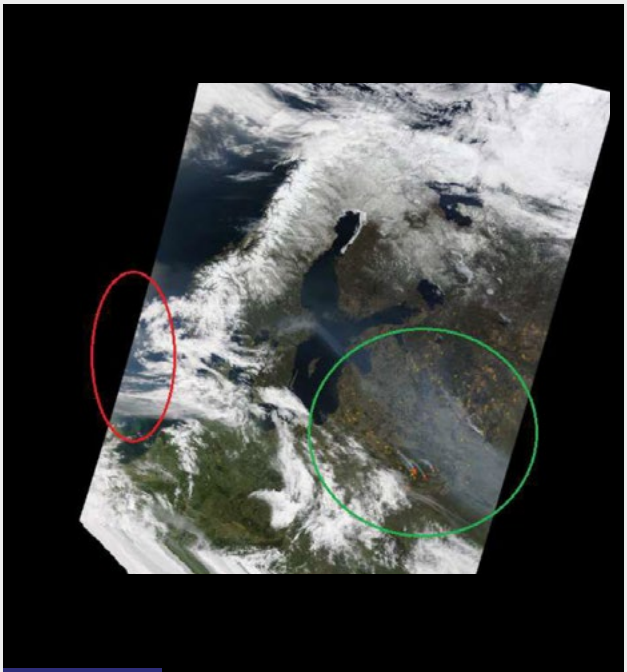


Figure 4.12

Satellite image from Dundee Satellite Receiving Station, Dundee University, available at http://www.sat.dundee.ac.uk/auth.html

For the April 2019 PM_{10} and O_3 pollution episode, analysis identified that air masses from the east (see Figure 4.11) along with strong easterly winds affecting the country, brought over polluted air from the continent. These strong easterly winds blew over smoke from large wildfires located in eastern Europe and Russia. The satellite image below (Figure 4.12) identifies the fires and smoke in eastern Europe (highlighted by the green circle) as well as smoke blowing over Scandinavia towards the east coast of Scotland (highlighted by the red circle). In addition, wildfires in southern Norway added to these poor air quality conditions resulting in the high to very high particulate matter concentrations measured across much of Scotland, and in particular Eastern Scotland.

5

Air Quality Mapping for Scotland

As part of the SAQD project, Ricardo Energy & Environment provides mapped concentrations of modelled background air pollutant concentrations on a 1 km x 1 km basis for the whole of Scotland. Modelled roadside air pollutant concentrations are provided for 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
2. Spatially disaggregated emissions information from the UK National Atmospheric Emissions Inventory (NAEI)

The maps 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. This is used for producing air pollution maps for the whole of the 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 (the most recent year available) 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)
- NO_x and NO_2

The air pollution measurements used to prepare the maps consists of appropriately scaled PM_{10} monitoring data and automatic monitoring measurements for NO_x and NO_2 in 2018. The model also uses Scottish meteorology observations (from Royal Air Force Station Leuchars) to create the Scotland-specific maps as shown in Figure 5.1.

This section discusses the maps of pollutant concentrations produced for the Scottish Government. The full range of maps, together with the most up-to-date interactive technical report, can be found here www.scottishairquality.co.uk/maps.php?n_action=data

This online, interactive reporting format makes reading the report a more dynamic experience. It does so by enabling the reader to interact with the maps and tables within the report itself allowing them to obtain usable data.

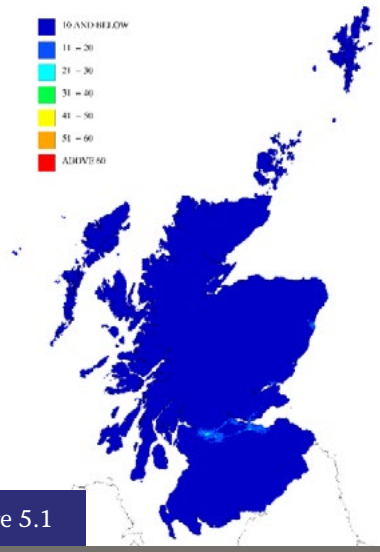


Figure 5.1

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

5.1 Air Quality Maps for Scotland

The 2018 annual mean NO_2 concentrations for Scotland were modelled for background and roadside locations. Figure 5.1 and Figure 5.2 show modelled annual mean NO_2 concentrations in Scotland for background and roadside locations, respectively.

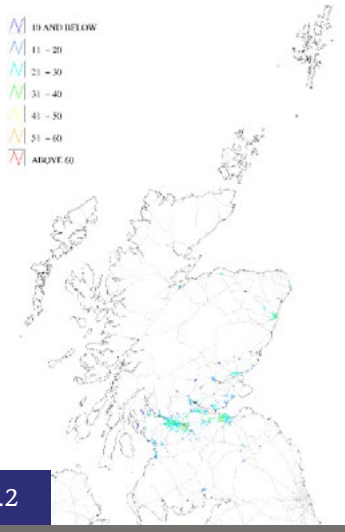


Figure 5.2

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

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 and the North East Scotland zone there were fewer than ten road links where exceedances of the Scottish annual mean NO_2 air quality objective were modelled, affecting less than 10 km of roads in each zone. 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.

