The Scottish Government

Air Pollution in Scotland 2015

RICARDO
Ricardo Energy & Environment

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Introduction

This brochure has been produced on behalf of the Scottish Government and is the ninth in an annual series. It aims to provide a summary of the air quality monitoring and associated work carried out by and on behalf of the Scottish Government and local authorities during 2015.

Section 2 of this brochure reviews the air quality legislation and policy applicable to Scotland. **Section 3** summarises the air quality monitoring carried out in Scotland and presents an overview of the data from 2015, including exceedances of air quality objectives. **Section 4** deals with trends in air pollution in Scotland and **Section 5** covers spatial patterns of pollution. **Section 6** provides information on educational activities that have taken place and **Section 7** is a summary of some recent developments. **Section 8** highlights all the different ways in which to get information regarding air quality.

A more detailed Annual Report on the Scottish Air Quality Database (SAQD) project will also be available on the Air Quality in Scotland website www.scottishairquality.co.uk in July 2016.

Since the initial development of the database in 2006, it has grown year on year. The total number of automatic air quality monitoring sites in the SAQD during 2015 was 92. The increase in the number of monitoring sites included in the SAQD since 2006 and locations of these sites are shown in Figures 1.1a and 1.1b. Whilst 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, combined with careful monitoring to access progress is vital in tackling the issue. For more information on air quality in Scotland, and more specifically your area, please visit the Air Quality in Scotland website www.airqualityinscotland.co.uk.

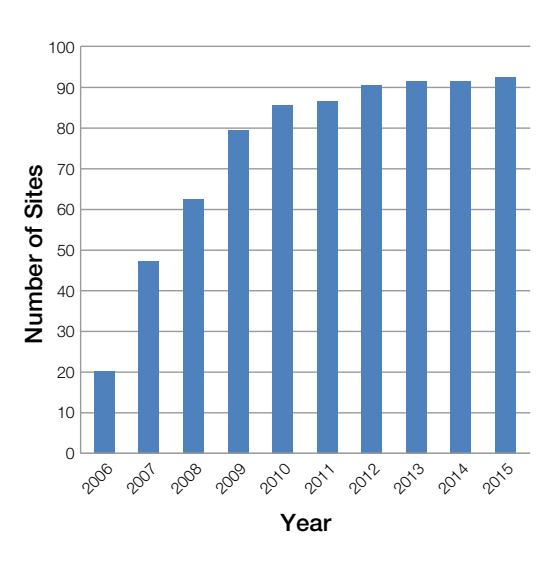


Figure 1.1a

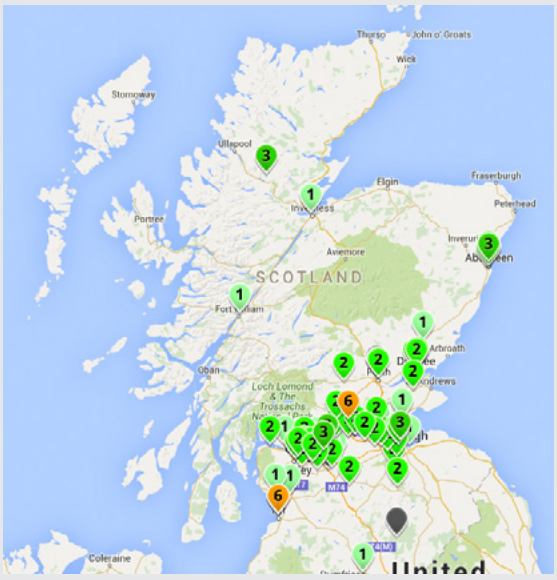


Figure 1.1b

Growth in the number of monitoring sites included in the SAQD since 2006, and Figure 1.1b locations of automatic air quality monitoring sites in Scotland (courtesy of Google™).

2

Legislation and Policy

The management of air quality is based on a series of statutory measures and policy programmes originating from Europe, the UK and Scotland. Together, these form the basis of a strong framework for managing air quality.

2.1 European Union Legislation

Much of the foundation of Scotland's air quality management has its roots in the 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)
- Directive 2004/107/EC (the Fourth Daughter Directive) relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons (PAH) in ambient air

The Scottish Government has duly transposed these Directives into national law. 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 co-operation.

2.2 Cleaner Air for Scotland – Road to a Healthier Future

The purpose of Cleaner Air for Scotland – The Road to a Healthier Future (CAFS) is to provide a Strategy which sets out how the Scottish Government and its partner organisations propose to achieve further reductions in air pollution and fulfil our legal responsibilities. This includes:

- Collaborative approach to seek full compliance with EU air quality legislation by 2020
- Establishing a network to monitor fine particulate matter ($PM_{2.5}$) and set an objective in line with WHO guidance
- Establishment of National Modelling framework and National Low Emission framework
- Local Air Quality Management (LAQM) system remains fit for purpose (see below)

2.3 The Air Quality Strategy

The Air Quality Strategy for England, Scotland, Wales and Northern Ireland (AQS - first published in 1997 and revised in 2000 and 2007), establishes a UK-wide strategy for tackling air pollution. It is based on strong scientific evidence and a science-based understanding of the effects of air pollutants on health and the environment.

The AQS sets objectives for a series of pollutants to be met in the UK. The scientific basis, the objectives set and provisions contained in the AQS are closely associated with the corresponding limit values set by European air quality directives, as described above. The AQS's provisions for some pollutants differ from those in the directives. These relate to scientific evidence and expert opinion that is specific to the UK situation. However, all the AQS objectives are at least as stringent as the corresponding limit values applicable in the European Union. For some pollutants, such as particulate matter, Scotland has adopted more stringent objectives than the rest of the UK and Europe.

As outlined in CAFS the Scottish government decided to replace the existing Scottish $PM_{2.5}$ objective with the WHO guideline value of 10 ug m^{-3}. This was introduced on the 1st April 2016.

The full revised AQS and its extended series of associated technical annexes can be found on the Scottish Government website (www.scottishairquality.co.uk/air-quality/legislation).

2.4 Local Air Quality Management

Local Air Quality Management (LAQM) provides the framework in which air quality is managed by local authorities in Scotland. LAQM requires local authorities to review and assess a range of air pollutants against the AQS objectives, using a range of monitoring, modelling, observations and corresponding analyses. For locations where objectives are not met by the specified date, local authorities are required to:

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

In April 2016 the LAQM Policy and Technical Guidance were updated. These can be found at www.scottishairquality.co.uk/air-quality/legislation

At the time of writing, 14 of Scotland's 32 local authorities have declared AQMAs. Since last year's edition, two new AQMA's have been declared in Scotland. The two AQMA's are located in South Lanarkshire, with one in Rutherglen for PM_{10} and another in Lanark for NO_2. No AQMAs have been revoked within 2015. The total number of AQMAs within Scotland is 34, this number does not include those that exist for more than one pollutant, and full details can be seen in Table 2.1 below.

All authorities with AQMAs have either prepared or are preparing AQAP(s) for their AQMAs.

The newly published Defra Technical Guidance on LAQM (TG16) and Scottish Government Policy Guidance (PG16) highlight a slight change in the way LAQM is reported. To simplify the procedure an Annual Progress Report (APR) will replace the previous 3-year cyclical process of Progress Reports and Updating Screening Assessments. The Technical Guidance also notes a change in the $PM_{2.5}$ objective to 10 µg m^{-3}. Further details are available in the both the TG16 and PG16.

Table 2.1 Current AQMAs in Scotland

Council	Pollutant (no of AQMAs)	Main Source	Data Declared/ Amended	AQMAs
Aberdeen	NO_2 and PM_{10}	Roads	June 2001, December 2008	3
City of Edinburgh	NO_2	Roads	December 2006 March 2009 April 2013	5
Dundee City	NO_2 and PM_{10}	Roads	July 2006	1
East Dunbartonshire	NO_2 and PM_{10}	Roads	December 2005 July 2011	2
East Lothian	NO_2	Roads	November 2013	1
Falkirk	SO_2 (1), NO_2 (1), PM_{10} (1), NO_2 and PM_{10} (1)	Industry and Roads	November 2015 March 2010 August 2011 January 2013	4
Fife	NO_2 and PM_{10} (1), NO_2 (1)	Roads	October 2008 November 2011	2
Glasgow City	NO_2 and PM_{10} (1), NO_2 (2)	Roads	January 2002 July 2007	3
Highland	NO_2	Roads	September 2014	1
North Lanarkshire	PM_{10}	Industry and Roads	December 2005 July 2011	5
Perth & Kinross	NO_2 and PM_{10}	Roads	May 2006 February 2013	2
Renfrewshire	NO_2	Roads	September 2005	1
South Lanarkshire	PM_{10}	Roads	November 2008 January 2016 January 2016	3
West Lothian	PM_{10}	Roads	March 2011	1

3

Networks and Data

3.1 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 2015:

- Benzene
- 1,3-butadiene
- Carbon monoxide (CO)
- Lead
- 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)

The locations of automatic monitoring sites are shown in Figure 1.1b. These provide high-resolution 15 minute and hourly information on a wide range of pollutants. Data from national network monitoring sites are updated hourly in near-real time on the Scottish Air Quality Database. Data from local authority operated monitoring sites are updated either hourly or daily, depending on the station configuration. A typical automatic monitoring site, Dundee Mains Loan / Alloa A707 Figure 3.1.

