Scottish Air Quality Database

Annual Report 2016

Report for Scottish Government

RICARDO
Ricardo Energy & Environment

The Scottish Government

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Executive summary

In April 2007, Ricardo Energy & Environment were commissioned by the Scottish Government to undertake a 3-year project (Apr 2007 – Apr 2010) to develop an Air Quality Database and Website for Scotland. This contract has been renewed in recent years, with the latest contract running from 2016-2019.

This report brings together all the Scottish Air Quality Database data for calendar year 2016 and associated work relating to project deliverables including: data management; QA/QC services; liaison with stakeholders; website development; spatial analysis of air quality data; trend analysis. In addition, the report presents the additional activities and further developments undertaken during the tenth year of the project, July 2016 – June 2017.

Legislation and Policy

The "Cleaner Air for Scotland – The Road to a Healthier Future" (CAFS) strategy was published by the Scottish Government in November 2015. The purpose of CAFS is to provide a national framework which sets out how the Scottish Government and its partner organisations propose to achieve further reductions in air pollution and fulfil their legal responsibilities as soon as possible. CAFS outlines the contribution that better air quality can make to sustainable development whilst improving health and the natural environment and reducing health inequalities for the citizens of Scotland.

As outlined in CAFS, the Scottish Government decided to replace the existing provisional Scottish $PM_{2.5}$ annual objective with the WHO guideline value of 10 µg m^{-3} and to include this in legislation. The Air Quality (Scotland) Amendment Regulations came into force on the 1st April 2016.

The Scottish Government Policy Guidance and the Defra and Devolved Administrations' Technical Guidance documents on LAQM were updated in April 2016. The newly published Technical Guidance on LAQM (TG16) and Scottish Government Policy Guidance (PG(S)16) were amended in line with recommendations which resulted from the 2014 LAQM review.

Air Quality Monitoring in Scotland

Air pollution data for 97 automatic monitoring sites throughout Scotland are available in the database for all or part of 2016. All automatic data maintained within the Scottish database are subject to the same QA/QC procedures as at the national network air quality monitoring stations within the UK Automatic Urban and Rural Network. This ensures that all data in the database are quality assured and traceable to UK national calibration standards for the various pollutants.

At the end of 2016 the Scottish Air Quality Database contained data for of 97 automatic monitoring sites. In total, 5 new monitoring sites were incorporated into the database during 2016: South Lanarkshire, Raith Interchange 2, Falkirk Bo'ness, Falkirk Graham's Road, Falkirk Main Street, Bainsford and Inverness Academy Road. Two monitoring sites; Edinburgh Queen Street and Dundee Union Street were decommissioned during 2016.

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

At the time of writing, 14 local authorities in Scotland have declared a total of 39 AQMAs. This is 2 more than 2015.

The Air Quality in Scotland Websites (www.airqualityscotland.co.uk) and this annual report also contain a summary of data from a wider range of pollutants measured in Scotland as part of several national network monitoring programmes.

Air Quality Mapping of Scotland

Ricardo Energy & Environment provide mapped concentrations of modelled background air pollutant concentrations on a 1 km x 1 km basis for the whole of Scotland. Modelled roadside air pollutant concentrations are provided for road links in Scotland. The air pollution maps are derived from a combination of (1) measurements from Scotland's network of air quality monitoring stations, and (2) spatially disaggregated emissions information from the UK National Atmospheric Emissions Inventory (NAEI).

During 2016/17, and at the time of writing this report, there are two versions of the UK 2015 modelling:

1. Modelling submitted to the European Commission for the UK compliance assessment in September 2016 (version 2015A)
2. Updated modelling for revised UK NO_2 air quality plans published in July 2017 (version 2015C)

After consultation, the Scottish Government agreed that the best approach for the scheduled 2015 Scottish mapping work would be to use the more up-to-date 2015C modelling being undertaken for the NO_2 Plans, as this incorporates more realistic vehicle emissions. In addition, it is also expected that Defra will provide an update to LAQM data (mapped data for all years from the base year to 2030) based on projections from model version 2015C in due course.

At the time of writing this report, the updates previously stated were not released. As a result, the Scottish Air Quality mapping work has not been completed. Once the relative updates have been released and mapping work completed, this report will be amended as appropriate.

Air Quality Trends for Scotland

Data held within the database covering many years have been used to assess possible trends in air pollution throughout Scotland. Air quality trends have been examined on the basis of individual monitoring sites, and subsets of long-running sites, rather than the composite data set. For this report, smoothed trend and Theil-Sen analysis has been used; utilising the Openair data analysis tools to quantify pollutant trends at individual sites. The trend plots are generally carried out over 10 years, however for traffic based site types 5 year plots have been produce to see if recent year trends differ.

NO_2

For three of the five longest running Urban Non-Roadside sites (Aberdeen Errol Place, Edinburgh St Leonards and Glasgow Anderston) the 10-year trend plots for NO_2 generally show a significant negative trend, with Grangemouth showing downward trend but not statically significant. For Fort William the trend is significantly positive.

When considering the three longest running rural sites, Bush Estate and Eskdalemuir showed small but highly significant downwards trends where by contrast Glasgow Waulkmillglen Reservoir site concentrations have increased year on year, though the trend is not significant.

For this report nine of the longest running traffic related urban sites, which have measured exceedances in recent years, were chosen for analysis. Ten-year trend plots showed that six of the nine sites (Aberdeen Union Street, Dundee Lochee Road, Edinburgh Gorgie Road, Edinburgh St John's Road, Glasgow Kerbside (Hope Street) and Perth Atholl Street) showed downward trends in NO_2 concentration which were highly significant. However, this was not the case at every site – at Glasgow Byres Road the trend was significant only at the 0.05 level; and Dundee Seagate and East Dunbartonshire Bearsden showed no significant trends.

Comparing the 10-year and five-year trends, the patterns differ from site to site: Aberdeen Union Street, Dundee Lochee Road, Dundee Seagate, Edinburgh Gorgie Road and Glasgow Byres Road show downward trends that have become greater, more statistically significant, or both. By contrast, the other four sites – East Dunbartonshire Bearsden, Edinburgh St John's Road, Glasgow Kerbside and Perth Atholl Street – downward trends have become smaller or less statistically significant. For

East Dunbartonshire Bearsden and Edinburgh St John's, the trend has changed from negative to positive. It is therefore not valid to assume that NO_2 is continuing to improve at all sites.

PM_{10}

For PM_{10} Urban sites trend analysis, sites were split into subsets of Urban Background/Industrial and Urban traffic.

For Urban Background and industrial all six sites (Aberdeen Errol Place, Dundee Broughty Ferry Road, Dundee Mains Loan, Edinburgh St Leonards, Glasgow Anderston, and Grangemouth) showed a negative trend, significant at the 0.001 level for all except Glasgow Anderston where it was significant at the 0.01 level.

Over the past 10 years, all nine Urban Traffic sites (Aberdeen Anderson Drive, Aberdeen Union Street, East Dunbartonshire Bearsden, East Dunbartonshire Bishopbriggs, Edinburgh Queen Street, Fife Cupar, Glasgow Byres Road, Perth Atholl Street and Perth High Street) showed 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. For the last five years, trends show that for four of the sites (the two in Aberdeen, plus Fife Cupar and Perth Atholl Street) the downward trend is stronger or more significant. However, in the remaining five, the downward trend has weakened or become insignificant. As in the case of NO_2, ongoing, targeted efforts are therefore still needed to ensure air quality continues to improve where necessary.

$PM_{2.5}$

In 2016 there were five 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), Grangemouth (urban industrial) and Inverness (roadside). All five of the long-running $PM_{2.5}$ monitoring sites showed a downward trend in this pollutant. However, it was only statistically significant at three of them - Edinburgh St Leonards, Grangemouth and the non-automatic Inverness site.

Ozone

Ozone has been measured at three rural sites in Scotland (Bush Estate, Eskdalemuir and Strath Vaich) for thirty years. All three sites showed small positive trends over this very long period, highly statistically significant at two of the three sites. Ozone has been measured for the past 10 years at six rural sites. Over this more recent period there are only two sites which show significant trends - one positive and one negative – so trends over this more recent period are less consistent. Ozone concentrations showed no significant trends at either of the two urban background sites which have monitored this pollutant for the past 10 years.

Sites with Significant Increasing Trends

Three of Scotland's current monitoring sites with at least five years of data show a statistically significant upward trend in NO_2 concentration. Of these, two (Dundee Mains Loan and Inverness) are well below the AQS annual mean NO_2 objective, but the third, South Lanarkshire Rutherglen, exceeded this objective in 2016. Dundee Lochee Road shows a significant upward trend in PM_{10} concentration. This site already exceeds the Scottish objective for annual mean PM_{10} and the trend indicates that this situation is not improving.

Emissions of Pollution Species

Scotland's NOx emissions have declined by 69% since 1990 and in 2015 accounted for 9% (84kt) of the UK total. Since 2008, emissions from passenger cars have further decreased, which is mainly driven by the assumption on improvements in catalyst repair rates made in the NAEI to take into account of the introduction of Regulations Controlling Sale and Installation of Replacement Catalytic Converters and Particle Filters for Light Vehicles for Euro 3 (or above) light duty vehicles. However, the increasing number of diesel cars within the fleet offsets these emissions reductions, because diesel cars emit higher NOx relative to their petrol counterparts. It should be noted that, since 2010 the decreasing trend in NOx emissions appears to have slowed across all sectors.

Emissions of PM_{10} have declined by 46% since 1990 and in 2015 accounted for 8% (12kt) of the UK total. Emissions from energy industries have had the most significant decline over the trend shown, due to the abatement methods in place at coal fired stations. However, emissions from Residential and Other Combustion sector has increased since 2005. The increase has been attributed to an increased quantity of wood fuel use, primarily in the domestic sector. Though PM_{10} emissions have reduced since 1990, mainly due to the reduced emissions from industry, overall there has been no significant reduction in PM_{10} emissions since 2002.

Development and Website Usage Statistics

Expansion of the $PM_{2.5}$ Network

A resulting effect of the new $PM_{2.5}$ legislation introduction in April 2016, has been the relatively rapid expansion of the $PM_{2.5}$ monitoring network within the SAQD. In 2016 there were 11 new $PM_{2.5}$ monitoring sites added bringing a total of 27 sites across Scotland. This compares with 2013 when there were only seven sites measuring the pollutant.

SEPA Data Analysis and Visualisation Tools

The new SEPA data analysis and visualisation tools were launched on the 24th January 2017 and are hosted on the Air Quality in Scotland website. The new tools aim to:

- Provide the public with pre-filtered data that allows them to access the monitoring network in a simple and meaningful way without being faced with the difficulty of interrogating the data;
- Allow those that are looking for more advanced analysis of the data, bring together other data sources and utilising visual functionalities to interrogate and report on the network;
- Provide local authorities with pre-set analysis tools for reporting purposes;
- Link with international data to help identify and visualise the movement of transboundary pollution as it crosses Scotland.
- Support Scottish Governments delivery within CAFS through informing, engaging and empowering to improve air quality.

SAQD Newsletter

In December 2016, the first edition of the quarterly newsletter was published via the Air Quality Scotland website (http://www.scottishairquality.co.uk/news/). The newsletter, produced by Ricardo Energy & Environment in conjunction with SEPA, is designed to provide regular updates and news regarding the SAQD and local air quality matters to all website users.

Website Usage

Statistics obtained indicate an upward trend in the number of unique visitors and pages viewed since the site was launched in 2007.

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Appendices

1 Introduction

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

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

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

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

This annual report summarises the progress made during 2016 in the on-going project tasks and also highlights the new work undertaken during 2016.

Section 2 of this report provides a breakdown of the legislation and policy that drives local air quality management within Scotland. The section looks at the policies and drivers within the Cleaner Air for Scotland strategy and also the associated introduction of the $PM_{2.5}$ Objective in April 2016.

Section 3 provides a brief summary of the annual Air Quality in Scotland Seminar and Newsletter, both key tasks within the SAQD project.

The network of sites within the Scottish Air Quality Database is dynamic and forever changing to address the requirements of the local authorities to deal with air pollution issues. Section 4 describes in detail the structure of the database in terms of number and type of sites as well as pollutants measured, and how it has changed over the past year.

Quality Assurance and Quality Control (QA/QC) is an integral part of the SAQD project. Since conception of the SAQD project, the QA/QC programme has expanded and adapted to encompass the dynamicity of the database and the changing best practice guidance and regulations. Section 5 of this report provides detailed information on the QA/QC process and how this was applied to the Scottish Air Quality Database during 2016.

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

In 2009, a pilot mapping exercise specific to Scotland was undertaken including future year projections for 2010, 2015 and 2020. This pilot exercise has been subject to further development in subsequent years and an improved methodology has been used to deliver pollution climate mapping of NO_x, NO_2 and PM_{10} including projections. As the number of monitoring sites in Scotland has significantly increased since 2006, it has become feasible to undertake pollution climate mapping of NO_x, NO_2 and PM_{10} using solely Scottish measurement data. As part of the Scottish Air Quality Database project, Ricardo Energy & Environment provide mapped concentrations of modelled background air pollutant concentrations on a 1 km x 1 km basis for the whole of Scotland. The Scottish pollution climate mapping work carried out in 2016 is described in Section 7.

The SAQD has accumulated a substantial body of air quality data since its establishment which in turn allows for robust statistical trend analysis to be undertaken. Section 8 of this report provides a discussion of trends in pollutant concentrations across Scotland, based on the latest available data. The trend analysis focuses on roadside and urban background locations across Scotland and pollutants nitrogen dioxide (NO_2) and particulate matter (PM_{10} and $PM_{2.5}$).

During 2009, the website was upgraded to include links to the SEPA Scottish Pollution Release Inventory (SPRI) in order to provide information on industrial releases of pollutants in Scotland. Section 9 of this report provides the most up to date (2014) data for source emissions of pollutant species in Scotland, focusing on the pollutants NOx and PM_{10}.

Throughout 2016 there were a number of developments and projects carried out as part of and in relation to the SAQD project. These include website and database developments, educational initiatives and research studies relating to local air quality management. Section 10 of this report provides information on these.

2 Legislation and Policy

Air quality management in Scotland is shaped by statutory requirements relating to EU Directives, reserved legislation implemented on a UK wide basis and policies which have been introduced specifically in Scotland by the Scottish Government. The key Directives relating to air quality are:

- Directive 2008/50/EC - on ambient air quality and cleaner air for Europe (the Air Quality Directive);
- Industrial Emissions Directive 2010/75/EC – controls emissions from industrial activities;
- Medium Combustion Plant Directive 2015/2193/EU - regulates pollutant emissions from the combustion of fuels in plants with a rated thermal input equal to or greater than 1 megawatt (MWth) and less than 50 MWth.
- National Emissions Ceiling Directive 2016/2284/EU – controls emissions of certain atmospheric pollutants at individual Member State level.

The Scottish Government has duly transposed the first three of these Directives into domestic legislation. The NECD is due to be transposed by June 2018.A substantial review of the EU's air quality policy, including the Air Quality Directive was undertaken in 2013 with the Commission adopting a new Clean Air package, including a new Clean Air programme for Europe with measures to ensure that existing targets are met in the short term, and new air quality objectives for the period up to 2030. The package also includes support measures to help cut air pollution, with a focus on improving air quality in cities, supporting research and innovation, and promoting international cooperation.

2.1 Air Quality Standards and Objectives

A set of air quality standards and objectives has been developed for several pollutants of concern for human health. The objectives are derived from the standards and are a compromise between what is desirable purely on health grounds and what is practical in terms of feasibility and costs. Each objective has a date by when it must be achieved. The objectives adopted in Scotland for the purpose of Local Air Quality Management are set out in the Air Quality (Scotland) Regulations 2000, the Air Quality (Scotland) Amendment Regulations 2002 and the Air Quality (Scotland) Amendment Regulations 2016. Similar targets are set at EU level, where there are called limit or target values.