5.2 PM_{10} Maps for 2018

Maps of the modelled 2018 annual mean PM_{10} concentrations for Scotland's background and roadside locations are shown in Figures 5.3 and 5.4, respectively.

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 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. sulfate, nitrate and ammonium-based particles)
- Secondary organic aerosols (SOA)
- Primary particles from long-range transport (e.g. soot particles from biomass burning)
- Sea-salt aerosol
- Iron- and calcium-based dusts

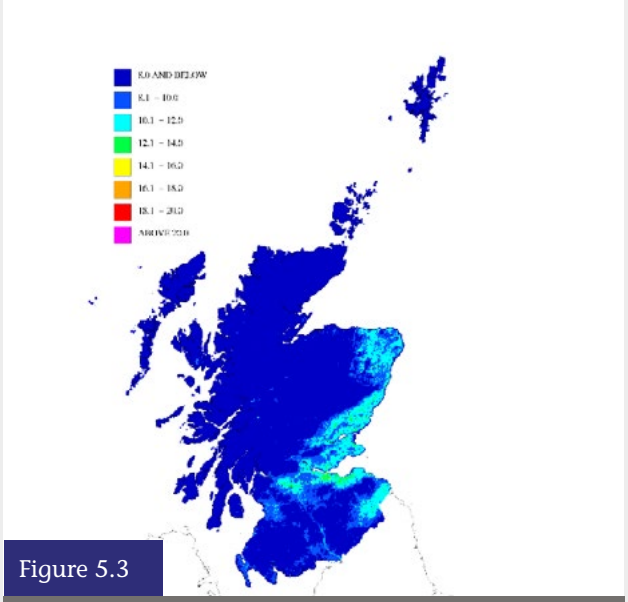


Figure 5.3

Background PM_{10} map for 2018 (µg m^{-3}) (Scotland specific)

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. Five road links (14.9 km of road) were located in the Glasgow Urban Area and one road link (4.4 km of road) was in Central Scotland.

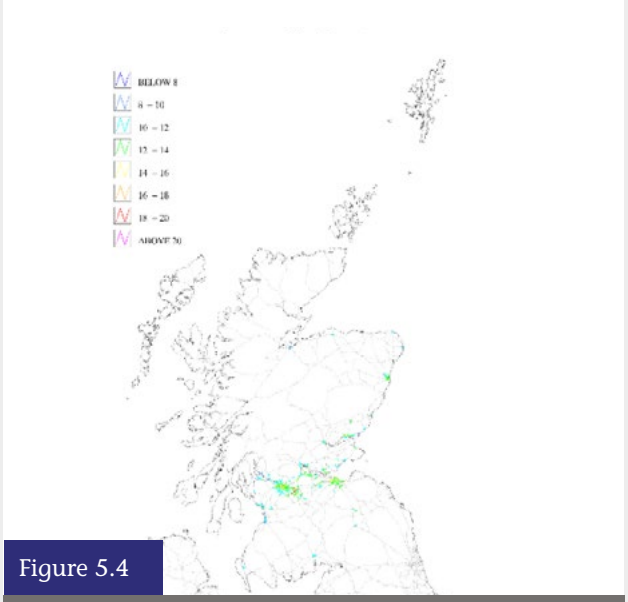


Figure 5.4

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

6

Covid-19

6.1 Covid-19 impact on Scottish air quality 2020

The Covid-19 lockdown measures (Phase 1 in late March 2020 – Phase 3 in 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 provided a unique opportunity to assess how it affected 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 (NO_x) 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 modelled comparison and more in-depth analysis please go to the Air Quality in Scotland Website www.scottishairquality.scot/news/.

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.

6.1.1.1 Nitrogen Dioxide Data Analysis

Figure 6.1 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 6.1 both NO_x 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 Figure 6.2.