Scotland's automatic monitoring is supplemented by non-automatic monitoring techniques, for example NO_2 diffusion tubes, pumped tubes samplers used to monitor benzene, the high-volume samplers used to measure PAH, and the non-automatic techniques used to monitor metals, such as lead.

3.2 Volatile Correction Model

Many monitoring sites use the Tapered Element Oscillating Microbalance (TEOM) to measure PM_{10}. The relatively high operating temperature of this instrument (necessary to prevent condensation on the filter) can result in the loss of volatile components of the particulate matter sampled, causing underestimation of the PM_{10} concentration.

However, it is possible to correct for this using the Volatile Correction Model (VCM) developed by King's College, London. The VCM uses data from Filter Dynamic Measurement Systems (FDMS) PM_{10} analysers in the region (which measure the volatile and non-volatile fractions) to calculate an appropriate correction based on the location of the instrument and the period of the measurements. The resulting corrected measurements have been demonstrated as equivalent to the gravimetric reference equivalent. Visit www.volatile-correction-model.info to access the model and for more information.

The VCM correction of PM_{10} data in this brochure is based on FDMS data from sites in the national Automatic Urban and Rural Network (AURN).

3.3 Key Results for 2015

This section provides a summary of results from automatic and non-automatic monitoring in Scotland in 2015 including compliance with AQS objectives. Further information is provided on the Scottish Air Quality 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.

Figure 3.1

Dundee Mains Loan / Alloa A707

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. Both 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. The 2015 annual mean has indicated that the AQS objective is met.

Carbon monoxide

This gas is a product of incomplete combustion, with vehicle exhaust emissions being an important source. It was monitored at two sites in Scotland in 2015 (Edinburgh St Leonards and North Lanarkshire Croy). Outdoor concentrations of CO were well within the AQS objective, as they have been for many years.

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. The full dataset for 2015 is not yet available, however data from 2014, from both sites, indicates that ambient concentrations are well within the AQS objective, so no exceedances are expected.

Nitrogen dioxide

This toxic gas is emitted from most combustion processes, including power generation, domestic heating and vehicle engines. It was monitored at 80 automatic sites in Scotland during 2015 (shown in Figure 3.2). Of these,10 achieved less than the 75% data capture generally considered necessary to calculate a representative annual mean. Reasons for this include; instrument faults; site enclosure upgrades; sites starting up or closing down part way through the year.

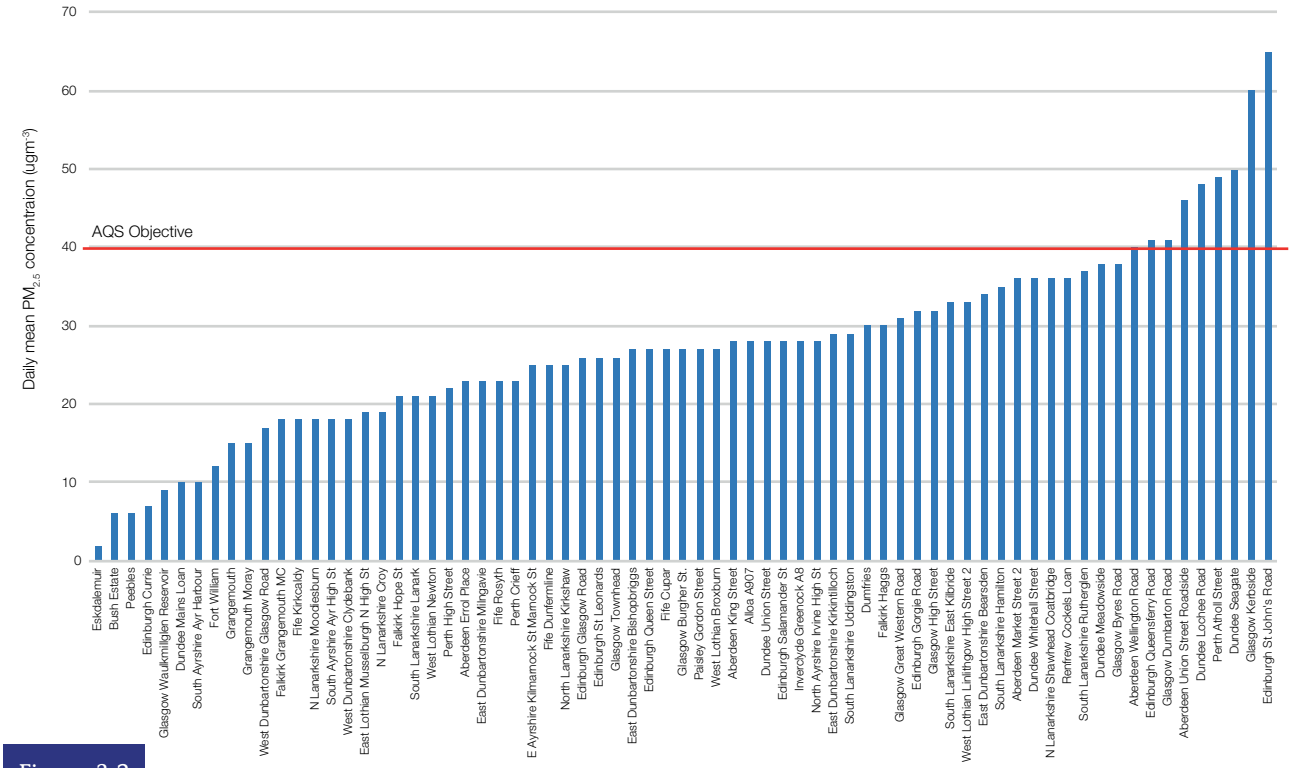


Figure 3.2

Annual Mean NO_2 Concentrations 2015 (minimum 75% data capture for inclusion)

Eight sites had annual mean NO_2 concentrations greater than the AQS objective of 40 µg m^{-3} (although two did not meet the AQS data capture target of 90%). The highest annual mean concentrations were measured at Edinburgh St Johns Road; located close to a busy road. Figure 3.2 shows annual mean NO_2 concentrations at each site (with at least 75% data capture).

One site exceeded the AQS objective of 200 µg m^{-3} on more than the 18 permitted occasions. This site was Edinburgh St Johns Road which also exceeded the annual mean hourly objective.

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 10 sites in 2015. During 2015 no site recorded more than the permitted 35 exceedances of the 15 minute mean (266 ug m^{-3}) AQS objective. This is illustrated in Figure 3.3. There were also no exceedances of the 1 hour (350 ug m^{-3} not to be exceed 24 times) and 24 hour (125 ug m^{-3} not to be exceed 3 times) AQS objectives in 2015.

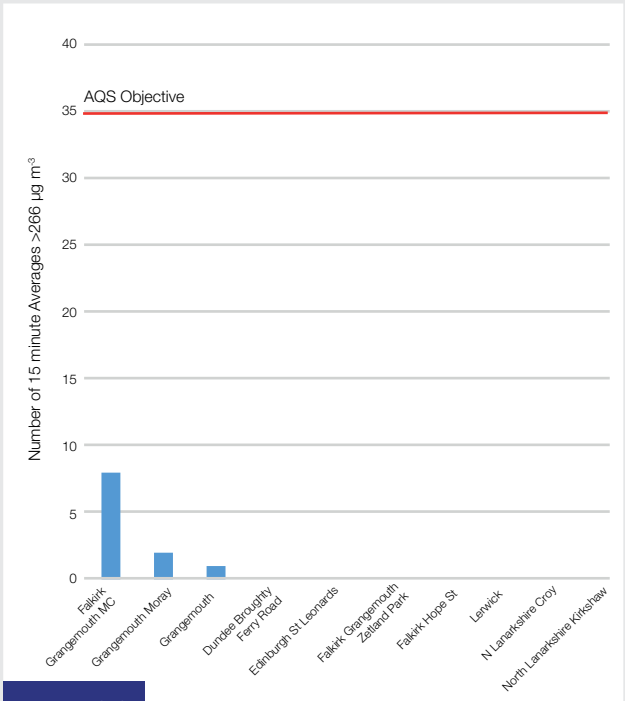


Figure 3.3

Exceedances of 15-min AQS objective for SO_2 2015

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 76 Scottish sites in 2015. No sites exceeded the UK AQS objective of 40 µg m^{-3} for the annual mean. However, Scotland has adopted a more stringent annual mean objective of 18 µg m^{-3}. This objective was exceeded at 4 sites in 2015 (Aberdeen Market Street, Aberdeen Wellington Road, Dundee Lochee Road and Edinburgh Salamander Street).