These limit values are set out in the European 2008 Ambient Air Quality Directive (2008/50/EC) and transposed into Scottish legislation. It is the responsibility of EU Member States to achieve the limit and target values.

On the 1st April 2016 and in line with the Cleaner Air for Scotland strategy, the Scottish Government brought into law the $PM_{2.5}$ annual objective of 10 µg m^{-3}. In doing so, Scotland is the first European country to implement a statutory objective for $PM_{2.5}$ in line with World Health Organisation (WHO) guidelines.

A summary of the current Scottish air quality objectives is provided in the table below.

Table 1- Summary of Air Quality in Scotland

AQ Objective-Pollutant	Concentration	Measured as	Date to be achieved by
Nitrogen Dioxide (NO_2)	200 µg m^{-3} not to be exceeded more than 18 times a year	1-hour mean	31.12.2005
	40 µg m^{-3}	Annual mean	31.12.2005
Particulate Matter (PM_{10})	50 µg m^{-3}, not to be exceeded more than 7 times a year	24-hour mean	31.12.2010
	18 µg m^{-3}	Annual mean	31.12.2010
Particulate Matter ($PM_{2.5}$)	10 µg m^{-3}	Annual mean	31.12.2020
Sulphur Dioxide (SO_2)	350 µg m^{-3}, not to be exceeded more than 24 times a year	1-hour mean	31.12.2004
	125 µg m^{-3}, not to be exceeded more than 3 times a year	24-hour mean	31.12.2004
	266 µg m^{-3}, not to be exceeded more than 35 times a year	15-minute mean	31.12.2005
Benzene	3.25 µg m^{-3}	Running annual mean	31.12.2010
1,3 Butadiene	2.25 µg m^{-3}	Running annual mean	31.12.2003
Carbon Monoxide	10.0 mg m^{-3}	Running 8-Hour mean	31.12.2003
Lead	0.25 µg m^{-3}	Annual Mean	31.12.2008

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

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

An important focus of CAFS is the impact of air quality on health. In 2010, the UK Government Department of Health's expert advisory committee, the Committee on the Medical Effects of Air Pollution (COMEAP) produced estimates of the burden of added mortality associated with ambient fine particulate pollution at UK level. COMEAP estimates that poor air quality shortens average life expectancy in Scotland by three to four months (compared with six to seven months in England and Wales).

CAFS outlines six main policy objectives, and also sets out a series of 40 actions intended to achieve further improvements in air quality. A summary of the policy objectives and actions is set out below.

i. TRANSPORT

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

This will be achieved by:

- Ensuring that all local authorities have a corporate travel plan which is consistent with any local air quality action plan;
- Delivering National Walking Strategy & Cycling Action Plan;

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

ii. HEALTH

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

This will be achieved by:

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

iii. LEGISLATION and POLICY

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

This will be achieved by:

- Refocus the Local Air Quality Management system;
- Establish a $PM_{2.5}$ monitoring network;
- Produce revised and updated Scottish action plans to demonstrate how compliance with the EU ambient air quality Directives will be achieved;
- Design develop and implement a two level modelling system for regional and local scales to support potential transport and planning solutions to air quality issues;
- Develop guidance and promote a support network for all practitioners in review and assessing air quality;
- Undertake detailed modelling of all four major cities in Scotland (National Modelling Framework;
- Identify requirements and undertake data collection for additional urban areas within three years;
- Implement the national databases for traffic data collection and local modelling outputs associated with CAFS;

- Ensure the NLEF criteria, test, and processes are developed, agreed and finalised
- Design and implement a standard appraisal process for assessing local air quality measures;
- Develop software tools and guidance for the NLEF including funding options and technical reports.

iv. PLACEMAKING

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

This will be achieved by:

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

v. COMMUNICATION

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

This will be achieved by:

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

vi. CLIMATE CHANGE

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

This will be achieved by:

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

In addition to the six main objectives, CAFS outlines new initiatives to be implemented to compliment the objectives set, these initiatives include a National Modelling Framework and Low Emissions Framework.

Local Air Quality Management

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

- Declare an Air Quality Management Area (AQMA);
- Assess and identify the reasons for the problem, quantifying the sources of emissions;

- Develop an Air Quality Action Plan (AQAP) to help address the problem.

In 2016 the Scottish Government produced and updated Technical Guidance and Policy Guidance for the LAQM regime in UK. One of the main changes was to the LAQM reporting process. An Annual Progress Report (APR) has replaced the previous 3-year cyclical process. The LAQM Policy and Technical Guidance are available at http://www.scottishairquality.co.uk/air-quality/legislation.

3 Air Quality Seminar

As part of the Scottish Air Quality Database project, Ricardo Energy & Environment organise, on behalf of the Scottish Government, organise an annual air quality seminar. The most recent Scottish Government Annual Air Quality Seminar was held in the Double Trees by Hilton, 34 Bread Street, Edinburgh, on Tuesday 24th January 2017. The event was attended by over 70 air quality experts representing the Scottish Government, local authorities, Health Protection Scotland, SEPA, consultancy, academia and students. The objective of the seminar was to discuss some of the most recent work carried under the Scottish Air Quality Database and Website project, and to consider a number of other topical air quality issues for Scotland.

The seminar covered a number of interesting topics in the field of air quality. These included amongst others; “How can we protect Scotland’s most vulnerable lungs from air pollution?” by Irene Johnstone (British Lung Foundation) ; Every Breath we take; the effects of Air Pollution across the Life-course by Professor Stephen Holgate (University of Southampton Faculty of Medicine); CAFS and the development of the National Low Emission Framework by Dr Stephen Thomson (Transport Scotland); Real World Emission and Control by Jon Anderson (Ricardo); National Clean Air Day 2017: Why it’s needed and how to take part by Chris Large (Global Action Plan); PN as the best approach for PEMS PM Measurement by Jon Anderson (Ricardo). All presentations can be found on the Scottish air Quality website (www.scottishairquality.co.uk). The full agenda for the day is shown in Figure 3.1.

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

Figure 3.1 Agenda for the Scottish Air Quality Seminar on 24th January 2017

The Scottish Government

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SCOTTISH AIR QUALITY DATABASE AND WEBSITE ANNUAL SEMINAR

Thursday 24th January 2017

Double Tree by Hilton, 34 Bread Street, Edinburgh, EH3 9AF

Agenda

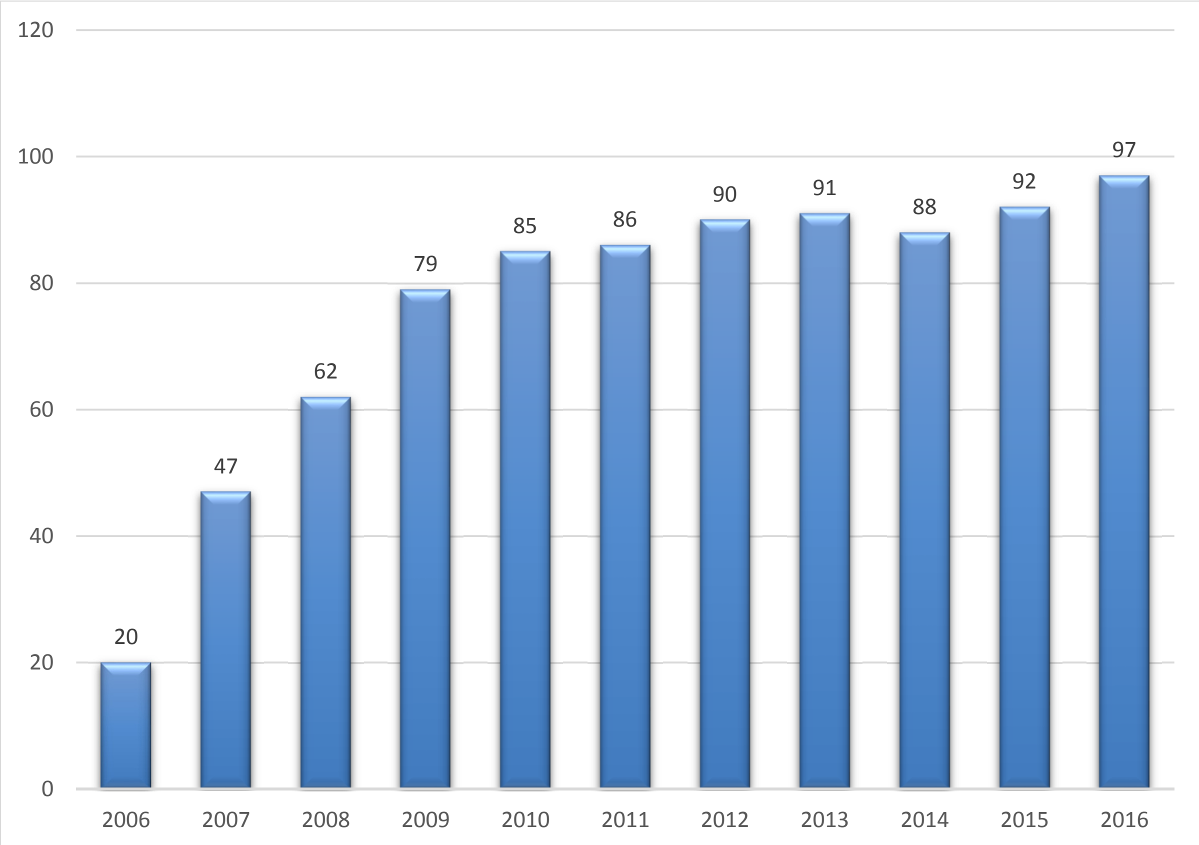
09:15	Registration	
10:00	Welcome and Introduction	Andrew Taylor – Scottish Government
10:15	Air Quality in Scotland	David Hector - Ricardo Energy & Environment
10:45	How can we protect Scotland's most vulnerable lungs from air pollution?	Irene Johnston, British Lung Foundation
11:15	Tea/Coffee Break	
11:35	Every Breath we take; the effects of Air Pollution Across the Life-course	Professor Stephen Holgate, University of Southampton (Faculty of Medicine)
12:05	Young Scots tackling air pollution	Dr Colin Gillespie, SEPA
12:30	Spotfire data analysis tools integration in the SAQD	Kieran Walesby, SEPA
12:50	Lunch	
13:35	CAFS and the development of the National Low Emission Framework	Dr Stephen Thomson, Transport Scotland
14:00	Real World Emissions and Control	Jon Andersson, Ricardo
14:20	National Clean Air Day 2017: Why its needed and how to take part	Chris Large, Senior Partner, Global Action Plan
14:50	Tea/Coffee Break	
15:05	PN as the best approach for PEMS PM Measurements	Jon Andersson, Ricardo
15:25	Air Pollution – future considerations – Ultra Fine Particles	Brian Stacey, Ricardo Energy & Environment
16:00	Q&A – Session Close	

4 Data Availability 2016

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

At the end of 2016, the Scottish Air Quality Database contained data for 97 automatic monitoring sites. In total, 5 new monitoring sites were incorporated into the database during 2016: South Lanarkshire Raith Interchange 2, Falkirk Bo'ness, Falkirk Graham's Road, Falkirk Main Street Bainsford and Inverness Academy Road. Two monitoring sites; Edinburgh Queen Street and Dundee Union Street were decommissioned during 2016. Figure 4.1 shows the growth of the SAQD from 20 sites in 2006 pilot study to 97 sites during 2016.

Figure 4.1 Number of Monitoring Sites within the Scottish Air Quality Database Network 2006 - 2016



For the 20 National Network AURN monitoring stations in the Scottish Database the data are available from the commencement of these stations, which in some cases is as long ago as 1986. However, for local authority monitoring stations, data are only available from when the station joined the database project. In many cases the stations commenced much earlier and these earlier data may be available from the relevant local authority.

Data availability for 2016, in terms of site, pollutants and months available, is summarised in Table 4.1. The full 12-figure OS grid reference and the site location classification are also provided for each site and the monitoring network the site is affiliated to; either the Scottish Air Quality Database Network (SAQD) or the Automatic Urban and Rural Network (AURN).

Table 4.1 also provides the start date for each site. However, not all pollutants are measured over the same period at all sites – measurements of some pollutants may commence or cease during the lifetime of monitoring at the particular site. The dates of availability of data for each pollutant measured at each site can be found by selecting the site on the 'Latest Data' page of the SAQD website (http://www.scottishairquality.co.uk/latest/) and then selecting the "site details" tab.

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

Table 4.1 Scottish Air Quality Database Data Availability in 2016

Site Name	Type	East	North	Pollutants	Network	Start Year#	Data in 2016
Aberdeen Anderson Dr	RS	392506	804186	NO_2 PM_{10}	SAQD	2004	Jan – Dec
Aberdeen Errol Place	UB	394416	807408	NO_2 O_3 PM_{10} $PM_{2.5}$	AURN	1999	Jan – Dec
Aberdeen King Street	RS	394333	808770	NO_2 PM_{10}	SAQD	2008	Jan – Dec
Aberdeen Market Street 2^	RS	394535	805687	NO_2 PM_{10} $PM_{2.5}$	SAQD	2009	Jan – Dec
Aberdeen Union St~	RS	393655	805984	PM_{10}, $PM_{2.5}$	SAQD	2005	Jan – Dec
Aberdeen Union Street Roadside~	RS	393655	805984	NO_2	AURN	2008	Jan – Dec
Aberdeen Wellington Road	RS	394395	804779	NO_2 PM_{10} $PM_{2.5}$	SAQD	2008	Jan – Dec
Alloa A907+	RS	288689	693068	NO_2 PM_{10}	SAQD	2016	Jan – Dec
Angus Forfar Glamis Road+	RS	345248	750385	PM_{10}	SAQD	2016	Jan – Dec
Auchencorth Moss	R	322167	656123	13BD BENZ O_3 PM_{10} $PM_{2.5}$ TOL XYL	AURN	2006	Jan – Dec
Bush Estate	R	324626	663880	NO_2 O_3	AURN	1986	Jan – Dec
Dumbarton Roadside	RS	240234	675193	NO_2	AURN	2010	Jan – Dec
Dumfries	RS	297012	576278	NO_2	AURN	2001	Jan – Dec
Dundee Broughty Ferry Road	UI	341970	730997	PM_{10} SO_2	SAQD	2006	Jan – Dec
Dundee Lochee Road	KS	330773	738861	NO_2 PM_{10}	SAQD	2006	Jan – Dec
Dundee Mains Loan	UB	340972	731893	NO_2 PM_{10}	SAQD	2006	Jan – Dec
Dundee Meadowside	RS	340241	730654	NO_2 PM_{10}	SAQD	2011	Jan – Dec
Dundee Seagate	KS	340487	730446	NO_2 PM_{10}	SAQD	2006	Jan – Dec
Dundee Union Street	KS	340236	730090	NO_2 PM_{10}	SAQD	2006	Jan
Dundee Whitehall Street	KS	330155	740279	NO_2	SAQD	2006	Jan – Dec
East Ayrshire Kilmarnock St Marnock St	RS	242742	637705	NO_2 PM_{10} $PM_{2.5}$	SAQD	2012	Jan – Dec
East Dunbartonshire Bearsden	RS	254269	672067	NO_2 PM_{10}	SAQD	2005	Jan – Dec
East Dunbartonshire Bishopbriggs	RS	260995	670130	NO_2 PM_{10}	SAQD	2003	Jan – Dec
East Dunbartonshire Kirkintilloch	RS	265700	673500	NO_2 PM_{10}	SAQD	2007	Jan – Dec
East Dunbartonshire Milngavie	RS	255325	674115	NO_2 PM_{10}	SAQD	2011	Jan – Dec