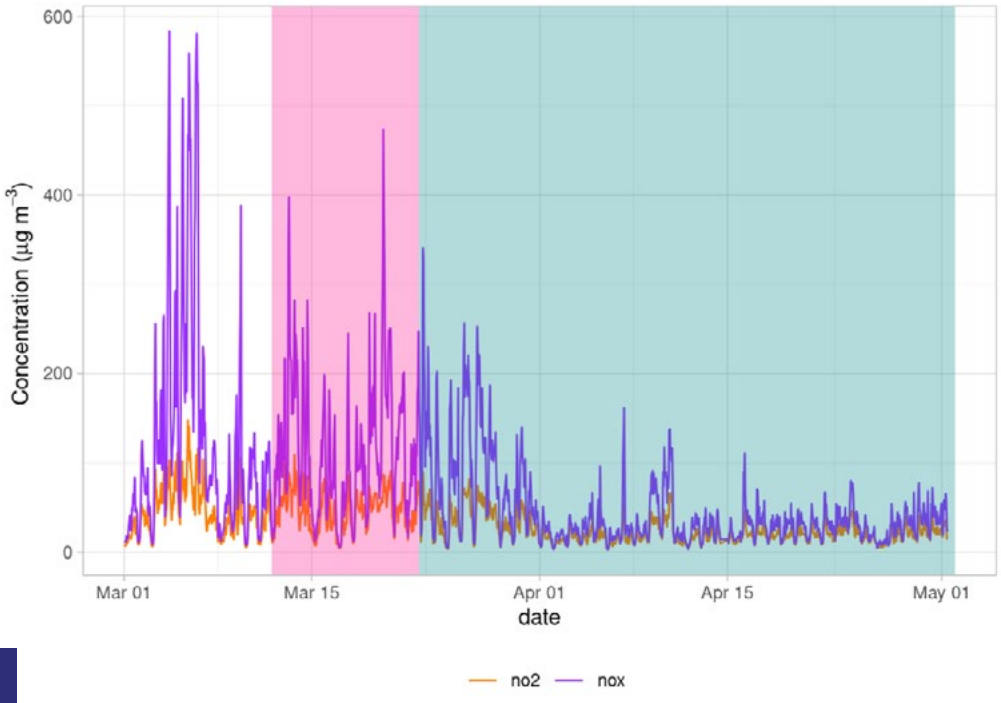


Figure 6.1

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

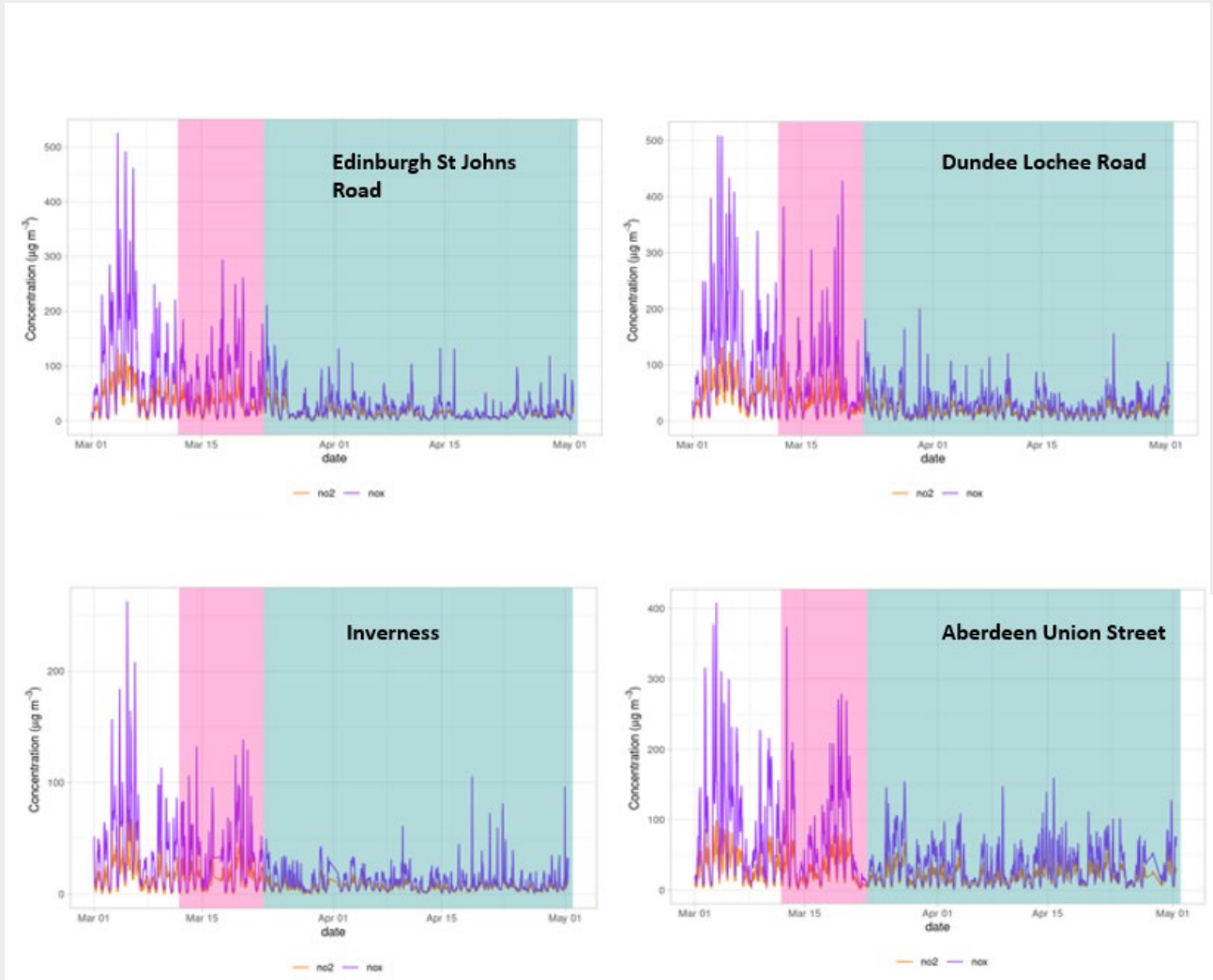


Figure 6.2

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

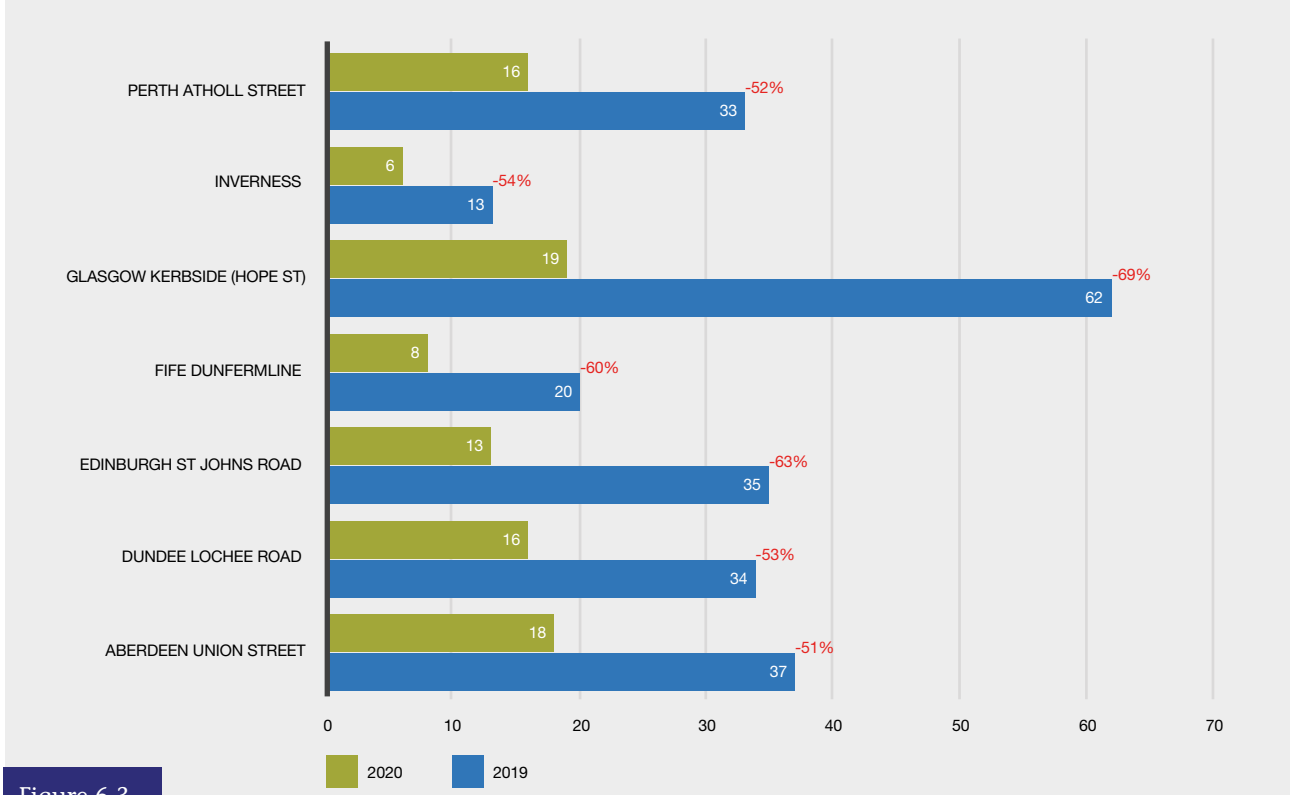


Figure 6.3

Difference in mean NO_2 concentrations (µg m^{-3}) 23rd March – 26th May 2019 and 2020

Figure 6.3 provides a direct comparison between NO_2 concentrations measure in 2020 and 2019 for the period 23rd March to 26th May. It illustrates the significant difference between 2019 and 2020 and provides the decrease as a percentage. For more in-depth analysis, go to the Air Quality in Scotland website (http://www.scottishairquality.scot/news/).

Figure 6.4 and 6.5 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 city centres.