The UK AQS objective for the 24-hour mean PM_{10} concentration is 50 µg m^{-3}, not to be exceeded on more than 35 days per calendar year. The more stringent Scottish objective requires the daily mean PM_{10} concentrations do not exceed 50 µg m^{-3} on more than seven days per year. Four Scottish sites measured more than 7 exceedances, Aberdeen Wellington Road (16 days), Aberdeen Market Street (12days), Edinburgh Salamander Street (8 days) and Aberdeen Kings Street (8 days) which recorded greater than 50 µg m^{-3} (Figure 3.4).

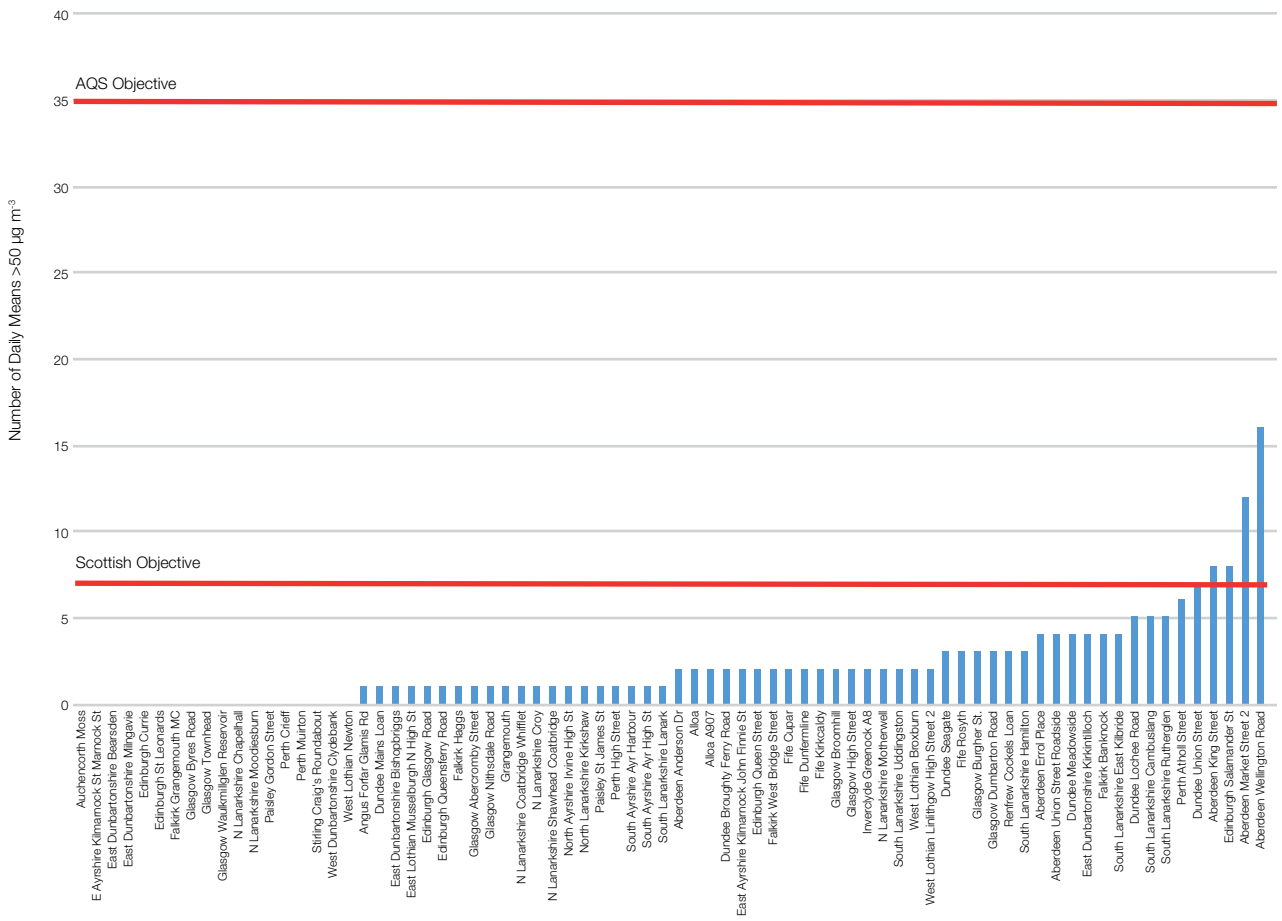


Figure 3.4

Exceedances of Daily Mean Objectives for PM_{10} 2015

Particulate Matter as $PM_{2.5}$

The finer particulate fraction, $PM_{2.5}$, was monitored at fifteen sites in Scotland during 2015 (shown in Figure 3.5). Of these, 5 achieved less than the 75% data capture generally considered necessary to calculate a representative annual mean. Reasons for this include; instrument faults; site enclosure upgrades and sites starting up part way through the year.

On the 1st April 2016 the new Scottish annual average objective of 10 µg m^{-3} was introduced. This objective was exceeded at one site in 2015 (Aberdeen Union Street).

Polycyclic Aromatic Hydrocarbons

This group of pollutants is monitored at four sites in Scotland. The full 2015 dataset is not yet available and will be reported in the full Annual Report later this year. The AQS objective of 0.25 ng m^{-3} for benzo[a]pyrene was not exceeded at any site during 2014.

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. O_3 is monitored at 11 sites in Scotland during 2015. Of these, the AQS objective of 100 µg m^{-3} as an 8-hour running mean (not to be exceeded more than ten days) was not exceeded in 2015.

The AQS objective for O_3 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.

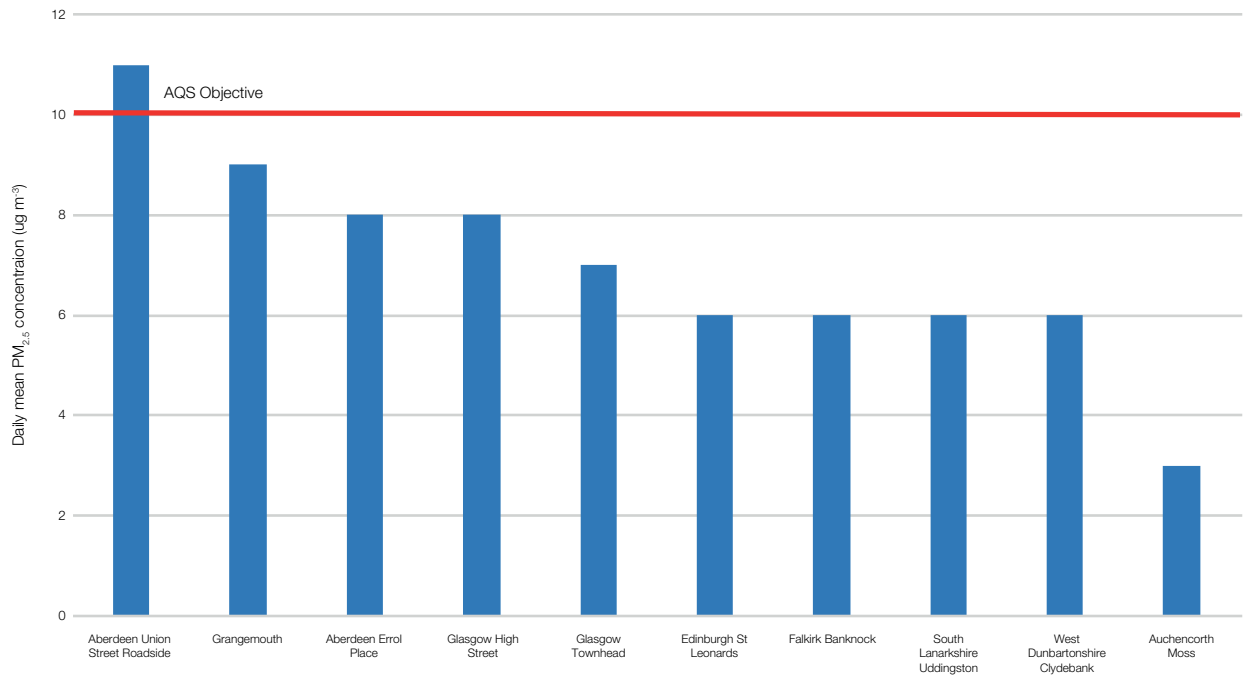


Figure 3.5

Annual Mean $PM_{2.5}$ Concentrations 2015 (minimum 75% data capture for inclusion)

4

Air Quality Trends for Scotland

This section summarises how Scotland's air quality in Scotland has changed in recent years. This year, it focuses on particulate matter as PM_{10} and $PM_{2.5}$. (The main report, to be published later this year, will cover a wider range of pollutants).