Site Name	Type	East	North	Pollutants	Network	Start Year#	Data in 2016
East Lothian Musselburgh N High St	RS	333941	672836	NO_2 PM_{10}	SAQD	2008	Jan – Dec
Edinburgh Currie	UB	317575	667874	NO_2 PM_{10}	SAQD	2013	Jan – Dec
Edinburgh Glasgow Road	RS	313101	672651	NO_2 PM_{10}	SAQD	2012	Jan – Dec
Edinburgh Gorgie Road	RS	323121	672314	NO_2	SAQD	2005	Jan – Dec
Edinburgh Queen Street	RS	324890	674100	NO_2 PM_{10}	SAQD	2007	Jan – Jul
Edinburgh Queensferry Road	RS	318734	674931	NO_2 PM_{10}	SAQD	2011	Jan – Dec
Edinburgh Salamander St	RS	327621	676342	NO_2 PM_{10}	SAQD	2009	Jan – Dec
Edinburgh St John's Road	KS	320100	672890	NO_2 PM_{10} $PM_{2.5}$	SAQD	2007	Jan – Dec
Edinburgh St Leonards	UB	326250	673132	CO NO_2 O_3 PM_{10} $PM_{2.5}$ SO_2	AURN	2003	Jan – Dec
Eskdalemuir	R	323552	603018	NO_2 O3	AURN	1986	Jan – Dec
Falkirk Main Street Bainsford	RS	288565	681520	NO_2 PM_{10}	SAQD	2015	Jan - Dec
Falkirk Banknock^	RS	277247	679026	PM_{10} $PM_{2.5}$	SAQD	2013	Jan – Dec
Falkirk Bo'ness	UI	299818	681483	SO_2	SAQD	2016	Apr - Dec
Falkirk Grahams Road	RS	288822	680245	PM_{10}	SAQD	2011	Jan - Dec
Falkirk Grangemouth MC	UB	292816	682009	NO_2 PM_{10} SO_2	SAQD	2003	Jan – Dec
Falkirk Grangemouth Zetland Park+	UI	292969	681106	SO_2	SAQD	2016	May – Dec
Falkirk Haggs	RS	278977	679271	NO_2	SAQD	2009	Jan – Dec
Falkirk Hope St	RS	288688	680218	NO_2 SO_2	SAQD	2007	Jan – Dec
Falkirk West Bridge Street	RS	288457	680064	NO_2 PM_{10} $PM_{2.5}$	SAQD	2007	Jan – Dec
Fife Cupar	RS	337401	714572	NO_2 PM_{10} $PM_{2.5}$	SAQD	2005	Jan – Dec
Fife Dunfermline	RS	309912	687738	NO_2 PM_{10} $PM_{2.5}$	SAQD	2007	Jan – Dec
Fife Kirkcaldy	RS	329143	692986	NO_2 PM_{10} $PM_{2.5}$	SAQD	2011	Jan – Dec
Fife Rosyth^	RS	311752	683515	NO_2 PM_{10} $PM_{2.5}$	SAQD	2008	Jan – Dec
Fort William	S	210849	774421	NO_2 O_3	AURN	2006	Jan – Dec
Glasgow Abercromby Street	RS	260420	664175	PM_{10}	SAQD	2007	Jan – Dec
Glasgow Anderston	UB	257925	665487	NO_2 PM_{10} SO_2	SAQD	2005	No Data
Glasgow Broomhill	RS	255030	667195	PM_{10}	SAQD	2007	Jan – Dec
Glasgow Burgher Street	RS	262548	664168	NO_2 PM_{10}	SAQD	2011	Jan – Dec
Glasgow Byres Road	RS	256553	665487	NO_2 PM_{10}	SAQD	2005	Jan – Dec

Site Name	Type	East	North	Pollutants	Network	Start Year#	Data in 2016
Glasgow Dumbarton Road	RS	255030	666608	NO_2 PM_{10}	SAQD	2012	Jan – Dec
Glasgow Kerbside (Hope Street)	KS	258708	665200	NO_2	AURN	1997	Jan – Dec
Glasgow Great Western Road	RS	258007	666650	NO_2	AURN	2016	Jan – Dec
Glasgow High Street+	RS	260014	665348	NO_2 PM_{10} $PM_{2.5}$	AURN	2016	Jan – Dec
Glasgow Nithsdale Road	RS	257883	662673	PM_{10}	SAQD	2007	Jan – Dec
Glasgow Townhead	UB	259692	665899	NO_2 O_3 PM_{10} $PM_{2.5}$	AURN	2013	Jan – Dec
Glasgow Waulkmillglen Reservoir	R	252520	658095	NO_2 O_3 PM_{10}	SAQD	2005	Jan – Dec
Grangemouth	UI	293837	681035	NO_2 PM_{10} $PM_{2.5}$ SO_2	AURN	2001	Jan – Dec
Grangemouth Moray~	UB	293469	681321	NO_2	AURN	2009	Jan – Dec
Grangemouth Moray Scot Gov~	UB	293469	681321	SO_2	SAQD	2007	Jan – Dec
Inverclyde Greenock A8	RS	229335	675710	NO_2 PM_{10} $PM_{2.5}$	SAQD	2016	Jan – Dec
Inverness	RS	265720	845680	NO_2 PM_{10} $PM_{2.5}$	AURN	2001	Jan – Dec
Inverness Academy Street	RS	266654	845446	NO_2	SAQD	2016	Jun – Dec
Lerwick~	R	445337	1139683	O_3	AURN	2005	-
N Lanarkshire Chapelhall	RS	278174	663124	NO_2 PM_{10}	SAQD	2005	Jan – Dec
N Lanarkshire Coatbridge Whifflet	UB	273668	663938	NO_2 PM_{10}	SAQD	2007	Jan – Dec
N Lanarkshire Croy	RS	272775	675738	CO NO_2 PM_{10} SO_2	SAQD	2006	Jan – Dec
N Lanarkshire Kirkshaws	RS	272522	663029	NO_2 PM_{10}	SAQD	2016	Jun – Dec
N Lanarkshire Moodiesburn	RS	269929	670386	NO_2 PM_{10}	SAQD	2008	Jan – Dec
N Lanarkshire Motherwell	RS	275460	656785	PM_{10}	SAQD	2007	Jan – Dec
N Lanarkshire Shawhead Coatbridge	RS	273411	662997	NO_2 PM_{10}	SAQD	2009	Jan – Dec
North Ayrshire Irvine High Street	KS	232142	638892	NO_2 PM_{10} $PM_{2.5}$	SAQD	2009	Jan – Dec
Paisley Gordon Street	RS	248316	663611	NO_2 PM_{10}	SAQD	2004	Jan – Dec
Paisley St James St	RS	248175	664311	PM_{10}	SAQD	2010	Jan – Dec
Peebles	S	324812	641083	NO_2 O_3	AURN	2009	Jan – Dec
Perth Atholl Street	RS	311582	723931	NO_2 PM_{10}	SAQD	2004	Jan – Dec
Perth Crieff	RS	286363	721614	NO_2 PM_{10}	SAQD	2010	Jan – Dec
Perth High Street	RS	311688	723625	NO_2 PM_{10}	SAQD	2003	Jan – Dec
Perth Muirton	UB	311688	723625	PM_{10}	SAQD	2012	Jan – Dec
Renfrew Cockles Loan	RS	250464	665933	NO_2 PM_{10}	SAQD	2013	Jan – Dec
Shetland Lerwick~	R	445337	1139683	NO_2 SO_2	SAQD	2012	Jan – Dec
South Ayrshire Ayr Harbour	RS	233617	622749	NO_2 $PM_{2.5}$	SAQD	2012	Jan – Dec

Site Name	Type	East	North	Pollutants	Network	Start Year#	Data in 2016
South Ayrshire Ayr High St	RS	233725	622120	NO_2 $PM_{2.5}$	SAQD	2007	Jan – Dec
South Lanarkshire Cambuslang	KS	264319	660519	NO_2 PM_{10}, $PM_{2.5}$	SAQD	2015	Jan – Dec
South Lanarkshire East Kilbride	RS	264390	655658	NO_2 PM_{10}	SAQD	2008	Jan – Dec
South Lanarkshire Hamilton	RS	272298	655289	NO_2 PM_{10}	SAQD	2013	Jan – Dec
South Lanarkshire Lanark^	RS	288427	643701	NO_2 PM_{10}, $PM_{2.5}$	SAQD	2012	Jan – Dec
South Lanarkshire Raith Interchange 2	KS	271065	658087	NO_2 PM_{10}, $PM_{2.6}$	SAQD	2016	Mar - Dec
South Lanarkshire Rutherglen	RS	261113	661690	NO_2 PM_{10}, $PM_{2.5}$	SAQD	2012	Jan – Dec
South Lanarkshire Uddingston^	RS	269657	660305	NO_2 PM_{10}, $PM_{2.5}$	SAQD	2013	Jan – Dec
Stirling Craig's Roundabout	RS	279955	693012	NO_2 PM_{10}	SAQD	2009	Jan – Dec
Strath Vaich	RS	234829	874785	O_3	AURN	1987	Jan – Dec
West Dunbartonshire Clydebank^	RS	249724	672042	NO_2 PM_{10} $PM_{2.5}$	SAQD	2007	Jan – Dec
West Lothian Broxburn	RS	308364	672248	NO_2 PM_{10}	SAQD	2008	Jan – Dec
West Lothian Linlithgow High St 2	RS	300419	677120	NO_2 PM_{10}	SAQD	2013	Jan – Dec
West Lothian Newton	RS	309258	677728	NO_2 PM_{10}	SAQD	2012	Jan – Dec

+ Sites added to database in 2016
* Sites closed during 2016
^Changes in number of measured pollutants or monitoring method during 2016
This is the date of the site joining the network. Data for some pollutants may not be available from this date. Also, data for some pollutants may be available from earlier dates from the Local Authority other networks. The period of availability for data for each pollutant measured at each site can be seen on www.scottishairquality.co.uk by selecting the site and the "site details" tab.
~ At these sites, some pollutants are affiliated to the AURN network and some pollutants are affiliated the SAQD Network.
A - Airport
KS – Kerbside
R – Rural
RS – Roadside
S – Suburban
UB – Urban Background
UI – Urban Industrial

4.1.1 Summary of Changes to Monitoring Sites within the Database During 2016

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

Sites opened during 2016:

- Falkirk Bainsford — NO_2, PM_{10} — from 18/01/2016
- Falkirk Bo'ness — SO2 — from 29/04/2016
- Falkirk Grahams Road — PM_{10} — from 01/01/2016
- Inverness Academy Street — NO_2, PM_{10} — from 24/06/2016
- South Lanarkshire Raith Interchange 2 — NO_2 PM_{10} $PM_{2.5}$ — from 21/03/2016

Sites closed during 2016:

- Edinburgh Queen Street — PM_{10} — on 01/07/2016
- Dundee Union Street — NO_2, PM_{10}, — on 06/01/2016

Sites changes during 2016:

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

- East Ayrshire Kilmarnock St Marnock Street on 19/08/2016
- Fife Kirkcaldy on 06/04/2016
- Fife Dunfermline on 05/09/2016
- Fife Cupar on 07/12/2016
- Inverclyde Greenock A8 on 23/03/2016

Monitoring of $PM_{2.5}$ instead of PM_{10} using a FDMS analyser at the following sites:

- South Ayrshire Ayr High Street on 27/09/2016
- South Ayrshire Harbour on 27/09/2016

5 QA/QC of the Scottish Database

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

The main elements of the QA/QC programme are on-site analyser and calibration gas inter-calibrations every six months, daily automatic data collection and validation and data ratification in three-monthly blocks.

5.1 On-Site Analyser and Calibration Gas Audits

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

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

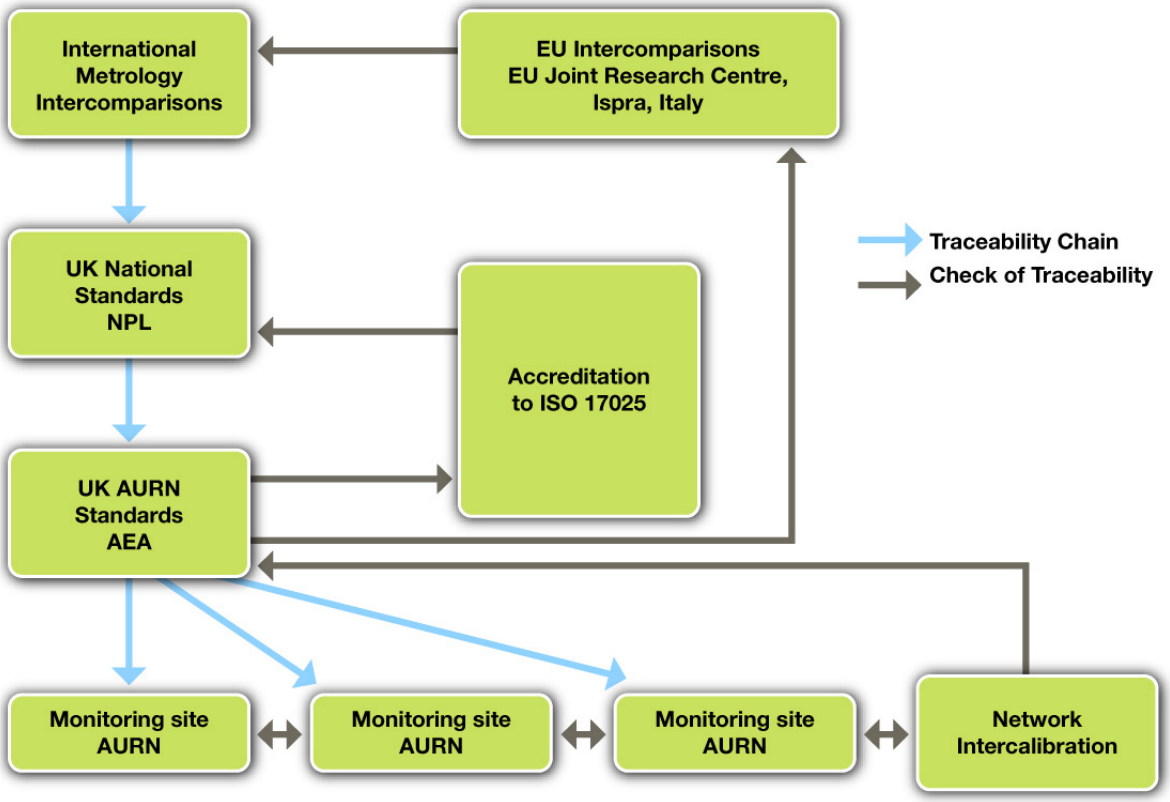
The assessment of the on-site calibration cylinder concentrations against accredited and traceable Ricardo Energy & Environment gas standard cylinders provides the essential final link in the measurement traceability chain (Fig 5.1). This process ensures that all monitoring stations in Scotland are traceable to reference gas standards held at Ricardo Energy & Environment. These in turn are traceable to UK national reference standard gases held by the National Physical Laboratory who, in turn regularly inter-compare these standards internationally. Ricardo Energy & Environment also participate in EU level inter-comparisons at the EU Joint Research Centre at Ispra, Italy. Hence, there is an unbroken traceability chain from each monitoring site in Scotland to internationally agreed gas calibration standards. This check also identifies any unstable gas cylinders which may need to be recertified or discarded.

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

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

Detailed audit procedures are provided in Appendix 2.

Figure 5.1 Traceability chain for the SAQD monitoring stations



5.2 Data Management

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

The process includes the following tasks:

- Data acquisition
- Data validation
- Ratification

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

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

The validated data are then updated to the Scottish Air Quality Database – and accessible via the web - as provisional data. These data are therefore available to all users on a day-to-day basis. This gives the local authority the opportunity to easily view both their own data and data from other stations throughout Scotland. This will assist in dealing with day-to-day requests for information on specific data or the overall pollution situation either locally or throughout Scotland. In particular, the automatic data summary bulletin, available by email from the website, and the plotting package incorporated into this, will be useful to authorities to rapidly evaluate their data against that available from other stations.