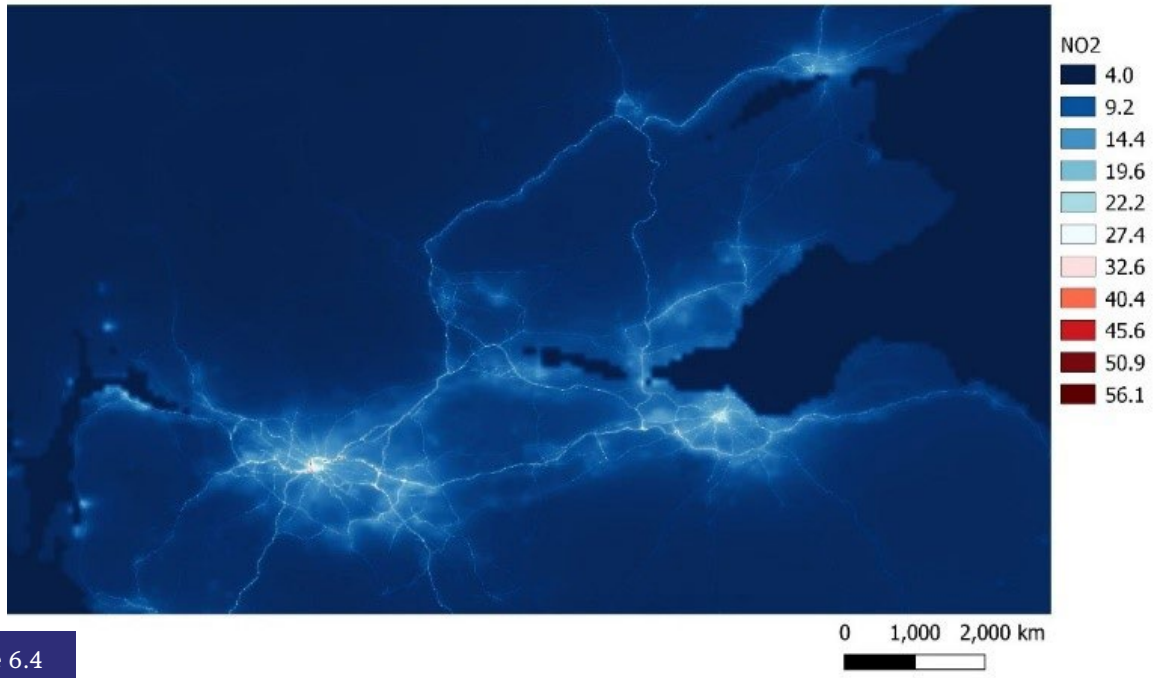


Figure 6.4

Rapid Air image depicting NO_2 concentrations across the central belt of Scotland before Covid-19 restrictions (µg m^{-3})

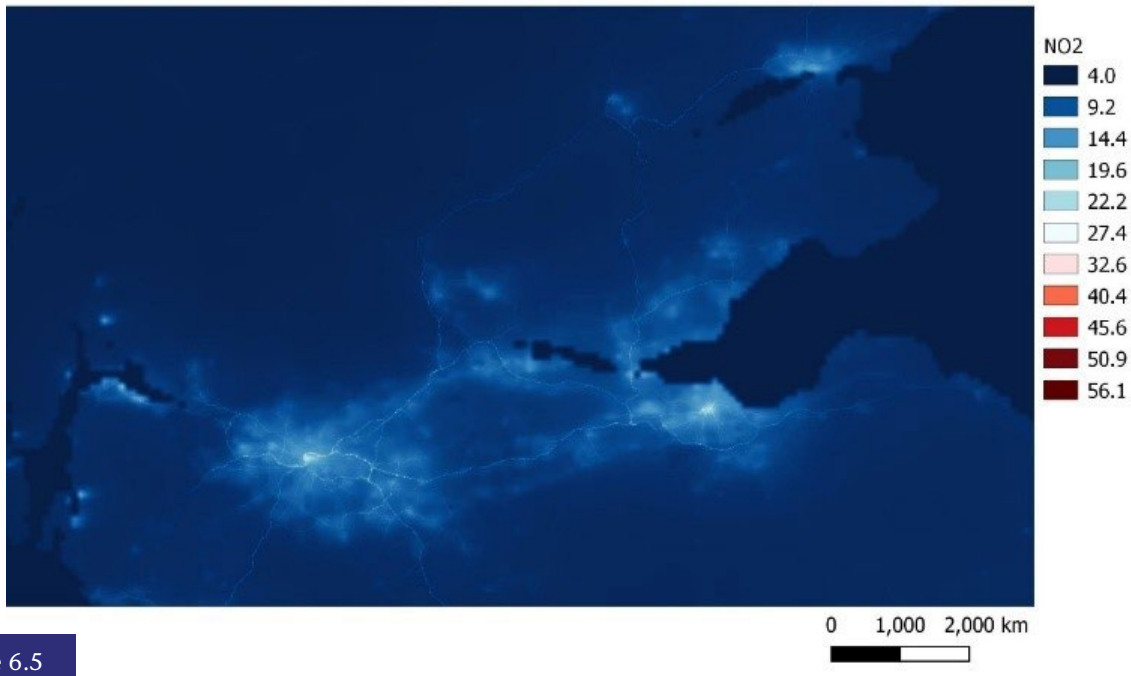


Figure 6.5

Rapid Air image depicting NO_2 concentrations across the central belt of Scotland during Covid-19 restrictions (µg m^{-3})

6.1.1.2 Particulate Matter

Decreases in concentrations 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 - again when directly compared to years back to 2015, decreases in concentrations vary 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 whereas for NO_x, at these locations, the main source is vehicle traffic. This analysis could help identify the contribution vehicles have to particulate matter concentrations at busy urban locations. However, it's not clear how the lockdown restrictions have affected other sources of PM and how that may have also contributed to the reduction in concentrations measured. This is due to the transboundary nature of this pollutant.