The trend analyses shown here are based on groups of automatic air quality monitoring sites that have been in operation for at least five years. They have been carried out using Openair: a free, open-source software package of tools for analysis of air pollution data. Openair was developed by King's College London with the University of Leeds: the Openair project is currently led by Dr David Carslaw, of Ricardo Energy & Environment and the University of York. For more information please see https://github.com/davidcarslaw/openair. 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: www.scottishairquality.co.uk/openair/openair.php

The Openair "TheilSen" tool uses the Theil-Sen statistical method to determine trends in pollutant concentrations over several years, based on monthly mean pollutant concentrations. It 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), which has been used in all the Theil-Sen trend graphs presented here.

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.

4.1 Particulate Matter

This pollutant is of particular interest because:

- Scientists do not believe that there is actually a safe level of this pollutant 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
- Scotland has recently 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

Many of Scotland's monitoring sites use the Tapered Element Oscillating Microbalance (TEOM) to monitor PM_{10}. For the reasons discussed in Section 3.2, 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 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 is used.

4.1.1 PM_{10} at Urban Background Sites

Four urban non-roadside sites in Scotland have been monitoring PM_{10} since 2006 or earlier. These are Aberdeen Errol Place (TEOM, converted to FDMS in 2009), Dundee Mains Loan (TEOM, data VCM corrected) Edinburgh St Leonards (FDMS since 2007), and the urban industrial site Grangemouth (FDMS since 2009). Figure 4.1 shows trends in de-seasonalised monthly mean PM_{10} at this subset of long-running sites. All four sites show a negative trend, significant at the 0.001 level (and strongest for Edinburgh St Leonard). Ambient concentrations of PM_{10} at urban background locations such as these appear to be decreasing.

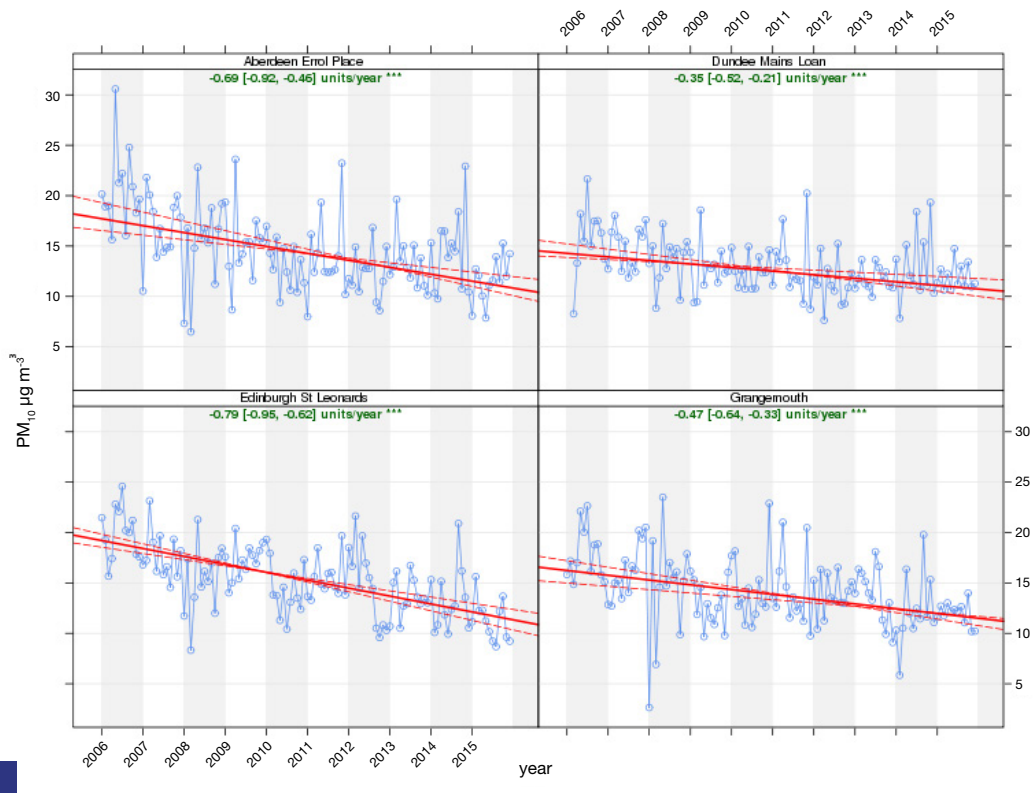


Figure 4.1

Trends in PM_{10} Concentration at Four Long-Running Urban Non-Roadside sites, 2006 – 2015

4.1.2 PM_{10} at Urban Traffic Sites

Trends in de-seasonalised monthly mean PM_{10} concentrations for nine traffic-related sites in operation since 2006 or earlier are shown in Figure 4.2. These are; Aberdeen Anderson Drive, Aberdeen Union Street, East Dunbartonshire Bearsden, East Dunbartonshire Bishopbriggs, Fife Cupar, Glasgow Byres Road, Glasgow Kerbside (shown although it closed at the end of 2014), Perth Atholl Street and Perth High Street. All nine sites show statistically significant downward trends, significant at the 0.001 level. The trends indicate that PM_{10} is decreasing year on year at these roadside sites.

Since Glasgow Kerbside ceased monitoring PM_{10} in 2014, the longest-running urban traffic PM_{10} monitoring site is now Inverness (which began monitoring this pollutant in 2001). However, as Inverness uses the Partisol gravimetric technique, which only gives daily (rather than hourly) means, it is not possible to include it in the above graph using the Openair tools on the SAQD website. The trend in PM_{10} concentration at Inverness is therefore shown separately in Figure 4.3. This site too shows a highly significant downward trend, significant at the 0.001 level.

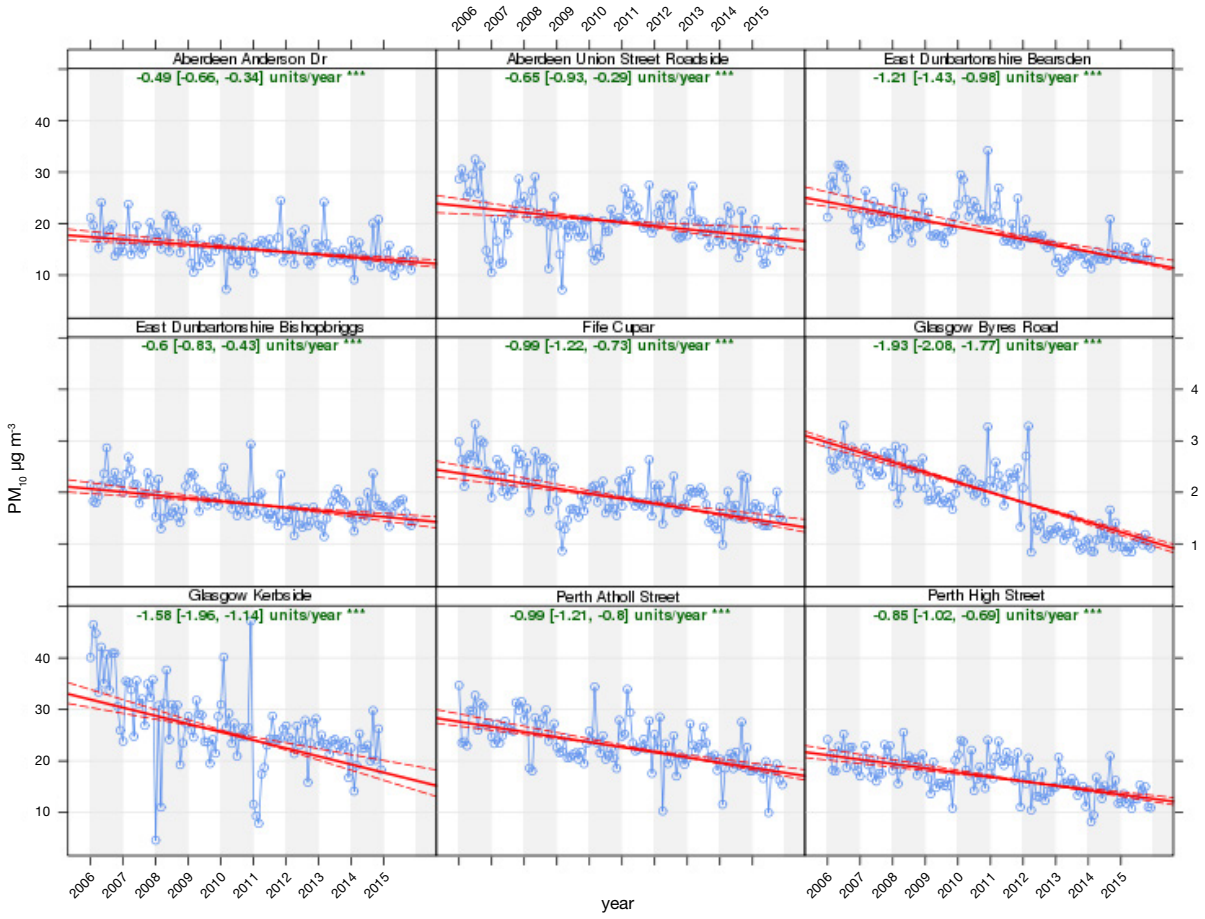


Figure 4.2

Trends in PM_{10} Concentration at Nine Long-Running Urban Traffic Sites, 2006 – 2015