5.3 Data Ratification

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

The aim of data ratification is to make use of all of the available information to identify and remove any faulty data, ensuring that remaining measurement data meet the accuracy and precision specifications of the Scottish Government for detailed Review and Assessment (LAQM.TG(16)).

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

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

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

5.4 QA/QC During 2016

As discussed above, site inter-calibrations and audit visits are undertaken at six-monthly intervals. Where a site joins the database part way through a year then it is possible that only one audit will be conducted during that year.

The majority of analysers and sites were found to be operating satisfactorily during the audits. However, inevitably some faults/issues were identified at a number of sites. The more significant faults/issues identified during 2016 are summarised in Table 5.1. All audit results are forwarded on to the relevant local authority site operator so that appropriate actions are carried out where required.

Table 5.1 Monitoring site faults identified during the 2016 audits

Fault	Number of Monitoring Sites Winter 2015/16	Number of Monitoring Sites Summer 2016
TEOM** and TEOM FDMS k_0 out by > 2.5%	0	6
Particulate Analyser*** flow out by >10%	6	7
NO_x analyser converter <97% efficiency	4	4
NO cylinder out by >10%	11	9
SO_2 cylinder out by >10%	1	0
CO cylinder out by >10%	0	0
O3 Analyser out by >5%	0	0

* Filter Dynamics Measurement System
** Tapered Element Oscillating Microbalance
*** These include TEOM, FDMS and Beta Attenuation Monitors (BAM)

These are all characteristic faults that are found during audit and intercalibration exercises and as can be seen from the 2016 figures.

In many cases, the results from the audit and intercalibration visits provide the information necessary to correct for these issues at the data ratification stage so that the data can be corrected and retained, rather than being deleted as erroneous data. Table 5.2 summarises the site inter-calibrations and audits undertaken during 2016, where the period Winter 2015/16 corresponds to Dec-15 to Mar-16 and Summer 2016 corresponds to Jun-16 to Aug-16.

5.4.1 Data Ratification

In 2013, data ratification was brought in line with the AURN schedule and is now undertaken at three-monthly intervals (previously six monthly. Hence, as with the inter-calibrations and audits, if the site joins the database part way through a year then data can only be ratified from the date of the site joining the database.

All ratified data for 2016 have now been uploaded to the Scottish Air Quality website and Table 5.3 summarises the ratification undertaken during 2016. The column headings labelled Q1 – Q4 refer to the quarter periods of the calendar year:

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

Table 5.2 Air quality site intercalibration and audits conducted during 2016

Site Name	Winter 2015/16	Summer 2016	Site Name	Winter 2015/16	Summer 2016
Aberdeen Anderson Dr	✓	✓	Glasgow Anderston	✓	✓
Aberdeen Errol Place	✓	✓	Glasgow Broomhill	✓	✓
Aberdeen King Street	✓	✓	Glasgow Burgher Street	✓	✓
Aberdeen Market Street 2	✓	✓	Glasgow Byres Road	✓	✓
Aberdeen Union St	✓	✓	Glasgow Dumbarton Road	✓	✓

Site Name	Winter 2015/16	Summer 2016	Site Name	Winter 2015/16	Summer 2016
Aberdeen Union Street Roadside	✓	✓	Glasgow Kerbside	✓	✓
Aberdeen Wellington Road	✓	✓	Glasgow Great Western Road	✓	✓
Alloa A907	✓	✓	Glasgow High Street+	✓	✓
Angus Forfar Glamis Road	-	✓	Glasgow Nithsdale Road	✓	✓
Auchencorth Moss	✓	✓	Glasgow Townhead	✓	✓
Bush Estate	✓	✓	Glasgow Waulkmillglen Reservoir	✓	✓
Dumbarton Roadside	✓	✓	Grangemouth	✓	✓
Dumfries	✓	✓	Grangemouth Moray	✓	✓
Dundee Broughty Ferry Road	✓	✓	Grangemouth Moray Scot Gov	✓	✓
Dundee Lochee Road	✓	✓	Inverclyde Greenock A8	✓	✓
Dundee Mains Loan	✓	✓	Inverness	✓	✓
Dundee Meadowside	✓	✓	Inverness Academy Street	-	✓
Dundee Seagate	✓	✓	Lerwick	✓	✓
Dundee Union Street	-	-	N Lanarkshire Chapelhall	✓	✓
Dundee Whitehall Street	✓	✓	N Lanarkshire Coatbridge Whifflet	✓	✓
East Ayrshire Kilmarnock St Marnock St	✓	✓	N Lanarkshire Croy	✓	✓
East Dunbartonshire Bearsden	✓	✓	N Lanarkshire Kirkshaws	✓	✓
East Dunbartonshire Bishopbriggs	✓	✓	N Lanarkshire Moodiesburn	✓	✓
East Dunbartonshire Kirkintilloch	✓	✓	N Lanarkshire Motherwell	✓	✓
East Dunbartonshire Milngavie	✓	✓	N Lanarkshire Shawhead Coatbridge	✓	✓
East Lothian Musselburgh N High St	✓	✓	North Ayrshire Irvine High St	✓	✓
Edinburgh Currie	✓	✓	Paisley Glasgow Airport	✓	✓
Edinburgh Glasgow Road	✓	✓	Paisley Gordon Street	✓	✓
Edinburgh Gorgie Road	✓	✓	Paisley St James St	✓	✓
Edinburgh Queen Street	✓	-	Peebles	✓	✓
Edinburgh Queensferry Road	✓	✓	Perth Atholl Street	✓	✓
Edinburgh Salamander St	✓	✓	Perth Crieff	✓	✓
Edinburgh St John's Road	✓	✓	Perth High Street	✓	✓
Edinburgh St Leonards	✓	✓	Perth Muirton	✓	✓
Eskdalemuir	✓	✓	Shetland Lerwick	✓	✓
Falkirk Main Street Bainsford	✓	✓	South Ayrshire Ayr Harbour	✓	✓
Falkirk Banknock	✓	✓	South Ayrshire Ayr High St	✓	✓
Falkirk Bo'ness	✓	✓	South Lanarkshire East Kilbride	✓	✓
Falkirk Grahams Road	✓	✓	South Lanarkshire Hamilton	✓	✓
Falkirk Grangemouth MC	✓	✓	South Lanarkshire Lanark	✓	✓
Falkirk Grangemouth Zetland Park	✓	✓	South Lanarkshire Raith Interchange	-	✓
Falkirk Haggs	✓	✓	South Lanarkshire Rutherglen	✓	✓
Falkirk Hope St	✓	✓	South Lanarkshire Uddingston	✓	✓
Falkirk West Bridge Street	✓	✓	Stirling Craig's Roundabout	✓	✓
Fife Cupar	✓	✓	Strath Vaich	✓	✓
Fife Dunfermline	✓	✓	West Dunbartonshire Clydebank	✓	✓
Fife Kirkcaldy	✓	✓	West Lothian Broxburn	✓	✓
Fife Rosyth	✓	✓	West Lothian Linlithgow High St 2	✓	✓
Fort William	✓	✓	West Lothian Newton	✓	✓
Glasgow Abercromby Street	✓	✓			

Table 5.3 Data ratification undertaken during 2016

Site Name	Q1	Q2	Q3	Q4	Site Name	Q1	Q2	Q3	Q4
Aberdeen Anderson Dr	✓	✓	✓	✓	Glasgow Anderston	✓	✓	✓	✓
Aberdeen Errol Place	✓	✓	✓	✓	Glasgow Broomhill	✓	✓	✓	✓
Aberdeen King Street	✓	✓	✓	✓	Glasgow Burgher Street	✓	✓	✓	✓
Aberdeen Market Street 2	✓	✓	✓	✓	Glasgow Byres Road	✓	✓	✓	✓
Aberdeen Union St	✓	✓	✓	✓	Glasgow Dumbarton Road	✓	✓	✓	✓
Aberdeen Union Street Roadside	✓	✓	✓	✓	Glasgow Kerbside	✓	✓	✓	✓
Aberdeen Wellington Road	✓	✓	✓	✓	Glasgow Great Western Road	✓	✓	✓	✓
Alloa A907	✓	✓	✓	-	Glasgow High Street+	✓	✓	✓	✓
Angus Forfar Glamis Road	✓	✓	✓	✓	Glasgow Nithsdale Road	✓	✓	✓	✓
Auchencorth Moss	✓	✓	✓	✓	Glasgow Townhead	✓	✓	✓	✓
Bush Estate	✓	✓	✓	✓	Glasgow Waulkmillglen Reservoir	✓	✓	✓	✓
Dumbarton Roadside	✓	✓	✓	✓	Grangemouth	✓	✓	✓	✓
Dumfries	✓	✓	✓	✓	Grangemouth Moray	✓	✓	✓	✓
Dundee Broughty Ferry Road	✓	✓	✓	✓	Grangemouth Moray Scot Gov	✓	✓	✓	✓
Dundee Lochee Road	✓	✓	✓	✓	Inverclyde Greenock A8	✓	✓	✓	✓
Dundee Mains Loan	✓	✓	✓	✓	Inverness	✓	✓	✓	✓
Dundee Meadowside	✓	✓	✓	✓	Inverness Academy Street	-	-	✓	✓
Dundee Seagate	✓	✓	✓	✓	Lerwick	✓	✓	✓	✓
Dundee Union Street	✓	-	-	-	N Lanarkshire Chapelhall	✓	✓	✓	✓
Dundee Whitehall Street	✓	✓	✓	✓	N Lanarkshire Coatbridge Whifflet	✓	✓	✓	✓
East Ayrshire Kilmarnock St Marnock St	✓	✓	✓	✓	N Lanarkshire Croy	✓	✓	✓	✓
East Dunbartonshire Bearsden	✓	✓	✓	✓	N Lanarkshire Kirkshaws	✓	✓	✓	✓
East Dunbartonshire Bishopbriggs	✓	✓	✓	✓	N Lanarkshire Moodiesburn	✓	✓	✓	✓
East Dunbartonshire Kirkintilloch	✓	✓	✓	✓	N Lanarkshire Motherwell	✓	✓	✓	✓
East Dunbartonshire Milngavie	✓	✓	✓	✓	N Lanarkshire Shawhead Coatbridge	✓	✓	✓	✓

Site Name	Q1	Q2	Q3	Q4	Site Name	Q1	Q2	Q3	Q4
East Lothian Musselburgh N High St	✓	✓	✓	✓	North Ayrshire Irvine High St	✓	✓	✓	✓
Edinburgh Currie	✓	✓	✓	✓	Paisley Glasgow Airport	✓	✓	✓	✓
Edinburgh Glasgow Road	✓	✓	✓	✓	Paisley Gordon Street	✓	✓	✓	✓
Edinburgh Gorgie Road	✓	✓	✓	✓	Paisley St James St	✓	✓	✓	✓
Edinburgh Queen Street	✓	✓	✓	-	Peebles	✓	✓	✓	✓
Edinburgh Queensferry Road	✓	✓	✓	✓	Perth Atholl Street	✓	✓	✓	✓
Edinburgh Salamander St	✓	✓	✓	✓	Perth Crieff	✓	✓	✓	✓
Edinburgh St John's Road	✓	✓	✓	✓	Perth High Street	✓	✓	✓	✓
Edinburgh St Leonards	✓	✓	✓	✓	Perth Muirton	✓	✓	✓	✓
Eskdalemuir	✓	✓	✓	✓	Shetland Lerwick	✓	✓	✓	✓
Falkirk Main Street Bainsford	✓	✓	✓	✓	South Ayrshire Ayr Harbour	✓	✓	✓	✓
Falkirk Banknock	✓	✓	✓	✓	South Ayrshire Ayr High St	✓	✓	✓	✓
Falkirk Bo'ness	-	✓	✓	✓	South Lanarkshire East Kilbride	✓	✓	✓	✓
Falkirk Grahams Road	✓	✓	✓	✓	South Lanarkshire Hamilton	✓	✓	✓	✓
Falkirk Grangemouth MC	✓	✓	✓	✓	South Lanarkshire Lanark	✓	✓	✓	✓
Falkirk Grangemouth Zetland Park	✓	✓	✓	✓	South Lanarkshire Raith Interchange	✓	✓	✓	✓
Falkirk Haggs	✓	✓	✓	✓	South Lanarkshire Rutherglen	✓	✓	✓	✓
Falkirk Hope St	✓	✓	✓	✓	South Lanarkshire Uddingston	✓	✓	✓	✓
Falkirk West Bridge Street	✓	✓	✓	✓	Stirling Craig's Roundabout	✓	✓	✓	✓
Fife Cupar	✓	✓	✓	✓	Strath Vaich	✓	✓	✓	✓
Fife Dunfermline	✓	✓	✓	✓	West Dunbartonshire Clydebank	✓	✓	✓	✓
Fife Kirkcaldy	✓	✓	✓	✓	West Lothian Broxburn	✓	✓	✓	✓
Fife Rosyth	✓	✓	✓	✓	West Lothian Linlithgow High St 2	✓	✓	✓	✓
Fort William	✓	✓	✓	✓	West Lothian Newton	✓	✓	✓	✓
Glasgow Abercromby Street	✓	✓	✓	✓					

5.5 Volatile Correction Model (VCM)

5.5.1 Background

The EU Directive on Ambient Air Quality[1] and the UK Air Quality Strategy[2] set target values and objectives respectively for PM_{10} concentrations in terms of gravimetric measurements referenced to the EU reference method of measurement (EN 12341). It has long been recognised that PM_{10} measurements made with many automatic PM_{10} monitors are not equivalent to the EU reference method. However, these analysers are widely used since they provide hourly resolved data and have many operational advantages over the manual reference method. Hence, correction factors, most noticeably the 1.3 correction factor for the TEOM analyser, have been widely used for many years. In setting the value of 1.3 as a correction factor, it was recognized that this was a conservative factor and that TEOMx1.3 data were likely to overestimate PM_{10} concentrations. In Scotland, a lower correction factor of 1.14, which was based on intercomparison data obtained in Edinburgh, has also been widely used.

The results of the formal UK PM_{10} Equivalence Study[3] carried out in 2006, showed that data from the TEOM could not be considered as equivalent to the EU reference method, whether or not a correction factor was used. The reason for this is that the TEOM heats the filter used to collect PM_{10} to 50°C in order to eliminate the possible interference from water vapour – this heating also removes some of the more volatile components of the particulate matter.

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

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

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

5.5.2 Use of the VCM in Scotland

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

However, additional refinement of the VCM model has been undertaken and hourly meteorological data for all parameters has been sourced. As a result, VCM correction of the 2009 to 2016 datasets has been undertaken on an hourly basis. This also brings into line the processing of the Scottish local authority data with that of the AURN.

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

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

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

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

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

- Hourly average temperatures (℃)
- Hourly average pressures (mbar)
- Hourly average TEOM concentrations (µg m^{-3})
- Hourly average FDMS purge concentrations (µg m^{-3})

For the 2016 corrections, temperature and pressure data from Edinburgh Airport meteorological monitoring stations were utilised. This site was selected as a good representation of weather conditions in the central belt of Scotland.

Hourly average purge measurements from all Scottish FDMS monitoring sites within the Scottish Government-run network (SAQD) and the UK national network (AURN) were used for the correction. A total of 34 FDMS sites were used for correcting hourly average TEOM data at 23 sites across Scotland. A list of sites used for correction is provided in appendix 3 of this report. Table 5.4 provides the names of the sites where data was corrected using VCM.

Any outliers in the FDMS purge measurements were identified using Grubbs' Test[4] on daily average data. All hourly data within a day identified as an outlier were then removed from the data set and the average of each hourly purge measurement from the FDMS sites was calculated and used in the VCM calculations.

The corrected data for 2016 and calculated summary statistics have been provided to the local authorities. In addition, the SAQD website database now shows all ratified TEOM data for 2016 as VCM corrected data via an additional selection option in the data download pages. A flow chart showing the overall process employed for VCM correction of 2016 SAQD TEOM data is provide in Appendix 3. It should be noted that it is not possible to correct historical data with the VCM as measurements of volatile particle concentrations are not available prior to 2008.