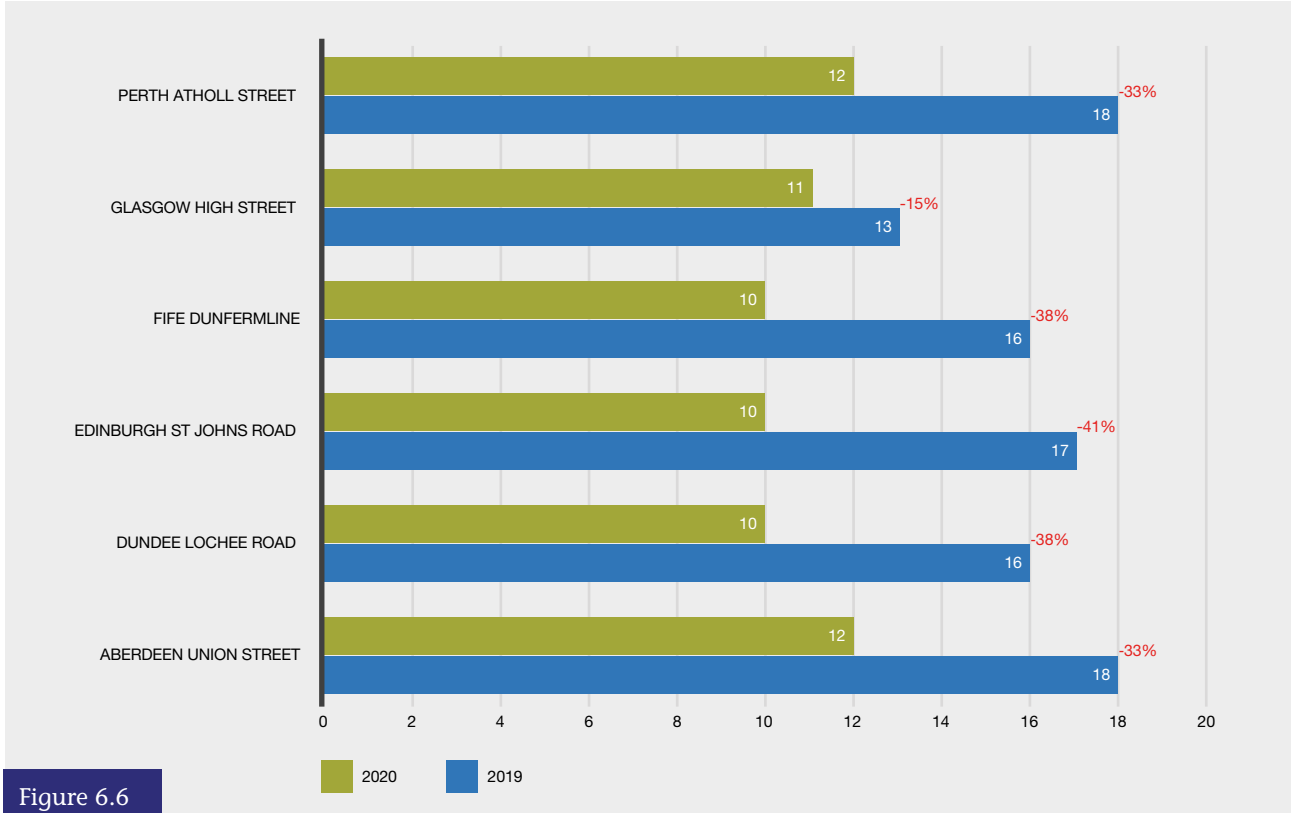


Figure 6.6

Difference in mean PM_{10} concentrations (µg m^{-3}) 23rd March – 26th May 2019 and 2020