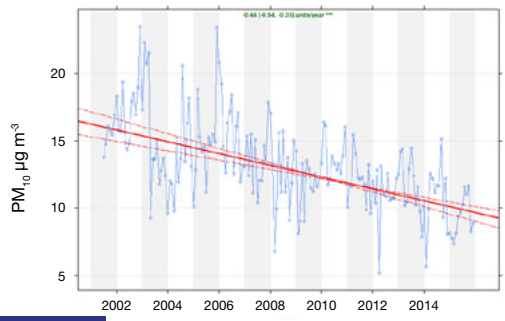


Figure 4.3

Trends in PM_{10} Concentration at Inverness (Partisol site), 2001 – 2015

4.1.3 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 becoming of increasing 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.

There are still relatively few monitoring sites measuring $PM_{2.5}$ compared with the number monitoring PM_{10}. However, by the end of 2015 there were six sites with at least five consecutive years of $PM_{2.5}$ data (the minimum considered necessary for assessment of long-term trends). These sites are as follows: Aberdeen Errol Place (urban background), Auchencorth Moss (rural), Edinburgh St Leonards (urban background), Glasgow Kerbside until 2014 (urban traffic) and Grangemouth (urban industrial), as well as Inverness which uses the Partisol gravimetric sampler and therefore only takes daily measurements. The trend plots are shown in Figure 4.4, with the Inverness Partisol data plotted separately in Figure 4.5 (please note, the scale in the latter plot is different).

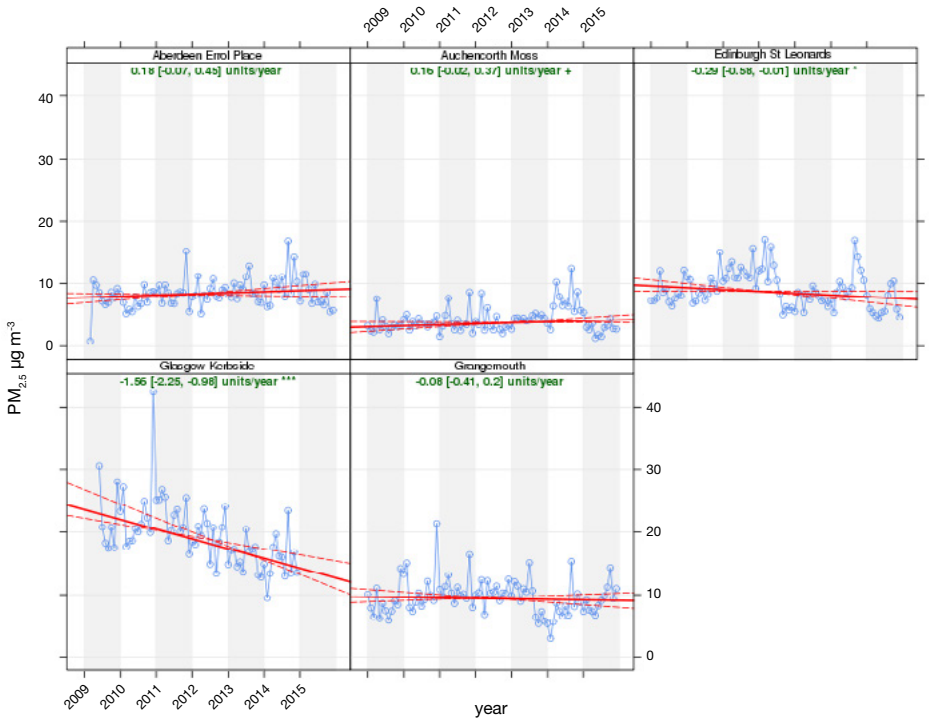


Figure 4.4

Trends in $PM_{2.5}$ Concentration at Five Long-Running Monitoring Sites, 2009 – 2015

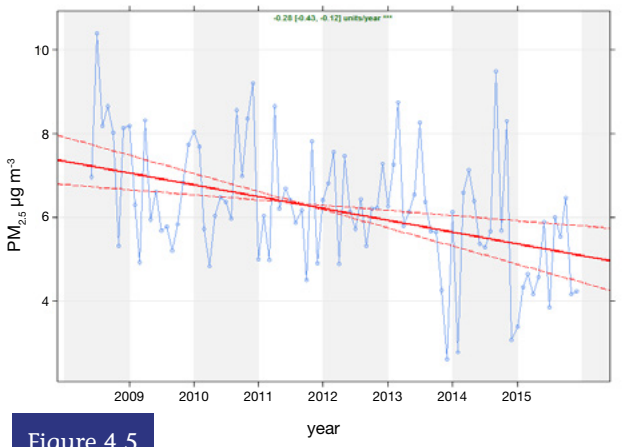


Figure 4.5

Trends in $PM_{2.5}$ Concentration at Inverness (Partisol site), 2008 – 2015

In contrast to PM_{10}, for which long-running sites consistently show a downward trend, in the case of $PM_{2.5}$ the trend appears to vary more from site to site. The rural Auchencorth Moss site shows a statistically significant upward trend in this particulate size fraction, since 2009 (though this is less strong than that reported in the 2014 report), while Edinburgh St Leonards and Glasgow Kerbside show statistically significant downward trends. Inverness (plotted separately) shows a highly significant downward trend in daily-measured $PM_{2.5}$.

By comparing the trend at Glasgow Kerbside with that at other similar monitoring sites, it may be possible to tell if the downward trend is typical. Since Glasgow Kerbside and Inverness are the only urban traffic sites in Scotland to have monitored $PM_{2.5}$ over this period, it is necessary to look elsewhere in the UK to find sites for comparison. Figure 4.6 compares the $PM_{2.5}$ trend at Glasgow Kerbside with those observed at seven other "urban traffic" air quality monitoring sites in cities in England and Wales. Five of these other sites (Birmingham Tyburn Roadside, Camden Kerbside, Carlisle Roadside, Leeds Headingley Kerbside and London Marylebone Road) also show statistically significant downward trends in $PM_{2.5}$ concentration: one (Swansea Roadside) shows a highly significant upward trend, and one (Stockton on Tees Eaglescliffe) shows no trend. On this basis, it appears that downward trends in $PM_{2.5}$ concentration are now being observed at roadside locations around the UK. However, the downward trend at Glasgow Kerbside is steeper than is typical. There is also considerable variation from site to site, possibly reflecting differing trends in relevant factors influencing localised $PM_{2.5}$ concentration, such as traffic flow.