Table 5.4 TEOM Sites data corrected using VCM in 2016

Site Name	Local Authority
Aberdeen Anderson Dr	Aberdeen City Council
Aberdeen Wellington Road	Aberdeen City Council
Dundee Broughty Ferry Road	Dundee City Council
Dundee Mains Loan	Dundee City Council
Edinburgh Currie	Edinburgh City Council
Edinburgh Glasgow Road	Edinburgh City Council
Edinburgh Queen Street	Edinburgh City Council
Edinburgh Salamander St	Edinburgh City Council
Falkirk Bainsford	Falkirk Council
Falkirk Grahams Rd	Falkirk Council
Falkirk Grangemouth MC	Falkirk Council

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

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

Falkirk Haggs	Falkirk Council
Falkirk West Bridge Street	Falkirk Council
Glasgow Dumbarton Road	Glasgow City Council
Glasgow Waulkmillglen Reservoir	Glasgow City Council
Inverclyde Greenock A8	Inverclyde Council
North Lanarkshire Chapelhall	North Lanarkshire Council
North Lanarkshire Coatbridge Whifflet	North Lanarkshire Council
North Lanarkshire Croy	North Lanarkshire Council
North Lanarkshire Motherwell	North Lanarkshire Council
Perth Atholl Street	Perth and Kinross Council
Perth High Street	Perth and Kinross Council
Stirling Craig's Roundabout	Stirling Council

6 Air Pollution in Scotland 2016

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

- Section 6.1 - Automatic monitoring of the pollutants NO_2, PM_{10}, $PM_{2.5}$ CO, SO_2 and O_3 summary data for 2016.

- Section 6.2 - Other pollutants covered by the Air Quality Strategy – PAH (benzo[a]pyrene), Benzene, 1,3-butadiene and lead - summary statistics for 2015 or 2016 depending on the availability of data.

- Section 6.3 - Other pollutants and/or other methods of monitoring:
    1. NO_2 Diffusion Tube Samplers
    2. Non-methane Volatile Organic Compounds (NMVOC)
    3. Poly-aromatic Hydrocarbons (PAH)
    4. Toxic Organic Micropollutants (TOMPS)
    5. Metals (Urban network)
    6. Metals (Rural and deposition network)
    7. United Kingdom Eutrophying & Acidifying Pollutants Network:
        a. The Precipitation Network
        b. NO_2 Rural Diffusion Tube Network
        c. Acid Gases and Aerosol Network (AGANET)
        d. National Ammonia Monitoring Network

6.1 Automatic monitoring of pollutants NO_2, PM_{10}, $PM_{2.5}$, CO, SO_2 and Ozone

Tables 6.1 – 6.2 show the 2016 annual average data statistics for NO_2, PM_{10}, $PM_{2.5}$, CO, SO_2 and O_3 respectively, for the ratified automatic data from monitoring sites included in the Scottish Air Quality Database. These are shown along with the corresponding data capture for the year.

These data will have been used by local authorities to assess air quality within their area as part of the review and assessment process. Where any of the air quality objectives for Scotland have been exceeded, at locations where there is relevant exposure to the general public, then the authority will need to carry out a more detailed assessment as an addendum to their Annual Progress Report (APR) to confirm the exceedance and estimate its extent. Where the exceedance is confirmed then the authority will declare an Air Quality Management Area (AQMA). It should be noted that not all automatic monitoring sites within the SAQD are located at sites of relevant exposure. For details regarding this please refer to individual local authority APRs.

At the time of writing, 14 local authorities in Scotland have declared a total of 39 AQMAs. There was one new AQMA declared in 2016. This was;

- Johnstone, Renfrewshire Council, declared on the 24th August 2016 for NO_2

For more detailed information on current and revoked Scottish AQMAs please visit
http://www.scottishairquality.co.uk/laqm/aqma

Based on the data in the database, a summary of the air quality situation throughout Scotland is given under each table.

6.1.1 Nitrogen Dioxide

Table 6.1 Ratified data annual average concentration and data capture for NO_2 in 2016 for monitoring sites in the Scottish Air Quality Database

Site Name	Type	Annual Average NO_2 2016 (µg m^{-3})	No. hours >200 µg m^{-3}	Data capture NO_2 2016 (%)
Aberdeen Anderson Dr	RS	21.4	0	93.6
Aberdeen Errol Place	UB	20.8	0	97.2
Aberdeen King Street	RS	27.6	0	95.8
Aberdeen Market Street 2	RS	35.4	1	94.2
Aberdeen Union Street Roadside	RS	43.0	0	96.0
Aberdeen Wellington Road	RS	45.6	2	97.5
Alloa A907	RS	27.1	0	70.1
Bush Estate	R	6.4	0	88.9
Dumfries	RS	30.9	0	95.4
Dundee Broughty Ferry Road	UI	19.3	0	95.6
Dundee Lochee Road	RS	44.9	4	97.3
Dundee Mains Loan	UB	12.3	0	65.3
Dundee Meadowside	RS	35.9	0	82.2
Dundee Seagate	KS	47.0	0	99.2
Dundee Whitehall Street	KS	37.4	0	95.4
E Ayrshire Kilmarnock St Marnock St	RS	29.4	0	93.8
East Dunbartonshire Bearsden	RS	46.4	19	97.0
East Dunbartonshire Bishopbriggs	RS	28.6	0	97.5
East Dunbartonshire Kirkintilloch	RS	33.6	0	95.3
East Dunbartonshire Milngavie	RS	22.3	0	94.7
East Lothian Musselburgh N High St	RS	24.7	0	93.9
Edinburgh Currie	UB	7.0	0	96.7
Edinburgh Glasgow Road	RS	27.8	0	99.3
Edinburgh Gorgie Road	RS	32.9	0	99.5
Edinburgh Queen Street	RS	26.3	0	48.9
Edinburgh Queensferry Road	RS	42.3	0	82.9
Edinburgh Salamander St	RS	26.6	0	91.9
Edinburgh St John's Road	KS	53.4	5	96.9
Edinburgh St Leonards	UB	20.1	0	64.3
Eskdalemuir	R	2.0	0	97.0
Falkirk Grangemouth MC	UB	20.5	0	82.0
Falkirk Haggs	RS	34.3	6	82.2
Falkirk Hope St	RS	22.5	0	98.1
Falkirk Main St Bainsford	RS	23.8	1	87.0
Falkirk West Bridge Street	RS	37.5	0	84.3
Fife Cupar	RS	31.5	0	95.3
Fife Dunfermline	RS	24.4	0	89.9
Fife Kirkcaldy	RS	17.4	0	83.1
Fife Rosyth	RS	25.3	0	89.9
Fort William	S	10.1	0	88.4
Glasgow Anderston	UB	20.3	0	92.9
Glasgow Burgher St.	RS	33.4	0	82.2
Glasgow Byres Road	RS	37.6	2	94.5
Glasgow Dumbarton Road	RS	45.5	3	91.8
Glasgow Great Western Road	RS	32.3	0	93.2
Glasgow High Street	RS	33.7	6	90.2
Glasgow Kerbside (Hope Street)	KS	64.9	4	99.1
Glasgow Townhead	UB	26.0	2	98.1
Glasgow Waulkmillglen Reservoir	R	11.2	0	92.7

Site Name	Type	Annual Average NO_2 2016 (µg m^{-3})	No. hours >200 µg m^{-3}	Data capture NO_2 2016 (%)
Grangemouth	UI	16.0	0	91.8
Grangemouth Moray	UB	17.8	0	95.2
Inverclyde Greenock A8	RS	28.1	0	97.5
Inverness	RS	23.9	0	98.7
Inverness Academy Street	RS	36.8	0	32.5
Lerwick	R	3.3	0	79.3
N Lanarkshire Chapelhall	RS	32.0	1	92.7
N Lanarkshire Croy	RS	20.1	0	95.1
N Lanarkshire Moodiesburn	RS	20.7	0	93.7
N Lanarkshire Shawhead Coatbridge	RS	29.7	0	99.3
North Ayrshire Irvine High St	RS	25.0	0	99.5
North Lanarkshire Kirkshaw	RS	33.5	3	98.7
Paisley Gordon Street	RS	29.6	0	99.4
Peebles	S	5.8	0	98.8
Perth Atholl Street	RS	44.8	0	99.0
Perth Crieff	RS	26.0	4	83.5
Perth High Street	RS	23.2	0	94.1
Renfrew Cockels Loan	RS	33.5	0	91.0
South Ayrshire Ayr Harbour	RS	8.3	0	71.6
South Ayrshire Ayr High St	RS	16.4	0	89.2
South Lanarkshire Cambuslang	RS	39.6	12	98.3
South Lanarkshire East Kilbride	RS	33.4	1	67.7
South Lanarkshire Hamilton	RS	42.2	0	42.3
South Lanarkshire Lanark	RS	23.8	0	95.3
South Lanarkshire Raith Interchange 2	RS	30.0	0	66.0
South Lanarkshire Rutherglen	RS	47.7	0	92.0
South Lanarkshire Uddingston	RS	28.6	0	99.7
Stirling Craig's Roundabout	RS	22.9	0	89.0
West Dunbartonshire Clydebank	RS	22.4	0	97.5
West Dunbartonshire Glasgow Road	RS	20.8	0	83.7
West Lothian Broxburn	RS	32.2	0	99.6
West Lothian Linlithgow High Street 2	RS	33.2	0	87.1
West Lothian Newton	RS	23.2	0	71.6

Shaded sites indicate data only available for part year and/or <75% data capture
Highlighted figures (in yellow) indicate exceedances of Scottish Air Quality Objectives
West Dunbartonshire Glasgow Road was referred tp as Dunbarton Roadside in SAQD Annual reports pre 2014

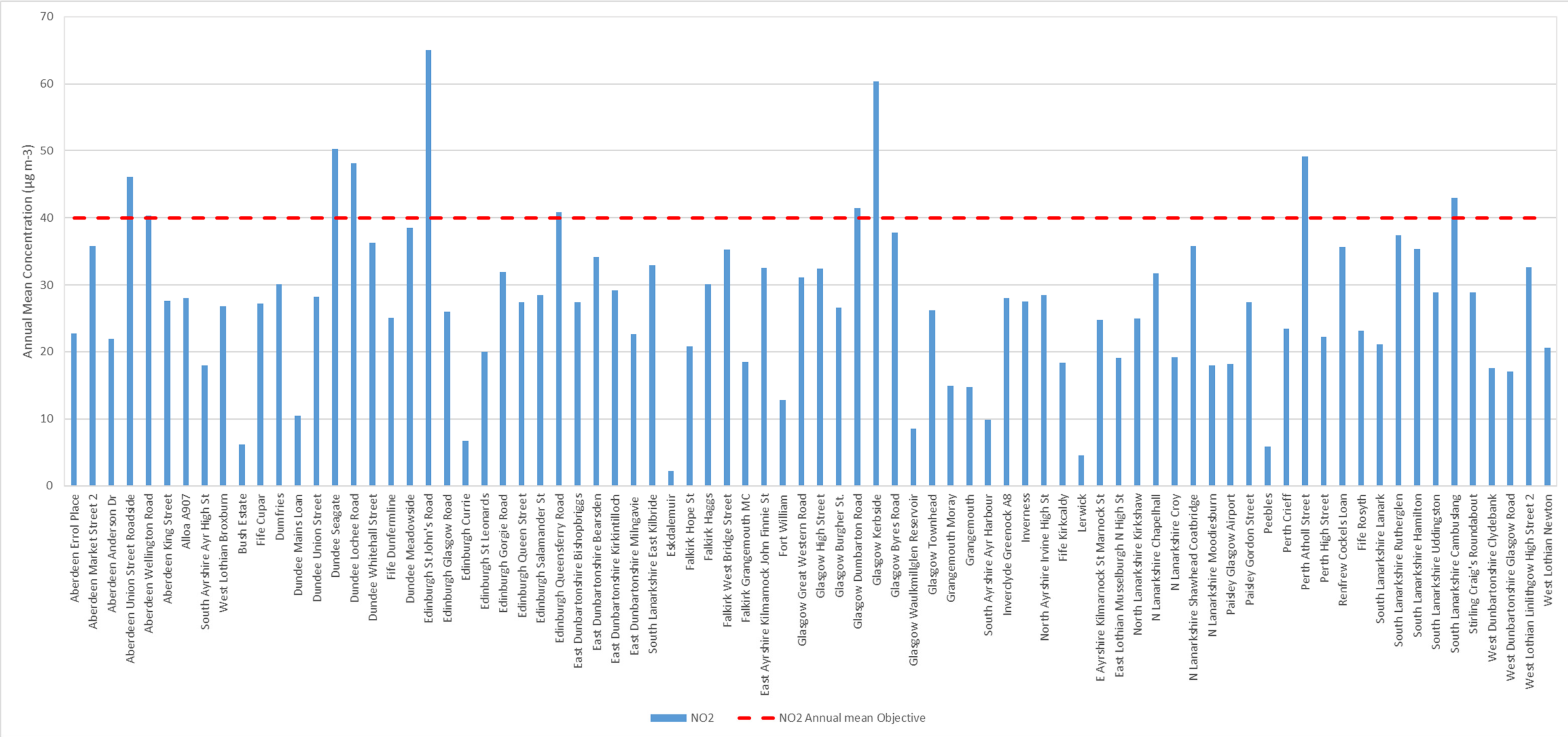
Table 6.1.1 shows NO_2 data for 83 sites utilising automatic monitoring during 2016. Data for 10 of these sites are only available for part of the year with the overall data capture less than 75%. These include sites which opened or closed during the year, and sites which were closed for part of the year due to instrument problems.

Of the remaining 73 sites with data capture 75% or more, 11 of these (kerbside or roadside sites) exceeded the annual mean objective for NO_2 (40 µg m^{-3}). The objective of not more than 18 exceedances of 200 µg m^{-3} for the hourly mean was also exceeded at East Dunbartonshire Bearsden, a Kerbside site.

The highest annual average concentrations were measured at Glasgow Kerbside (Hope Street), with a measured concentration of 64.9 µg m^{-3}. The greatest number of exceedances of the hourly mean objective was measured at East Dunbartonshire Bearsden with 19 exceedances.

Figure 6.1 show NO_2 data for all 83 sites compared against the annual average of objective.