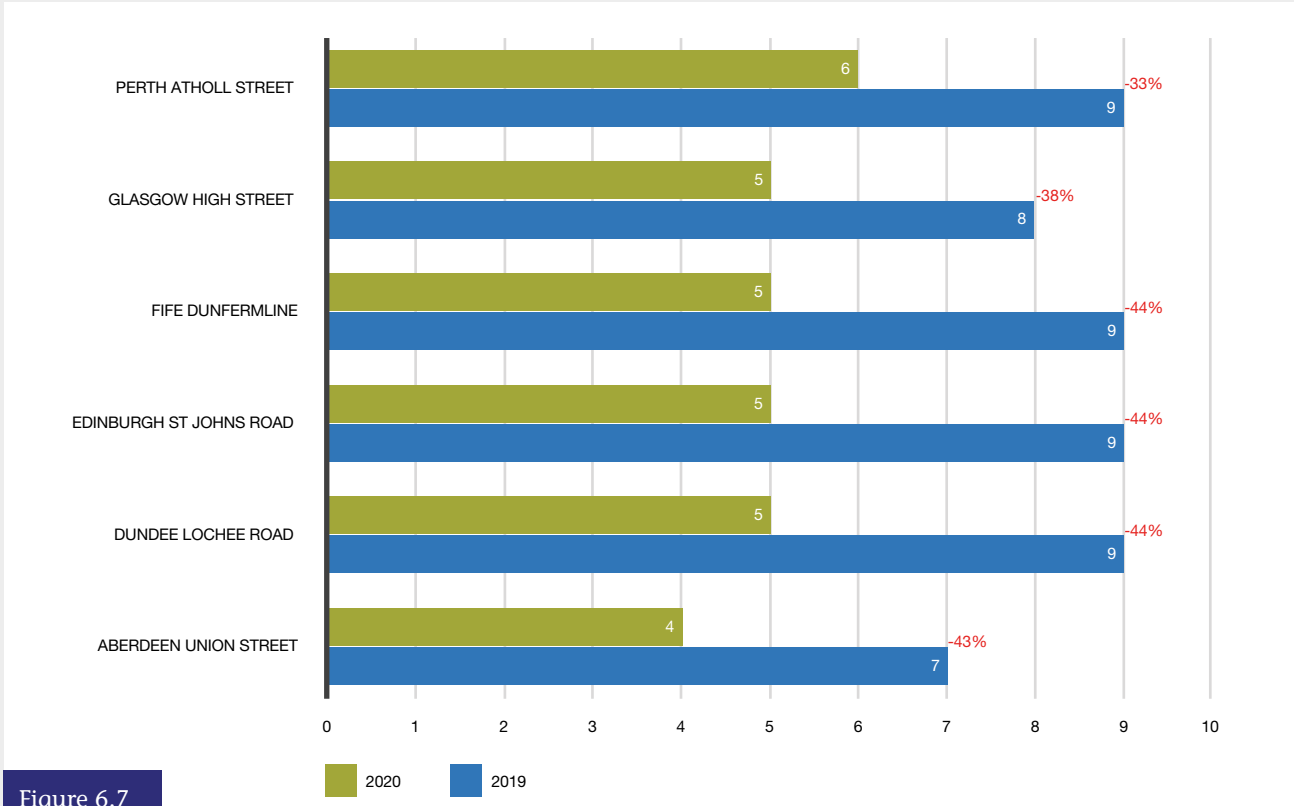


Figure 6.7

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

In conclusion, initial analysis indicates that the Covid-19 lockdown resulted in a dramatic drop in NO_2, PM_{10} and $PM_{2.5}$ concentrations levels in Scottish cities.

7

Education

Education has been an ongoing development for air quality in Scotland. Interactive education packages have been developed through the creation of two sections that form part of the Air Quality in Scotland website. The first education website, 'Air Pollution Detectives', was created for schoolchildren in P5 to P7 (8-11 years old). The second website, 'Clear the Air', was developed in partnership with a number of secondary schools for pupils in S1 to S3 (12-15 years old).

The education packages can be accessed from the Air Quality in Scotland website (www.scottishairquality.co.uk/education).

7.1 Air Pollution Detectives

Initially launched in 2011, the Air Pollution Detectives website has been continuously revised and updated. It was designed to introduce air quality issues to primary school pupils between the ages of 8 and 11. The animated, interactive webpages provide an introduction to air pollution sources and how pupils' actions can impact the air quality around them. Pupils can select individual pollutants to learn more and can take the quiz after each section to see what they have learned. The website is accompanied by a set of teachers' notes to enhance the learning experience and worksheets for pupils are provided.

Figure 7.1 shows the worksheets that were updated during 2016.

Visit the Air Pollution Detectives website at: www.scottishairquality.co.uk/education/

Figure 7.1

Updated worksheets are available on the Air Pollution Detectives webpage

7.2 Clear the Air

The Clear the Air website was developed following the success of Pollution Detectives. The webpage, as presented in Figure 7.2, provides an interactive learning experience for air quality and citizen science aimed at secondary school age and above.

Figure 7.2

Clear the Air webpage

The Clear the Air package includes a series of interactive webinars and exercises designed to be undertaken by pupils. These interactive exercises include 'What air pollution is like near me', 'Calculating your emissions to school' and a citizen science project that enables classes to monitor air quality around the school by using NO_2 diffusion tubes. Pupils are given an NO_2 diffusion tube to take home so they can monitor outside their house.

7.2.1 The Clear the Air – Air Quality Monitoring Pack

The Clear the Air monitoring pack has been designed to give pupils hands-on experience with air quality monitoring equipment and a better understanding of the underlying science. As a class or group, pupils can undertake air quality monitoring around their school grounds, or at, or near their homes. Once the results have been analysed, the monitoring data (location and measured concentration) can be uploaded via the school's private user portal so that the results can be displayed on a map (see Figure 7.3).