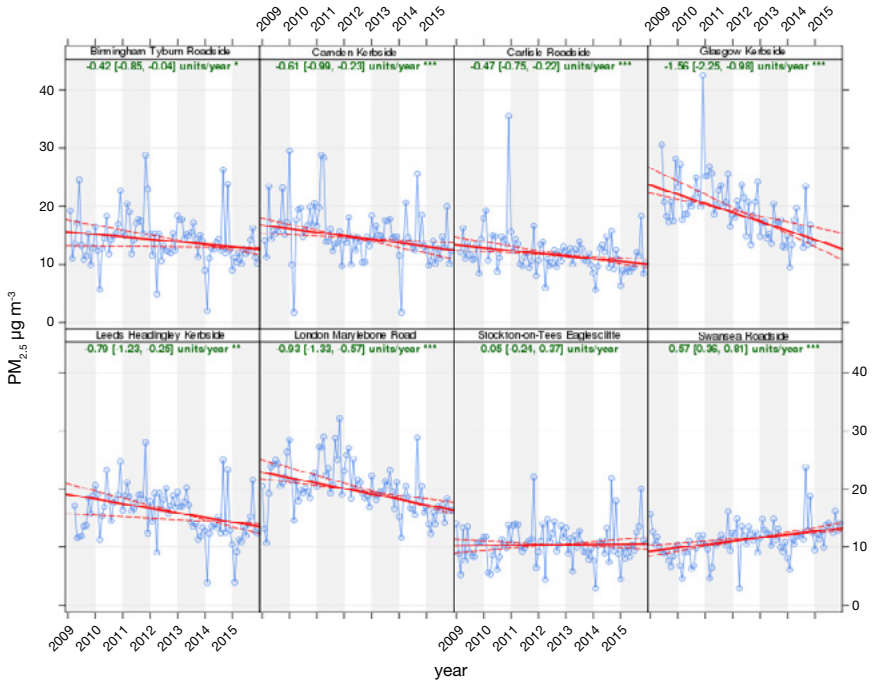


Figure 4.6

Comparison of Trends in $PM_{2.5}$ at Urban Traffic sites in Selected UK Cities, 2009-2015

5

Maps of Air Quality

As part of the Air Quality in Scotland project, Ricardo Energy & Environment calculates mapped concentrations of modelled background air pollutant concentrations on a 1 x 1 km square grid basis. Modelled roadside air pollutant concentrations are provided for road links in Scotland. These pollution maps combine measurements from Scottish air quality monitoring sites, spatially disaggregated emissions data from the National Atmospheric Emissions Inventory (NAEI) and Scottish meteorology data (from RAF Leuchars) to 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 compliance reporting.

The PCM methodology has been applied to provide pollution maps of Scotland for the Scottish Government for 2014 (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)
- NOx and NO_2

The air pollution measurements used to prepare the maps presented here consists of appropriately scaled PM_{10} monitoring data (FDMS, Partisol and VCM-corrected TEOM data) and automatic monitoring measurements for NOx and NO_2 in 2014. The model also uses Scottish meteorology observations (from RAF Leuchars) to create the Scotland-specific maps.

This section discusses the maps of pollutant concentrations produced for the Scottish Government. The full range of maps, together with a technical report describing the method[1], will be published on the 'Maps' page of the Scottish Air Quality website.

5.1 Air Quality Maps for Scotland

5.1.2 NO_2 maps for 2014

The 2014 annual mean concentration of total NOx and of NO_2 were modelled for Scotland at roadside and background locations. Figure 5.1 presents the 2014 modelled background annual mean concentrations of NO_2. Throughout much of Scotland, modelled background concentrations of NO_2 were low (less than 10 µg m^{-3}). Higher concentrations are evident in built-up areas due to combustion-derived NOx emissions, mainly from road transport. The outlines of the major cities and the main road links between them are clearly visible. Background NO_2 concentrations in the range 30-40 µg m^{-3} are modelled only for small areas in Glasgow, Edinburgh and Aberdeen. Three square kilometers in North East Scotland were modelled to exceed the Scottish NO_2 AQS objective of 40 µg m^{-3}. These three exceedances are located close to Aberdeen Harbour and are linked to emissions from shipping.

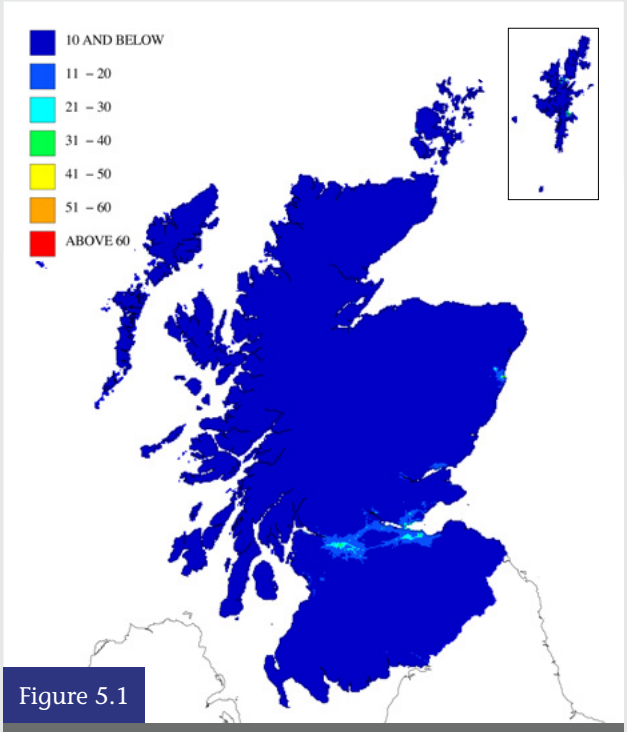


Figure 5.1

Background NO_2 map for 2014, µg m^{-3} (Scotland specific model)

[1] Rose, R.A. (2016). Scottish Air Quality Maps. Pollutant modelling for 2014: annual mean NOx, NO_2 and PM_{10}. To be published.

Figure 5.2 presents the 2014 modelled roadside annual mean concentrations of NO_2. NO_2 concentrations exceeded the Scottish AQS objective on a number of road links in Edinburgh, Glasgow, Central and North East Scotland.

5.1.2 PM_{10}: Maps for 2014

The 2014 annual mean PM_{10} concentrations (as gravimetric equivalent) were modelled for Scotland at 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 (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 following components:

- Secondary inorganic aerosols (e.g., sulphate, nitrate, ammonium)
- Secondary organic aerosols
- Long-range transport primary component
- Sea salt contributions
- Iron and calcium associated dusts

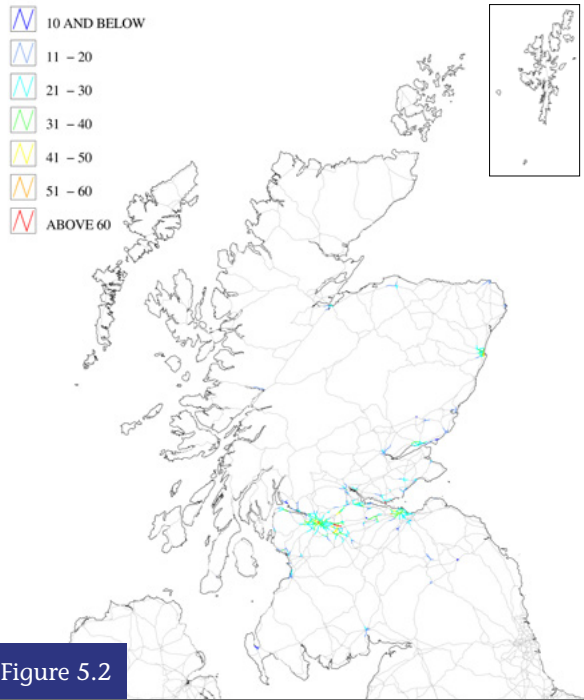


Figure 5.2

Roadside NO_2 map for 2014, µg m^{-3} (Scotland specific model)

Figure 5.3 presents modelled annual mean background concentrations of PM_{10} for 2014. Throughout much of Scotland, the 2014 ambient PM_{10} concentrations were low. Typically, PM_{10} concentrations were less than 10 µg m^{-3} and, therefore, well below the Scottish PM_{10} AQS objective of 18 µg m^{-3}. As in previous years, the spatial variation of PM_{10} reflects the location of built-up areas, major road links and the contribution of combustion-derived PM_{10} emissions to ambient concentrations. For example, the A74 heading southwards from Glasgow towards the border can be seen in Figure 5.3.

Exceedances of the Scottish annual mean PM_{10} objective of 18 µg m^{-3} were modelled at seventy one 1 km^2 grid squares in Scotland. Twenty nine exceedances in background concentrations of PM_{10} occur in the vicinity of Edinburgh. The majority of these are located on the western outskirts of Edinburgh close to Edinburgh airport and the M8 corridor. This location contains various industrial and traffic sources which are believed to contribute to the elevated modelled PM_{10} concentrations in this area. Additional isolated exceedances on the outskirts of Edinburgh are related to industry and agriculture. Forty one exceedances are located close to Aberdeen. The causes of exceedances modelled in these areas are varied and relate to a combination of quarrying and industry, the contribution of road transport emissions to background, or shipping close to Aberdeen Harbor. One further isolated exceedance is located in the Scottish borders and is related to emissions of PM_{10} from agriculture.

Figure 5.4 presents the 2014 modelled annual mean roadside concentrations of PM_{10}. 72 out 761 modelled road links exceed Scottish PM_{10} AQS objective. Exceedances are most prevalent for roads in and connecting Glasgow and Edinburgh.