Figure 6.1 Annual Average NO_2 concentrations (µg m^{-3}) for all SAQD sites in 2016



6.1.2 Particulate Matter – PM_{10}

Table 6.2 Ratified data annual average concentration and data capture for PM_{10} in 2016 for monitoring sites in the Scottish Air Quality Database

Site Name	Type	PM_{10} Analyser Type*	Annual Average PM_{10} 2016 ($\mu g\ m^{-3}$)	No. Days > 50 $\mu g\ m^{-3}$	Data Capture (%)
Aberdeen Anderson Dr	RS	VCM	12.2	0	94.4
Aberdeen Errol Place	UB	FDMS	11.8	0	96.3
Aberdeen King Street	RS	BAM (unheated inlet)	16.1	1	89.1
Aberdeen Market Street 2	RS	FIDAS	12.3	1	98.3
Aberdeen Union Street Roadside	RS	FDMS	12.6	0	78.0
Aberdeen Wellington Road	RS	VCM/FIDAS	15.9	2	96.6
Alloa A907	RS	FDMS	15.0	3	68.3
Angus Forfar Glamis Rd	RS	FDMS	10.5	0	86.6
Auchencorth Moss	R	Partisol	5.8	0	71.4
Auchencorth Moss PM10 PM2.5	R	FDMS	7.2	0	77.6
Dundee Broughty Ferry Road	RS	VCM	12.1	0	90.4
Dundee Lochee Road	KS	BAM (unheated inlet)	18.9	2	98.2
Dundee Mains Loan	UB	VCM	10.2	0	67.1
Dundee Meadowside	RS	BAM (unheated inlet)	16.4	3	93.9
Dundee Seagate	KS	BAM (unheated inlet)	13.7	0	85.8
Dundee Whitehall Street	KS	BAM (unheated inlet)	15.1	1	85.8
E Ayrshire Kilmarnock St Marnock St	RS	FIDAS	14.3	0	86.1
East Dunbartonshire Bearsden	RS	Eberline (heated inlet)	13.8	0	97.1
East Dunbartonshire Bishopbriggs	RS	Eberline (heated inlet)	14.9	0	95.0
East Dunbartonshire Kirkintilloch	RS	FDMS/FIDAS	16.2	0	84.5
East Dunbartonshire Milngavie	RS	FDMS	12.9	0	96.5
East Lothian Musselburgh N High St	RS	BAM (unheated	10.3	0	90.6
Edinburgh Currie	UB	VCM	9.2	0	97.9
Edinburgh Glasgow Road	RS	VCM	15.1	0	84.5
Edinburgh Queen Street	RS	TEOM	13.2	0	49.4
Edinburgh Queensferry Road	RS	FDMS	19.4	0	77.5
Edinburgh Salamander St	RS	VCM	16.5	0	97.6
Edinburgh St John's Road	UB	FIDAS	15.0	1	6.8
Edinburgh St Leonards	UB	FDMS	10.7	0	78.7
Falkirk Banknock	RS	FIDAS	10.5	3	83.4
Falkirk Graham's Road	RS	VCM	13.0		95.2
Falkirk Grangemouth MC	UB	VCM	12.8	0	89.8
Falkirk Haggs	RS	VCM	14.0	0	95.7
Falkirk Main St Bainsford	RS	VCM	12.0	0	41.4
Falkirk West Bridge Street	RS	VCM/FIDAS	15.0	0	98.4
Fife Cupar	RS	FIDAS	14.9	0	91.3

Site Name	Type	PM_{10} Analyser Type*	Annual Average PM_{10} 2016 ($\mu g\ m^{-3}$)	No. Days > 50 µg m^{-3}	Data Capture (%)
Fife Dunfermline	RS	FDMS/FIDAS	12.8	1	81.5
Fife Kirkcaldy	RS	FIDAS	9.5	0	83.1
Fife Rosyth	RS	FIDAS	10.3	1	89.8
Glasgow Abercromby Street	RS	FDMS	13.6	0	94.1
Glasgow Anderston	UB	FDMS	15.3	0	68.7
Glasgow Broomhill	RS	FDMS	14.7	2	92.8
Glasgow Burgher St.	RS	FDMS	15.6	0	72.7
Glasgow Byres Road	RS	FDMS	11.5	2	97.6
Glasgow Dumbarton Road	RS	VCM	15.4	0	97.7
Glasgow High Street	RS	FDMS	13.1	0	93.0
Glasgow Nithsdale Road	RS	FDMS	12.8	0	91.0
Glasgow Townhead	UB	FDMS	11.9	0	97.1
Glasgow Waulkmillglen Reservoir	R	VCM	9.4	0	64.5
Grangemouth	UI	FDMS	10.7	0	94.8
Inverclyde Greenock A8	RS	VCM/FIDAS	10.7	0	94.2
Inverness	RS	Partisol	8.6	0	90.2
N Lanarkshire Chapelhall	RS	VCM	15.1	0	60.7
N Lanarkshire Coatbridge Whifflet	RS	VCM	12.0	0	61.2
N Lanarkshire Croy	RS	VCM	13.4	2	84.9
N Lanarkshire Moodiesburn	RS	BAM (unheated inlet)	11.0	2	81.9
N Lanarkshire Motherwell	RS	VCM	12.9	0	97.3
N Lanarkshire Shawhead Coatbridge	RS	BAM (unheated inlet)	12.5	0	90.7
North Ayrshire Irvine High St	RS	FIDAS	14.5	0	98.9
North Lanarkshire Kirkshaw	RS	BAM (unheated	10.9	0	97.3
Paisley Gordon Street	RS	FDMS	13.9	0	91.3
Paisley St James St	RS	FDMS	13.3	0	99.2
Perth Atholl Street	RS	VCM	17.9	0	94.7
Perth Crieff	RS	BAM (unheated	16.1	0	75.3
Perth High Street	RS	VCM	12.6	0	97.5
Perth Muirton	RS	FDMS	9.8	0	72.6
Renfrew Cockels Loan	RS	FDMS	13.7	1	90.0
South Ayrshire Ayr Harbour	RS	FDMS	13.7	0	47.1
South Ayrshire Ayr High St	RS	FDMS	12.0	0	47.3
South Lanarkshire Cambuslang	RS	FDMS	14.8	0	97.8
South Lanarkshire East Kilbride	RS	FDMS	15.8	0	95.8
South Lanarkshire Hamilton	RS	FDMS	14.8	0	6.3
South Lanarkshire Lanark	RS	FIDAS	11.0	0	99.6
South Lanarkshire Raith Interchange 2	RS	FDMS	17.3	0	52.9
South Lanarkshire Rutherglen	RS	FDMS	17.1	1	94.2
South Lanarkshire Uddingston	RS	FIDAS	8.6	0	94.3
Stirling Craig's Roundabout	RS	VCM	13.0	0	88.7
West Dunbartonshire Clydebank	RS	FIDAS	8.5	0	73.2
West Lothian Broxburn	RS	FDMS	14.8	0	88.2
West Lothian Linlithgow High Street 2	RS	FDMS/FIDAS	14.5	0	75.3

Site Name	Type	PM_{10} Analyser Type*	Annual Average PM_{10} 2016 (µg m^{-3})	No. Days > 50 µg m^{-3}	Data Capture (%)
West Lothian Newton	RS	FDMS	15.1	0	81.9

Highlighted figures (in yellow) indicate exceedance of Scottish Air Quality Objectives
*FDMS data are equivalent to gravimetric and hence are not adjusted
FIDAS data are equivalent to gravimetric and hence are not adjusted
Partisol data are equivalent to gravimetric and hence are not adjusted
BAM (heated inlet) data are adjusted using gravimetric equivalent factor of 0.966
BAM (un-heated inlet) data are adjusted using gravimetric equivalent factor of 0.8333
VCM data are TEOM data corrected using the Volatile Correction Model

Table 6.2 and Figure 6.2 shows the 2016 gravimetric equivalent particulate matter PM_{10} data from 80 sites utilising automatic monitoring and the Partisol daily sampler. Of these sites, 17 have less than 75% data capture. As discussed in Section 4.2.2, all TEOM data have been adjusted using the VCM.

Of the 63 sites with 75% or greater data capture, two sites exceeded the annual average PM_{10} objective of 18 µg m^{-3}: Dundee Lochee Road and Edinburgh Queensferry Road. No site exceeded the daily mean objective of 50 µg m^{-3} not to be exceeded more than 7 times in a year.

The maximum PM_{10} annual mean concentration was measured at Edinburgh Queensferry Road with a measured annual mean concentration of 19.4 µg m^{-3}. Of the 16 sites with less than 75% data capture, no site measured average PM_{10} concentrations greater than the annual average PM_{10} objective of 18 µg m^{-3}. No sites exceeded the UK wideobjective of 40 µg m^{-3} for the annual mean PM_{10} and the daily mean objective of no more than 35 exceedances of 50 µg m^{-3}.

Note that at the rural Auchencorth Moss site south of Edinburgh, both FDMS and Partisol analysers are operated for PM_{10} (and $PM_{2.5}$). The results for both sites are shown in Table 6.2 under the site names of Auchencorth Moss (for measurements using Partisol samplers) and Auchencorth Moss PM_{10} $PM_{2.5}$ (for measurements using FDMS analysers). As can be seen both methods measured similar annual average PM_{10} concentrations of 5.8 µg m^{-3} and 7.2 µg m^{-3}, respectively. No exceedances of the daily objective were measured at the two sites.

6.1.3 Particulate Matter – $PM_{2.5}$

Table 6.3 Ratified data annual average concentration and data capture for $PM_{2.5}$ in 2016 for monitoring sites in the Scottish Air Quality Database

Site Name	Type	$PM_{2.5}$ Analyser Type	Annual Average $PM_{2.5}$ 2016 (µg m^{-3} gravimetric equivalent)	Data Capture (%)
Aberdeen Errol Place	UB	FDMS	5.4	94.9
Aberdeen Market Street 2	RS	FIDAS	6.5	97.9
Aberdeen Union Street	R	FDMS	7.5	77.0
Aberdeen Wellington Road	RS	FIDAS	6.6	27.0
Auchencorth Moss	R	Partisol	3.0	73.5
Auchencorth Moss PM10 PM25	R	FDMS	2.5	87.0
E Ayrshire Kilmarnock St	RS	FIDAS	6.2	35.5
Edinburgh St John's Road	UB	FIDAS	8.0	6.8
Edinburgh St Leonards	UB	FDMS	6.4	92.2
Falkirk Banknock	RS	FIDAS	5.2	83.5
Falkirk West Bridge Street	RS	FIDAS	8.4	13.6
Fife Cupar	RS	FIDAS	8.6	6.6
Fife Dunfermline	RS	FDMS/FIDAS	6.4	32.0
Fife Kirkcaldy	RS	FIDAS	5.4	73.4
Fife Rosyth	RS	FIDAS	6.2	89.8
Glasgow High St	RS	FDMS	8.0	93.9
Glasgow Townhead	UB	FDMS	6.8	96.5
Grangemouth	UI	FDMS	6.4	92.0

Site Name	Type	$PM_{2.5}$ Analyser Type	Annual Average $PM_{2.5}$ 2016 (µg m^{-3} gravimetric equivalent)	Data Capture (%)
Inverness	RS	Partisol	4.7	97.8
Inverclyde Greenock A8	RS	FIDAS	5.0	98.0
North Ayrshire Irvine High St	RS	FIDAS	7.3	98.9
South Ayrshire Ayr Harbour	RS	FDMS	6.3	23.7
South Ayrshire Ayr High St	RS	FDMS	6.6	25.9
South Lanarkshire Lanark	RS	FIDAS	6.7	99.6
South Lanarkshire Uddingston	RS	FIDAS	4.6	94.3
West Dunbartonshire	RS	FIDAS	5.5	73.2
West Lothian Linlithgow High	RS	FIDAS	10.1	9.3

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

For compliance with the EU Directive, three $PM_{2.5}$ urban background monitoring sites are required in Scotland. These have been established as part of the AURN in Edinburgh, Glasgow and Aberdeen. In addition, for research purposes, additional monitors have been installed at the rural site at Auchencorth Moss. Also, with support from the Scottish Government, the daily gravimetric monitoring of $PM_{2.5}$ continues at Inverness. With the introduction of the new $PM_{2.5}$ annual mean objective of 10 µg m^{-3} introduced in April 2016, local authorities have also introduced $PM_{2.5}$ monitoring. During 2016 the number of $PM_{2.5}$ monitoring sites increased from 16 to 27.

Table 6.3 shows the 2016 gravimetric equivalent particulate matter $PM_{2.5}$ data. Data capture rates of less than 75% were measured at 12 sites. $PM_{2.5}$ concentrations in excess of the Scottish objective of 10 µg m^{-3} as an annual mean was not measured at any site. Figure 6.2 shows the 2016 Annual Average $PM_{2.5}$ and PM_{10} concentrations for all SAQD monitoring sites.

At the rural Auchencorth Moss site south of Edinburgh, both FDMS and Partisol analysers are operated for $PM_{2.5}$. No difference in annual mean $PM_{2.5}$ concentrations were measured by the Partisol sampler and FDMS analyser during 2016, with measured annual average $PM_{2.5}$ concentrations of 3 µg m^{-3} by both analysers.

The $PM_{2.5}/PM_{10}$ ratios calculated for each site for the years 2009 to 2016 are shown in Table 6.1.4. The maximum and minimum $PM_{2.5}/PM_{10}$ ratios during 2016 for sites with greater than 75% data capture were calculated at South Lanarkshire Lanark with calculated ratios of 0.60, and Aberdeen Errol Place with a calculated ratio of 0.46.The average ration across for 2016 was calculated to be 0.53. These ratios can be used to calculate an indicative value for $PM_{2.5}$ where no monitoring has been carried out.

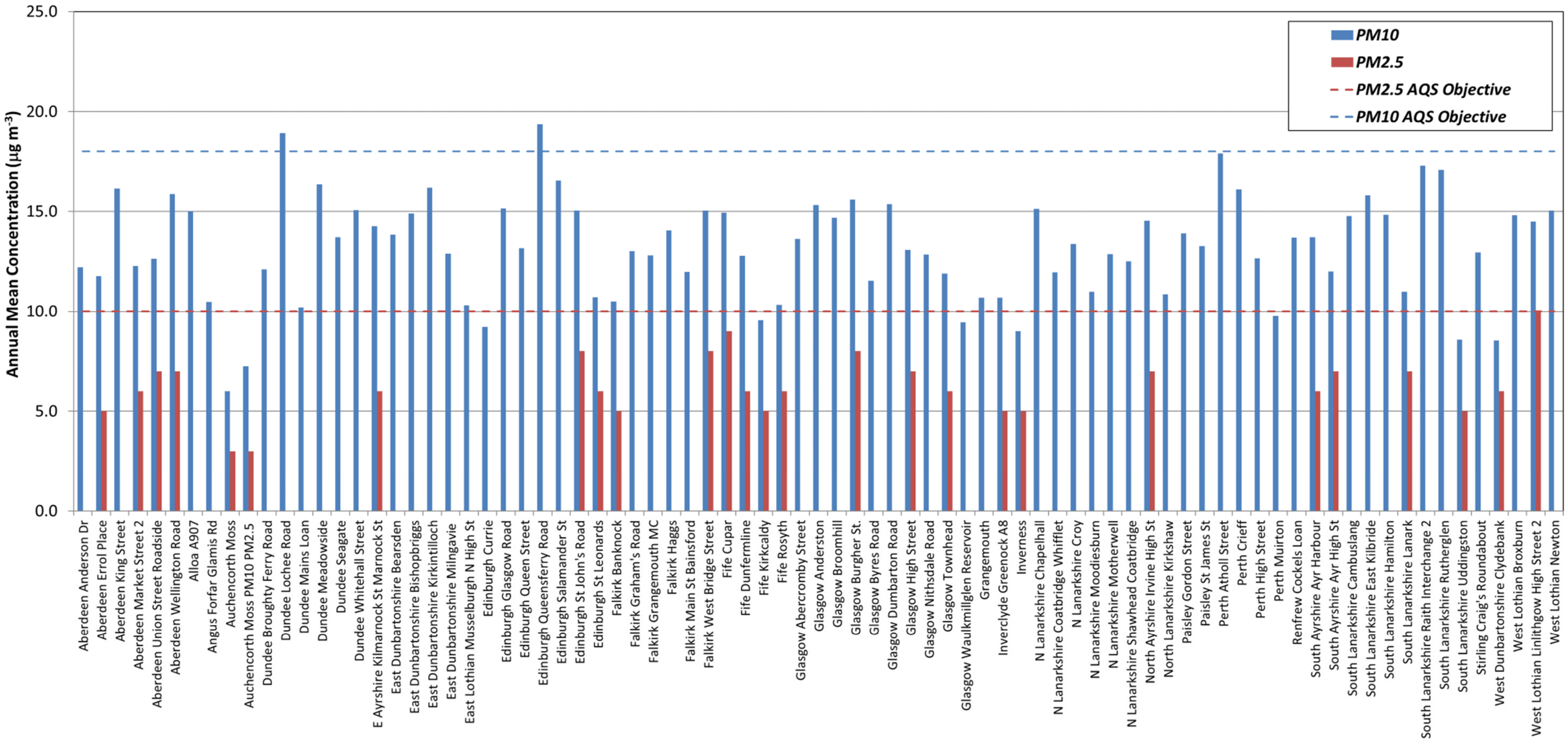
Table 6.4 $PM_{2.5}/PM_{10}$ ratios for 2009 - 2016 annual average concentrations