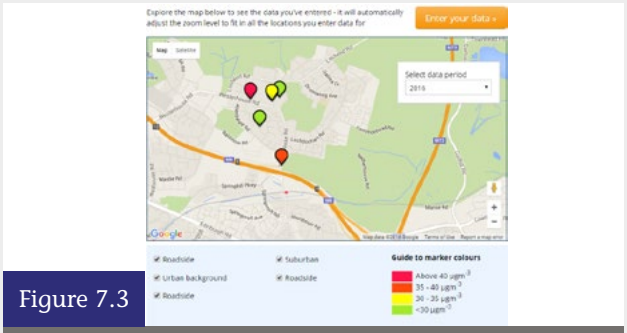


Figure 7.3

Data entry available for each school profile

The package encourages pupils to discuss the results and the factors influencing the air quality measured within the area. The Clear the Air package is supported by a teachers' pack including notes to supplement the monitoring equipment, and webinars to help introduce the concept of local air quality and how to conduct the monitoring.

Further information can be obtained at: http://cleartheair.scottishairquality.co.uk.

8

Stay Informed

8.1 Scotland Air Pollution Forecast

A 5-day forecast for each local authority in Scotland is available on the Air Quality in Scotland website. The forecasts provide a greater level of detail, which can benefit the public – particularly those with health issues. Forecasts are displayed through a summary table and a map.

The 5-day forecast map and summary table are available at: www.scottishairquality.co.uk/latest/forecast

8.2 Air Quality in Scotland App

The Air Quality in Scotland app gives the latest air quality levels for each site, forecasts for the day ahead and alerts when air pollution levels are forecast to increase and when you are entering an AQMA. The free Air Quality in Scotland app is available for most mobile devices.

The AQ Scotland App was updated in 2019 with new functionality and can be downloaded from the Apple Store and Google Play now.

The App provides:

- Easy access to the latest pollution levels from the monitoring sites
- Colour coded map showing the pollution forecasts, plus a detailed breakdown
- Approved health advice based on the pollution levels
- Information on Air Quality management Areas (AQMA) in Scotland in the form of an interactive map

8.3 Know & Respond

Know & Respond is a free service providing alerts when pollution levels are forecast to increase (http://www.scottishairquality.scot/know-and-respond/). Users can subscribe to a specific local authority and will receive push notifications directly to their device if 'moderate' or higher air pollution is forecast each day. Users can choose to receive alerts by text, voicemail or email. Know & Respond alerts are also available via the Air Quality in Scotland app.

8.4 Email Alerts

Sign up to our email bulletins and receive summaries directly to your inbox (http://www.scottishairquality.scot/stay-informed/) . You can choose how frequently you receive them and what type of summary you are interested in.

8.5 Interactive Mapping and Analytical Tools

Visualisation and data analysis tools are available on the Air Quality in Scotland website (http://analysistools.scottishairquality.scot/). The tools pull data from the SAQD and present it in several pre-analysed formats. These tools enable the data to be customised and filtered to meet individual requirements, such as viewing air quality in a particular area or for local authorities when preparing annual reports.

8.6 Twitter

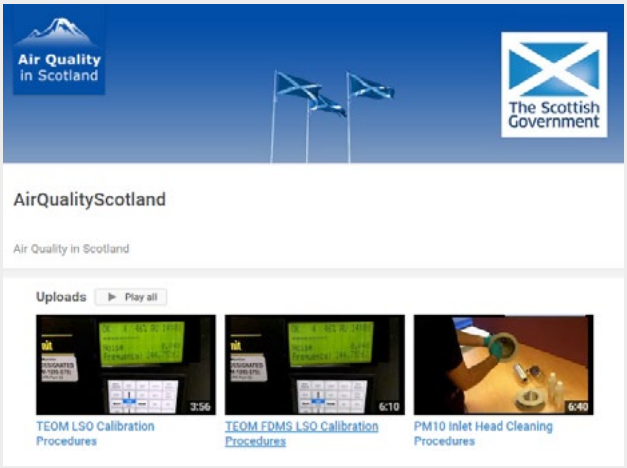
Follow Air Quality in Scotland on Twitter (@scotairquality) for air quality forecasts and summaries of measurements from Scotland.

The service enables you to stay informed about current and forecast air quality including the occurrence of air quality episodes. Health advice and information on the UK Air Quality Index should be considered in conjunction with the tweets, particularly when air pollution is elevated.

8.7 Youtube™

The Air Quality in Scotland YouTube account was initially launched to provide a platform for related videos and it hosts the 'How To' videos for the Local Site Operator manual.

Each video is available through the YouTube website itself, but can also be accessed directly on the Air Quality in Scotland website (https://www.youtube.com/user/AirQualityScotland).



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