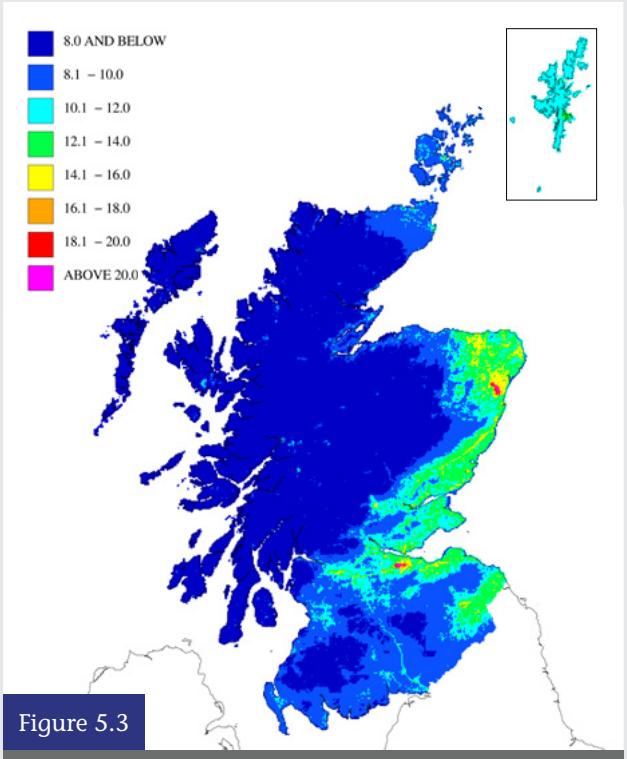


Figure 5.3

Background PM_{10} map for 2014, µg m^{-3} (Scotland specific model)

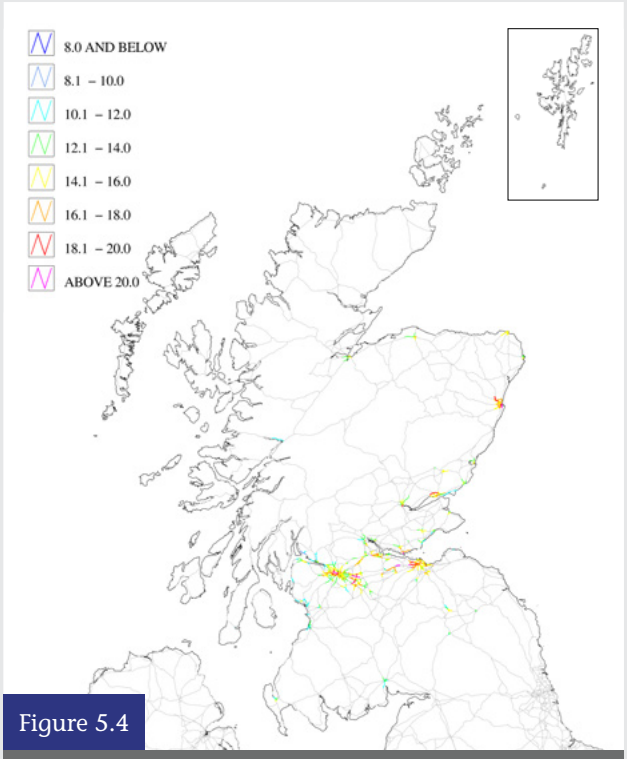


Figure 5.4

Roadside PM_{10} map for 2014, µg m^{-3} (Scotland specific model)

6

Education

Education has been a recent development for Air Quality in Scotland. Interactive education packages have been developed through the creation of two sections which form part of Air Quality in Scotland website. The first education website 'Air Pollution Detectives' was created for primary school pupils in primary 5 to 7 age range (aged 8-11 years old). The second website "Clear the Air" was developed in partnership with a number of secondary schools for pupils in the S1 – S3 age range (aged 12-15 years old). The education packages can be accessed from the Air Quality in Scotland website (www.scottishairquality.co.uk/education).

Figure 6.1

Air Pollution Detectives and Clear the Air

6.1 Air Pollution Detectives

Initially launched in 2011, the Air Pollution Detectives has been revised and updated. The webpage was designed to introduce air quality issues to primary school pupils between the ages of 8-11 years old. The animated, interactive webpages provide an introduction to air pollution sources and how pupil's 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 6.2

Interactive sections on the Air Pollution Detectives webpages

The Air Pollution Detectives is available at: www.scottishairquality.co.uk/education

6.2 Clear the Air

The Clear the Air web page was developed following the success of the Pollution Detectives. The webpage provides an interactive learning experience for air quality and citizen science. The webpage is aimed at secondary school pupils between the ages of 12-15 years old.

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 lastly a class citizen science project which allows air quality to be monitored around the school by using NO_2 diffusion tubes. Pupils will also be given an NO_2 diffusion tube to take home so they may also monitor outside their house.

'As a teacher I want to ensure I have helped develop the necessary skills in our future workforce that will help make Scotland sector leading in sciences. To do that, projects like Clear the Air, help to switch these young minds on to science subjects by making them enjoyable, practical and relevant to their lives.'

John Ferguson, Acting Faculty Head of Science at St. John Ogilvie High School'

6.2.1 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 together with 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 website enables the monitoring data to be input in terms of location and measured concentration via the school's private user portal so that the results can be displayed on a map, as shown in Figure 6.3.

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 teacher's pack including notes to supplement the monitoring equipment and webinars to help introduce the concept of local air quality and conduct the monitoring. Further information regarding the programme can be obtained at: http://cleartheair.scottishairquality.co.uk

6.2.2 Clear the Air – Funded Schools

In 2015, the Scottish Government allocated funds to provide the Clear the Air packs to a number of Scottish secondary schools. The ten schools selected to receive funded packs are shown in figure 6.4. Each school is in the process of going through the Clear the Air programme.

Initial feedback from teachers that received funded packs has been positive, an example of feedback received is shown above.

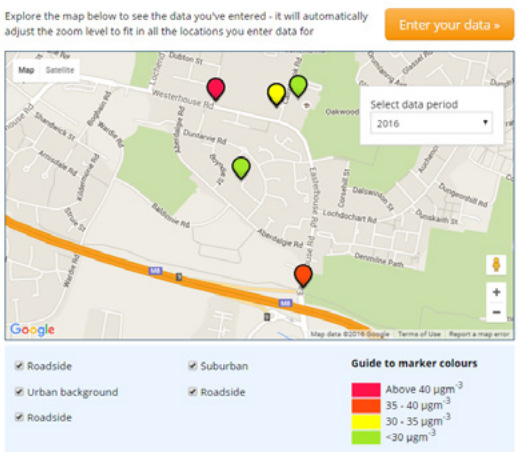


Figure 6.3

Data entry available on each school profile

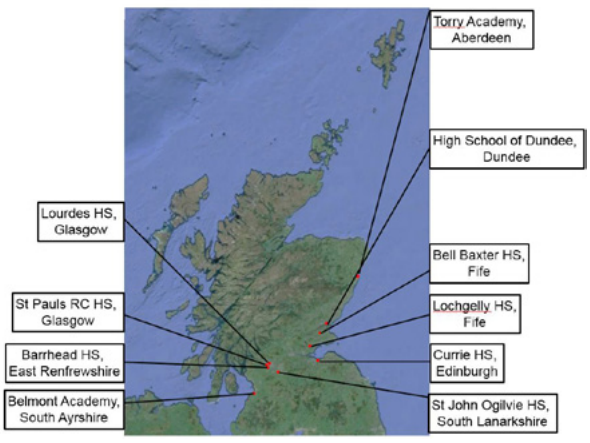


Figure 6.4

Schools allocated Scottish Government funded packs

7

Recent Developments

7.1 $PM_{2.5}$ Monitoring

In 2015, the Scottish Government commissioned two reports to review the planned changes to the Particulate Matter (PM) objectives to align them with the World Health Organisation (WHO) Guideline Values. The Scottish Government commissioned the work to help inform the potential impact of the changes on LAQM and AQMAs across Scotland. Summaries of these reports are given below.

7.1.1 $PM_{2.5}$ and PM_{10} in Scotland

In 2015, the Scottish Government considered aligning the Scottish Air Quality Objectives for Particulate Matter (PM) with the WHO guideline values for PM_{10} and $PM_{2.5}$ (20 and 10 µg m^{-3} respectively as annual means). These values are considerably more stringent than the equivalent EU and UK targets, but similar to the Scottish objectives (18 and 12 µg m^{-3} for PM_{10} and $PM_{2.5}$ respectively). It should be noted, that the Scottish objective for $PM_{2.5}$ of 10 µg m^{-3} came into force on the 1st April 2016.

The $PM_{2.5}$ and PM_{10} in Scotland Report was an investigation of concentrations and ratios of $PM_{2.5}$ and PM_{10} across Scotland. It aimed to help inform these potential changes to Air Quality Strategy Objectives and Local Air Quality Management by reviewing data from the Scottish Air Quality Database (SAQD), Pollution Concentration Mapping and mobile monitoring, shown in Figure 7.1.