Site Name	Annual Average PM_{10} 2016 (µg m^{-3})	Annual Average $PM_{2.5}$ 2016 (µg m^{-3})	Ratio							
			2016	2015	2014	2013	2012	2011	2010	2009
Aberdeen Errol Place	11.8	5.4	0.46	0.67	0.67	0.69	0.75	0.57	0.54	0.47
Aberdeen Market Street 2	12.3	6.5	0.53	0.42	-	-	-	-	-	-
Aberdeen Union Street	12.6	7.5	0.59	0.65	0.72	-	-	-	-	-
Aberdeen Wellington Road	15.9	6.6	0.42	-	-	-	-	-	-	-
Auchencorth Moss	6.0	3.0	0.50	0.50	0.57	0.57	0.57	0.71	0.50	0.64
Auchencorth Moss PM10 PM25	7.2	2.5	0.34	0.43	0.88	0.50	0.57	0.50	0.57	0.51

Site Name	Annual Average PM_{10} 2016 (µg m^{-3})	Annual Average $PM_{2.5}$ 2016 (µg m^{-3})	Ratio							
			2016	2015	2014	2013	2012	2011	2010	2009
E Ayrshire Kilmarnock St Marnock St	14.3	6.2	0.43	-	-	-	-	-	-	-
Edinburgh St John's Road	15.0	8.0	0.53	-	-	-	-	-	-	-
Edinburgh St Leonards	10.7	6.4	0.60	0.55	0.69	0.57	0.69	0.80	0.64	0.50
Falkirk Banknock	10.5	5.2	0.50	0.55	-	-	-	-	-	-
Falkirk West Bridge Street	15.0	8.4	0.56	-	-	-	-	-	-	-
Fife Cupar	14.9	8.6	0.58	-	-	-	-	-	-	-
Fife Rosyth	12.8	6.4	0.50	-	-	-	-	-	-	-
Fife Kirkcaldy	9.5	5.4	0.57	-	-	-	-	-	-	-
Fife Rosyth	10.3	6.2	0.60	0.43	-	-	-	-	-	-
Glasgow High St	15.6	8.0	0.51	0.50	-	-	-	-	-	-
Glasgow Townhead	13.1	6.8	0.52	0.58	0.54	0.50	0.83	1.22	0.79	0.81
Grangemouth	11.9	6.4	0.54	0.75	0.67	0.64	0.79	0.79	0.79	0.68
Inverclyde Greenock A8	10.7	5.3	0.50	-	-	-	-	-	-	-
Inverness	9.0	5.0	0.56	0.56	0.55	0.50	0.55	0.50	0.50	0.55
North Ayrshire Irvine High St	14.5	7.3	0.50	0.50	-	-	-	-	-	-
South Ayrshire Ayr Harbour	13.7	6.3	0.46	-	-	-	-	-	-	-
South Ayrshire Ayr High St	12.0	6.6	0.55	-	-	-	-	-	-	-
South Lanarkshire Lanark	11.0	6.7	0.61	0.60	-	-	-	-	-	-
South Lanarkshire Uddingston	8.6	4.6	0.54	0.55	-	-	-	-	-	-
West Dunbartonshire Clydebank	8.5	5.5	0.64	0.60	-	-	-	-	-	-
West Lothian Linlithgow High Street 2	14.5	10.1	0.70	-	-	-	-	-	-	-

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

Figure 6.2 Annual Average PM_{10} and $PM_{2.5}$ concentrations (µg m^{-3}) for all SAQD sites in 2016



6.1.4 Carbon Monoxide

Table 6.5 Ratified data annual average concentration and data capture for CO in 2016 for monitoring sites in the Scottish Air Quality Database

Site Name	Type	Annual Average CO 2016 (mg m^{-3})	Max. Running 8hr Mean CO 2016 (mg m^{-3})	Data Capture (%)
Edinburgh St Leonards	UB	0.17	0	67.7
N Lanarkshire Croy	UB	0.18	0	66.6

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

Table 6.5 shows carbon monoxide was monitored using automatic techniques at two sites during 2016. All monitoring sites achieved the objective for this pollutant.

6.1.5 Sulphur Dioxide

Table 6.6 Ratified data annual average concentration and data capture for SO_2 in 2016 for monitoring sites in the Scottish Air Quality Database

Site Name	Type	Annual Average SO_2 2016 (µg m^{-3})	No. 15 min SO_2 > 266µg m^{-3} 2016	No. 1 hr SO_2 > 350µg m^{-3} 2016	No. 24 hr SO_2 > 125µg m^{-3} 2016	Data Capture (%)
Edinburgh St Leonards	UB	2.4	0	0	0	95.3
Falkirk Bo'ness	UI	1.3	0	0	0	67.3
Falkirk Grangemouth MC	UB	7.4	28	3	2	86.1
Falkirk Grangemouth Zetland Park	UI	0.8	0	0	0	99.5
Falkirk Hope St	RS	3.3	3	0	0	98.1
Glasgow Anderston	UB	2.7	0	0	0	26.5
Grangemouth	UI	3.5	3	0	0	98.1
Grangemouth Moray	UB	6.8	26	1	0	96.6
Shetland Lerwick	R	-	-	-	-	0
N Lanarkshire Croy	RS	2.6	0	0	0	93.4

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

Table 6.6 shows sulphur dioxide data from the 10 sites utilising automatic monitoring for 2016. All sites in Scotland met the requirements for the 15 minute, 1-hour and 24-hour mean objectives SO_2 in 2016. Sites Falkirk Bo'ness and Glasgow Anderston data capture were below 75% at 67.3% and 26.5% respectively. No data at the Shetland Lerwick site was monitored during 2016 due to an analyser fault.

6.1.6 Ozone

Table 6.7 Ratified data annual average concentration and data capture for O_3 in 2016 for monitoring sites in the Scottish Air Quality Database

Site Name	Type	Annual Average O_3 2016 ($\mu g\ m^{-3}$)	No of days with running 8-hr mean >100 ug m^{-3}	Data capture O_3 2016 (%)
Aberdeen Errol Place	UB	47.4	5	99.4
Auchencorth Moss	R	55.9	3	95.7
Bush Estate	R	56.8	7	89.0
Edinburgh St Leonards	UB	45.2	3	97.2
Eskdalemuir	R	54.2	8	98.0
Fort William	S	50.1	4	97.0
Glasgow Townhead	UB	39.1	5	99.2
Glasgow Waulkmillglen Reservoir	R	49.2	6	99.7
Lerwick	R	68.9	5	98.0
Peebles	S	53.0	8	99.1
Strath Vaich	R	67.9	10	86.2

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

Table 6.7 shows ozone data from 11 sites utilising automatic monitoring for 2016. Ozone (O_3) is a secondary pollutant formed by reactions involving other pollutant gases in the presence of sunlight and over several hours; it may persist for several days and be transported over long distances. This means that local authorities have little control over ozone levels in their area. In 2016, the objective of not more than 10 days with a maximum 8 hour running mean greater than 100 $\mu g\ m^{-3}$ was not exceeded at any sites but equaled at Strath Vaich.

6.2 Other pollutants covered by the Air Quality Strategy – PAH (benzo[a]pyrene), Benzene, 1,3-butadiene and Lead

In this section, we present a summary of data from a range of national monitoring networks. Summaries are provided for pollutants covered by the Air Quality Strategy. As some of these networks are based on sampler measurement techniques and subsequent chemical analysis there is often a considerable delay in the availability of data. Hence, in some cases, the latest data available at the time of preparing this report is for 2016. Where other pollutants are also monitored in these networks, these pollutants are listed, but the data are not provided in this report.

6.2.1 PAH Monitoring Network

The UK Monitoring and Analysis Network monitor some 39 Poly Aromatic Hydrocarbon (PAH) species at about 30 sites.

PAH monitoring of the compound benzo[a]pyrene is undertaken to provide data in compliance with the EU Air Quality Directive (Directive 2004/107/EC). An air quality objective for this compound is also set in the Air Quality Strategy. A wide range of other PAH species is also monitored in the particulate phase and in the gaseous phase at some sites, for research purposes. The monthly summary results for all species monitored in the PAH network can be downloaded as spreadsheet summary data from http://uk-air.defra.gov.uk/interactive-map.

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

The PAH monitoring sites in Scotland are shown in Table 6.8. The sites at Edinburgh and Glasgow are co-located with the Edinburgh St Leonards and Glasgow Townhead AURN sites respectively. The Glasgow Centre site was decommissioned in August 2012 and a replacement site, Glasgow Townhead, was commissioned in October 2013. The site at Kinlochleven is located close to the closed aluminium works and the site at Auchencorth Moss is a rural EMEP site as discussed in the automatic hydrocarbon section.

Table 6.8 PAH Monitoring Sites in Scotland

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

Annual average concentrations for Benzo(a)pyrene (B(a)P) for 2015 and 2016 are shown in Table 6.9. As can be seen the Air Quality Objective for B(a)P of 0.25 ng m^{-3} as an annual average or the EU Directive target value of 1 ng m^{-3} was not exceeded at any site in 2015 or 2016.

Table 6.9 Annual Average Benzo(a)Pyrene concentrations for 2015 - 2016 at 4 sites in Scotland

Site	2015 Annual Mean B(a)P Concentration (ng m^{-3})	2016 Annual Mean B(a)P Concentration (ng m^{-3})
Auchencorth Moss	0.022	0.023
Edinburgh St Leonards	0.072	0.077
Glasgow Townhead	0.090	0.090
Kinlochleven	0.218	0.171

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

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

6.2.2 Benzene

Non- automatic hydrocarbon monitoring

Monitoring of benzene is undertaken on a two weekly basis with pumped tube samplers at 34 sites throughout the UK – The UK Non-automatic Hydrocarbon Network. Two of these sites are located in Grangemouth and Glasgow Kerbside (Hope Street) and are co-located with the Grangemouth and Glasgow Kerbside AURN sites. The non-automatic monitoring network provides benzene data for compliance with the EU Air Quality Directive limit value of 5 µg m^{-3} and Scottish objective of 3.25 µg m^{-3} as an annual mean.

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

Results for this site for 2015 and 2016 are provided in Table 6.10.

Table 6.10 Annual Mean Benzene Concentrations in 2015 and 2016 at 2 sites in Scotland in the UK Non-automatic Hydrocarbon Network

Site Name	Annual Mean benzene for 2015 (µg m^{-3})	Annual Mean benzene for 2016 (µg m^{-3})
Glasgow Kerbside (Hope	0.77	0.70

Street)		
Grangemouth	0.73	0.63

6.2.3 Automatic Hydrocarbon Monitoring

Table 6.11 gives the site details for the one automatic hydrocarbon monitoring station in Scotland - Auchencorth Moss; a rural site south of Edinburgh. The data from this site are used to provide data for ozone precursor hydrocarbon species, in compliance with the EU Air Quality Directive (2008/50/EC). In addition, this site is one of the two European Monitoring and Evaluation Programme (EMEP) level II sites (EMEP "supersites") in the UK. The other EMEP supersite is located at Chilbolton in Hampshire. A much wider range of hydrocarbon species is monitored at Auchencorth Moss. However, the rural nature of this site means that often the concentrations are below the detection limit and hence, the data capture is low. Data for the full range of hydrocarbon species monitored at Auchencorth Moss can be downloaded from www.scottishairquality.co.uk.

Table 6.11 Location of Automatic Hydrocarbon monitoring sites in Scotland

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

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

Table 6.12 Annual Average Benzene concentration at Auchencorth Moss in the UK Automatic Hydrocarbon Network, for 2016

Site	2016 Benzene Annual mean concentration (μg m^{-3})	2016 Benzene Maximum running annual concentration (μg m^{-3})	2016 % Data Capture
Auchencorth Moss	0.14	0.21	91

Table 6.10 and 6.12 indicate that it is unlikely that the EU limit value for benzene of 5 μg m^{-3} and the Scottish Objective of 3.25 μg m^{-3} for the annual running mean concentration are unlikely to have been exceeded at Auchencorth Moss during 2016.

6.2.4 1,3-Butadiene

The species 1,3-butadiene is also measured as part of the UK Automatic Hydrocarbon Network at the same sites as for Benzene. Measurements of 1,3-butadiene within the non-automatic hydrocarbon network stopped during 2007.

Table 6.13 Annual Average 1,3-butadiene concentration at Auchencorth Moss in the UK Automatic Hydrocarbon Network, for 2016

Site	2016 1,3-butadiene Annual mean concentration (μg m^{-3})	2016 1,3-butadiene maximum running annual concentration (μg m^{-3})	2016 % Data capture
Auchencorth Moss	0.01	0.01	90

Table 6.13 indicates that it is unlikely that the air quality Objective for 1,3-butadiene of 2.25 μg m^{-3} has been exceeded in Scotland in 2016. There is no EU Directive covering 1,3-butadiene.

6.2.5 Heavy Metals

Lead and a wide range of other metals are monitored in two UK networks – the UK Heavy Metals Monitoring Network (mainly urban sites) and the National Monitoring Network for Heavy Metals (mostly rural sites). The urban network determines airborne particulate concentrations of 15 metals, including the metals lead, nickel, arsenic, cadmium and mercury which are covered by the EU Directive (Directives 2008/50/EC for lead and Directive 2004/107/EC for other metals). The rural network determines the concentration of more than 20 metals both as airborne particulate matter and as deposited material in rainwater samples. Results for all metals monitored in the UK Heavy Metals Monitoring Network and for a selection of metals monitored in the National Monitoring Network for Heavy Metals are available from annual average spreadsheet summaries at https://uk-air.defra.gov.uk/.

6.2.5.1 Rural Heavy Metals

In the National Monitoring Network for Heavy Metals, particles are collected using either single sample or multiple-sample FH95 samplers which draw air through a PM_{10} head at a flow rate of 1 m^3 h^{-1}. Particulate metals are collected on a filter paper for subsequent analysis. The sampling period is normally one week. Rainwater collectors are used to collect samples for rainwater analysis of metals to determine metal deposition.

Details of the two rural sites in Scotland are provided in Table 6.14 and data for the measurement of lead, nickel, arsenic and cadmium in 2016 are provided in Table 6.15.

Table 6.14 Rural Network Metals Monitoring Sites in Scotland

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

Table 6.15 Annual Mean metal concentrations 2016 (Rural Network)

Site	Annual Mean Lead Concentration (ng m^{-3})	Annual Mean Nickel Concentration (ng m^{-3})	Annual Mean Arsenic Concentration (ng m^{-3})	Annual Mean Cadmium Concentration (ng m^{-3})
Auchencorth Moss	1.13	0.25	0.15	0.02
Eskdalemuir	0.79	0.38	0.09	0.02

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

6.3 Discussion of additional pollutants monitored and/or other methods of monitoring

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

1. NO_2 diffusion tube samplers
2. Non- methane Volatile Organic Compounds (NMVOC)
3. Poly aromatic hydrocarbons (PAH)
4. Toxic Organic Micropollutants (TOMPS)
5. Metals (Urban network)
6. Metals (Rural and deposition network)
7. United Kingdom Eutrophying & Acidifying Pollutants Network:

1. The Precipitation Network
2. NO_2 rural diffusion tube Network
3. Acid Gases and Aerosol Network (AGANET)
4. National Ammonia Monitoring Network

6.3.1 NO_2 Diffusion Tube Results

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

6.3.2 Non-Methane Volatile Organic Compounds (NMVOC)

At Auchencorth Moss a much wider range of NMVOCs are monitored to provide ozone precursor pollutant concentrations in compliance with the EU Directive (2008/50/EC). The following compounds are monitored:

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

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

6.3.3 Poly-Aromatic Hydrocarbons (PAH)

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

- Benzo(c)phenanthrene
- Benzo(a)anthracene
- Chrysene
- Cyclopenta(c,d)pyrene
- Benzo(b)naph(2,1-d)thiophene
- Benzo(k)fluoranthene
- Benzo(e)pyrene
- Benzo(a)pyrene
- Perylene
- Indeno(1,2,3-cd)pyrene
- Dibenzo(al)pyrene
- Dibenzo (ae)pyrene
- Dibenzo(ai)pyrene
- Dibenzo(ah)pyrene
- Coronene

- 5-Methyl Chrysene
- Benzo(b+j)fluoranthene
- Dibenzo(ah.ac)anthracene
- Benzo(ghi)perylene
- Cholanthrene
- Dibenzo(al)pyrene

6.3.4 Toxic Organic Micropollutants

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

There were six sites in the TOMPs network during 2016, one in Scotland at Auchencorth Moss.