The report concluded that aligning Scotland's PM_{10} objective with the more lenient WHO guideline would lead to fewer exceedances and possible questioning of the need for the Air Quality Management Areas (AQMAs) and Air Quality Action Plans (AQAPs). In contrast, the alignment of the $PM_{2.5}$ objective with the more stringent WHO guideline would lead to more exceedances, more AQMAs and AQAPs and would probably prompt more monitoring and hopefully a better understanding of $PM_{2.5}$.

7.1.2 Expanding the $PM_{2.5}$ Network

The $PM_{2.5}$ Network in Scotland Report investigated the current $PM_{2.5}$ and PM_{10} monitoring network and aimed to help inform the future expansion of the network. The report looked at the existing $PM_{2.5}$ network, shown in Figure 7.2, the type of analysers available to measure $PM_{2.5}$ fraction and monitoring site locations. It also took into consideration the current PM_{10} network, the potential to include $PM_{2.5}$ monitoring through supplements or upgrades and the potential costs.

The report has a number of findings and suggests that the estimated number of necessary $PM_{2.5}$ analysers is in the order of 24 throughout Scotland. This would mean expanding the current 15 sites to 39 sites. An indication of costs associated with this expansion are also provided, as well as options on how it could be implemented.

Figure 7.1

Mobile Monitoring equipment used to measure Particulate Matter concentrations

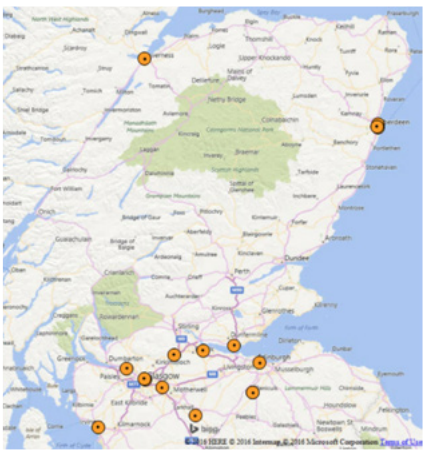


Figure 7.2

$PM_{2.5}$ monitoring sites in Scotland as of January 2016 (each site also measures PM_{10})

7.2 Sensor Observatory Service

In December 2009, the INSPIRE directive (European Directive 2007/2/EC) was transposed into UK law. INSPIRE establishes an infrastructure for spatial information in the European Union with the aim of facilitating better environmental policy across the EU. This will be achieved by:

- improving the joining up of and access to existing spatial data across the European Union at a local, regional, national and international level
- facilitating improvements in the sharing of spatial data between public authorities
- improving public access to spatial data

In keeping with the INSPIRE directive, the Scottish Air Quality Website has a new data sharing mechanism called Open Data Services. This mechanism is based on recognised internet and open data standards. The data is also machine readable based on XML encoding and is easily configurable to be human readable.

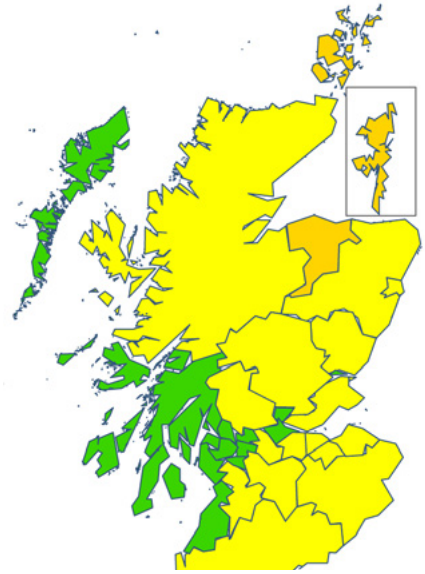
8

Stay Informed

8.1 Scotland Air Pollution Forecast

A 5-day forecast for each local authority in Scotland is available on the Scottish Air Quality website. The forecasts provide a greater level of detail which can benefit the public and 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
www.scottishairquality.co.uk/latest/forecast-summary

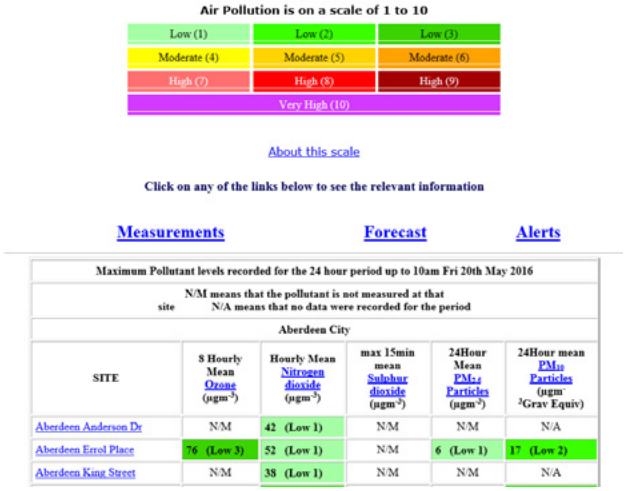


8.2 Know and Respond

Know & Respond is a free service providing you with alerts when pollution levels are forecast to increase. You can choose to receive alerts by SMS, voicemail or email. Know & Respond alerts are also available via the Air Quality in Scotland app.

8.3 Email Alerts

Sign up to our email bulletins and receive summaries directly to your inbox. You can choose how frequently you receive them and what type of summary you are interested in.



Air Pollution is on a scale of 1 to 10

Low (1)	Low (2)	Low (3)
Moderate (4)	Moderate (5)	Moderate (6)
High (7)	High (8)	High (9)
Very High (10)		

About this scale

Click on any of the links below to see the relevant information

Measurements **Forecast** **Alerts**

Maximum Pollutant levels recorded for the 24 hour period up to 10am Fri 20th May 2016

N/M means that the pollutant is not measured at that site
N/A means that no data were recorded for the period

Aberdeen City

SITE	8 Hourly Mean Ozone (μgm^{-3})	Hourly Mean Nitrogen dioxide (μgm^{-3})	max 15min mean Sulphur dioxide (μgm^{-3})	24Hour Mean $PM_{2.5}$ Particles (μgm^{-3})	24Hour mean PM_{10} Particles (μgm^{-3} Grav Equiv)
Aberdeen Anderson Dr	N/M	42 (Low 1)	N/M	N/M	N/A
Aberdeen Errol Place	76 (Low 3)	52 (Low 1)	N/M	6 (Low 1)	17 (Low 2)
Aberdeen King Street	N/M	38 (Low 1)	N/M	N/M	N/A

8.4 Twitter

You can follow Air Quality in Scotland on twitter for air quality forecasts and summaries of measurements from Scotland. Follow @scotairquality for the latest pollution information for Scotland.

The service allows you to stay informed about current and forecasted 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.

@scotairquality

8.5 Air Quality in Scotland App

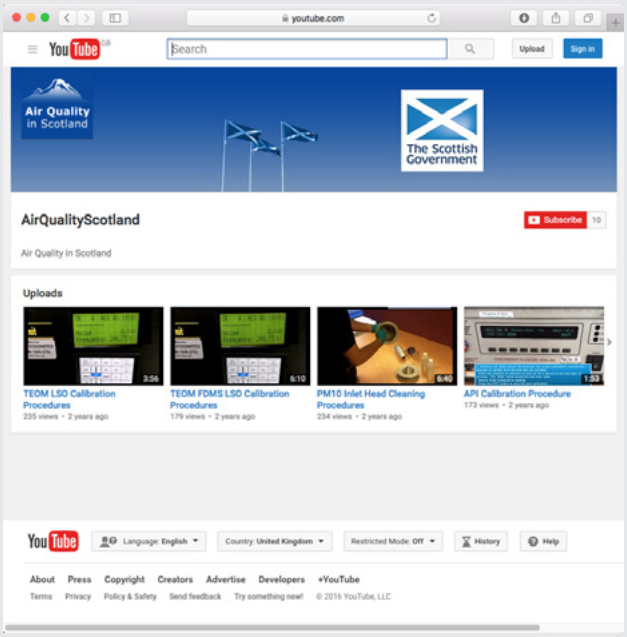
The Air Quality in Scotland app will give you the latest air quality levels for each site, forecasts for the day ahead, and you can receive alerts when air pollution levels increase. The free Air Quality in Scotland app is available for both iPhone or Android mobile devices.

In addition, the app integrates the Know and Respond health alerts service. 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.

8.6 Youtube

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

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



The Scottish Government

Ricardo Energy & Environment

This report has been produced by Ricardo Energy and Environment on behalf of the Scottish Government.

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www.scottishairquality.co.uk