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

6.3.5 Heavy Metals Network

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

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

6.3.6 United Kingdom Eutrophying & Acidifying Pollutant Network (UKEAP)

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

The UKEAP has four component networks:

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

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

The Air Pollution Identification System[5] (APIS) can be used to identify and search for information on acidification and euthrophication air pollution related issues, including related pollutants and affected habitats/sites.

6.3.7 The Precipitation Network (Precip-Net)

There are 38 sites in PrecipNet at which the chemical composition of precipitation (i.e. rainwater) is measured. Six of the sites, Lochnagar, Llyn Llagi, Scoat Tarn, Loch Chon/Tinker, River Etherow,

[5] http://www.apis.ac.uk/

Beaghs Burn and Crai Reservoir (Head of the Valleys) were specifically located within sensitive ecosystems. The network allows estimates of wet deposition of sulphur and nitrogen chemicals.

Fortnightly precipitation samples are collected at 38 sites throughout the UK, of which 13 are in Scotland (see Appendix 1). Sampling is undertaken using a bulk rainwater collector. The collected rainwater samples are analysed for sulphate, nitrate, chloride, phosphate, sodium, magnesium, calcium, potassium, pH and conductivity.

6.3.8 Rural NO_2 Network (NO_2-Net)

The nitrogen dioxide measurements are made at 24 of the 38 Precip-Net composition sites. Diffusion tubes are used to measure nitrogen dioxide. The tubes are mounted on the upright of the rain collector stand and exposed for four or five week periods throughout each year.

Triplicate nitrogen dioxide diffusion tube measurements are run at three AURN sites with co-located automatic instruments (Yarner Wood, Harwell and Eskdalemuir). The annual average NO_2 concentration measured at the Eskdalemuir automatic monitoring site was 2 µg m^{-3} in 2016 with a data capture rate of 99%.

Nitrogen dioxide is measured with diffusion tube samplers at nine sites in Scotland. The annual average concentrations measured in 2016 are provided in Table 6.16.

Table 6.16 NO_2 annual average concentrations 2016 at rural monitoring sites

Site	NO_2 (ug m^{-3})	Data Capture (%)
Allt a'Mharcaidh	1.5	91.7
Balquhidder 2	2.5	100
Eskdalemuir	3.0	100
Forsinain 2	2.7	100
Glensaugh	3.1	100
Loch Dee	3.0	91.7
Polloch	1.6	91.7
Strath Vaich	1.2	100
Whiteadder	3.5	100

6.3.9 Acid Gas and Aerosol Network (AGANET)

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

An extension of the CEH DEnuder for Long Term Atmospheric sampling (DELTA) system at the network sites is used to additionally sample gaseous HNO_3, SO_2, HCl and particulate NO^{3-}, SO_4^{2-}, Cl^-, Na^+, Ca^{2+}, Mg^{2+}. The new expanded network includes measurements of gaseous SO_2 and particulate SO_4^{2-} .

The 11 sites in this network located in Scotland are listed in Appendix 1.

6.3.10 National Ammonia Monitoring Network (NAMN)

Established in 1996, the objectives of the network are to quantify temporal and spatial changes in air concentrations and deposition in NH3 and NH4+ (included since 1999) on a long term basis. The monitoring provides a baseline in the reduced nitrogen species (NH_3 + NH_4^+), which is necessary for examining responses to changes in the agricultural sector and to verify compliance with targets set by international agreements.

The 22 sites in this network located in Scotland are listed in Appendix 1.

6.3.11 Volcanic Emissions Network

SEPA operates the Scottish Government funded Volcanic Emissions Network[6]. The monitoring network is specifically designed to detect polluted air mass originating from erupting Icelandic volcanoes, which have the potential to impact on Scotland's air quality.

The network consists of four monitoring stations located in Lewis, Orkney, Tulloch Bridge and Loch of Strathbeg, that are set up to detect ground level sulphur dioxide gas and fine dust resulting from grounding volcanic plumes. The network acts as part of an early warning system, providing information to our health partners and the Scottish Government, enabling them to provide appropriate public health advice and assess potential effects on the Scottish environment.

[6] http://apps.sepa.org.uk/volcanicemissionsnetwork/Index.aspx

7 Air Quality Mapping for Scotland

As part of the Scottish Air Quality Database project, Ricardo Energy & Environment provide mapped concentrations of modelled background air pollutant concentrations on a 1 km x 1 km basis for the whole of Scotland. Modelled roadside air pollutant concentrations are provided for road links in Scotland. The air pollution maps are derived from a combination of:

1. Measurements from Scotland's network of air quality monitoring stations, and
2. Spatially disaggregated emissions information from the UK National Atmospheric Emissions Inventory (NAEI).

They provide estimated pollutant concentrations for the whole of Scotland. The methodology for producing the Scottish maps is based on the UK Pollution Climate Mapping (PCM) approach, used for producing air pollution maps for the whole UK for the purposes of annual compliance reporting to the European Commission.

The PCM methodology has been applied to provide pollution maps of Scotland for the Scottish Government for 2014 (the most recent year currently 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), and
- NO_X and NO_2.

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

In 2009 AEA undertook a short study[7] on behalf of the Scottish Government which demonstrated that air pollutant source apportionment data and forward-projected concentrations of air pollutants were required for the Scottish pollution maps. These parameters were calculated for 2009, using Scotland-specific data, for use by Scottish local authorities for their Local Air Quality Management Review and Assessment (LAQM) reports. These Scotland-specific air pollutant source apportionment data and forward-projected concentrations of air pollutants for LAQM were subsequently updated to a base year of 2013 and are available at:

http://www.scottishairquality.co.uk/maps.php?n_action=data.

7.1 Update to Air Quality Maps for Scotland 2016

Ricardo are contracted to provide updated mapped concentrations of NO_x, NO_2 and PM_{10} for 2015.

During 2016/17, and at the time of writing this report, there are two versions of the UK 2015 modelling:

3. modelling submitted to the European Commission for the UK compliance assessment in September 2016 (version 2015A)
4. updated modelling for revised UK NO_2 air quality plans, published at the end of July 2017 (version 2015C)

The major difference between the two is that the 2015C model version uses more up-to-date COPERT vehicle emission factors that are more realistic for real world driving (the revised, COPERT 5, emission factors are being used for both NO_2 and PM_{10}, but the impact of the change is much greater for NO_2).

After consultation, the Scottish Government agreed that the best approach for the scheduled 2015 Scottish mapping work would be to use the more up-to-date 2015C modelling being undertaken for the NO_2 Plans, as this incorporates more realistic vehicle emissions. In addition, it is also expected

[7] Stevenson, K., Kent, A.J., and Stedman, J. (2010). Investigation of the possible effect of the use of Scottish specific air quality maps in the LAQM process in four selected Local Authorities. AEA Report AEAT/ENV/R/2948. http://www.scottishairquality.co.uk/documents/reports2/258100203_LA_mapping_Report_Issue_1_FINAL.PDF

that Defra will provide an update to LAQM data (mapped data for all years from the base year to 2030) based on projections from model version 2015C in due course.

In previous years, the Scottish Government updated its version of these data in line with Defra updates. Defra are not expected to update their LAQM data until after September 2017, thereforeScottish local authority data will not be updated until after this time.

Providing maps for Scotland based on version 2015C and not version 2015A will avoid having different versions of maps for the base year modelling to be undertaken now and local authority data to be provided in the future. It should also be note that:

The results of NOx and NO_2 modelling for version 2015C for the base year 2015 and projections to the years 2017-2030 were published at the end of July 2017 to support the air quality plans.[8] At the time of writing this report, the updates to PM maps and LAQM data for version 2015C were not released. As a result, the Scottish Air Quality mapping work has not been completed. Once the relative updates have been released and mapping work completed, this report will be amended as appropriate.

For reference, the details of the methodology and full results of the most recent mapping study are provided in a separate report[9] and can be found at:

http://www.scottishairquality.co.uk/assets/documents/ScottishAQmapping2014_final.pdf

[8] https://www.gov.uk/government/publications/air-quality-plan-for-nitrogen-dioxide-no2-in-uk-2017
[9] Rose R.A. (2016). Scottish Air Quality Maps. Pollutant modelling for 2014: annual mean NO_X, NO_2, and PM_{10}.
http://www.scottishairquality.co.uk/news/reports?view=technical&id=525

8 Air Quality Trends for Scotland

This section of the report summarises how air quality in Scotland has changed in recent years. It focuses on those pollutants for which not all monitoring stations (or sites) in Scotland currently meet the Air Quality Strategy objectives. These pollutants are nitrogen dioxide, particulate matter and ozone.

Automatic monitoring of oxides of nitrogen and of ozone has been routinely carried out in Scotland since 1987, with automatic PM_{10} monitoring carried out since the 1990s. However, until 2000 there were relatively few automatic monitoring sites. Subsequent years have seen the number of monitoring sites in the Scottish Air Quality database increase from 20 sites (in 2000) to the current total of 95 sites (as of April 2017). The data produced by these monitoring sites have improved our understanding of Scotland's pollution climate. However, the increase in site numbers potentially complicates the investigation of trends in air quality. If trend investigation is based on all available data, the apparent trends we see may not reflect real changes in Scotland's air quality; instead, they may be due to the changes in the number of sites (and their distribution). Therefore, in reports in this series from 2010 onwards, investigation of trends has been based on subsets of long-running sites.

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

The trend analysis presented in this section has been carried out using Openair: a free, open-source software package of tools for analysis of air pollution data. Openair was initially developed with Natural Environment Research Council (NERC) funding[10]. The Openair project is led by Dr David Carslaw, of Ricardo Energy & Environment and the University of York. A range of Openair tools are available on the Air Quality in Scotland website; for more information on the tools and how to use them, please see:
http://www.scottishairquality.co.uk/openair/openair.php

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

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

8.1 Nitrogen Dioxide

In Scotland (as elsewhere in the UK) the largest number of Air Quality Management Areas (AQMAs) has been declared in response to exceedances of objectives for nitrogen dioxide (NO_2). This is also reflected in the number of monitoring stations reporting exceedances for this pollutant (see Section 6 of this report). In particular, the objective of 40 $\mu g\ m^{-3}$ for annual mean NO_2 concentration is the most widely exceeded. It is therefore important to understand how concentrations of this pollutant are varying with time.

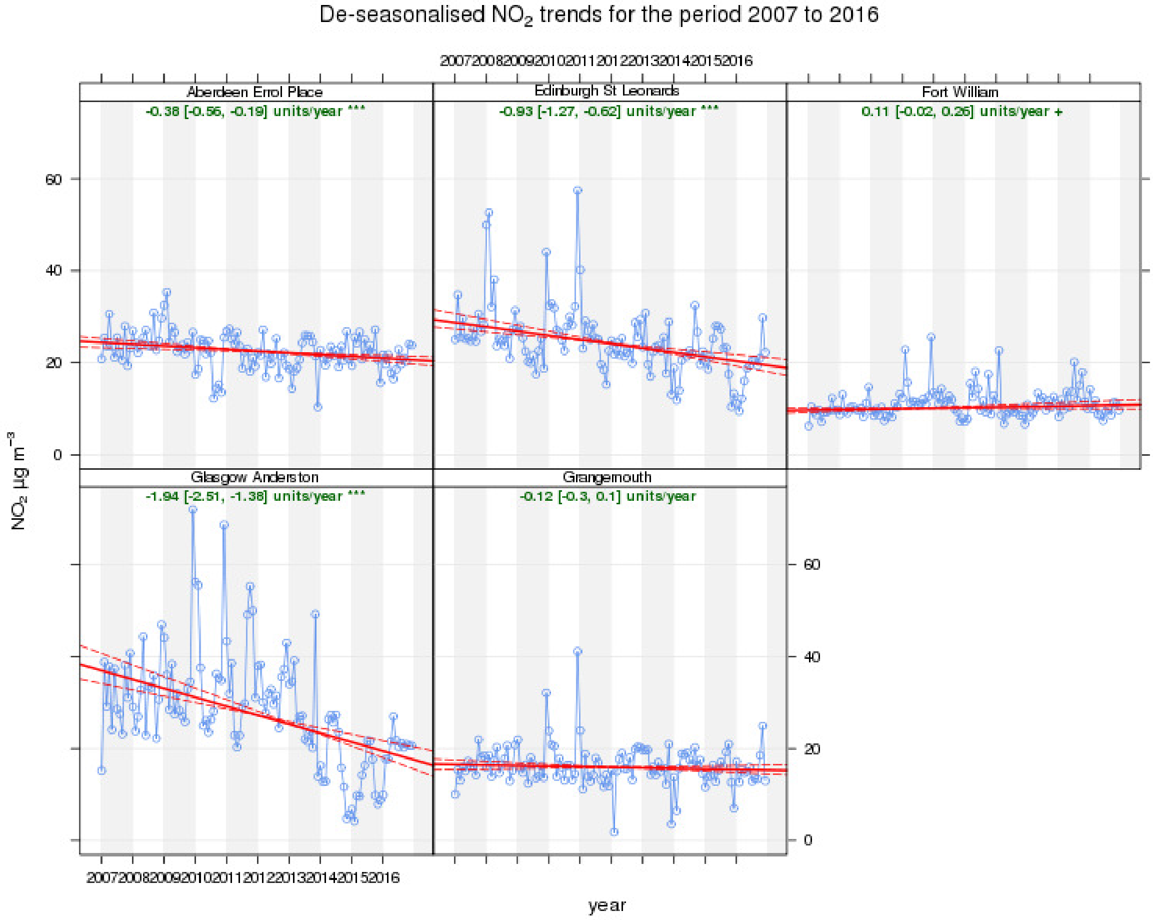
[10] Carslaw, D.C. and K. Ropkins, (2012). Openair — an R package for air quality data analysis. *Environmental Modelling & Software*. Volume 27-28, pp 52-61.

8.1.1 NO_2 at Urban Background Sites

There are relatively few long-running urban background monitoring stations in Scotland. Five urban non-roadside sites have been in operation for the past 10 years, 2007-2016.These are as follows: Aberdeen Errol Place, Edinburgh St Leonards, Fort William, Glasgow Anderston and Grangemouth. Fort William is classified as a ‘suburban’ site, Grangemouth is an ‘urban industrial’ site, and the other three are ‘urban background’.

The Openair Theil-Sen function has been used to quantify trends in NO_2 at these five urban non-roadside monitoring stations, over the 10-year period 2007-2016: the trend plots for NO_2 are shown in Figure 8-1. *Please note that both Edinburgh St Leonards and Glasgow Anderston have large gaps in their 2014 and 2015 datasets: as stated above, where there are gaps in the data, Openair fills these in using an interpolation method*. Aberdeen Errol Place, Edinburgh St Leonards and Glasgow Anderston showed highly significant negative trends (at the 0.001 level). For Fort William, there was a significant *positive* trend in NO_2 at the 0.1 level. At Grangemouth there was a downward trend for NO_2 but it was not statistically significant.

Figure 8-1 Trends in NO_2 Concentration at Five Long-running Urban Non-Roadside Sites, 2007-2016



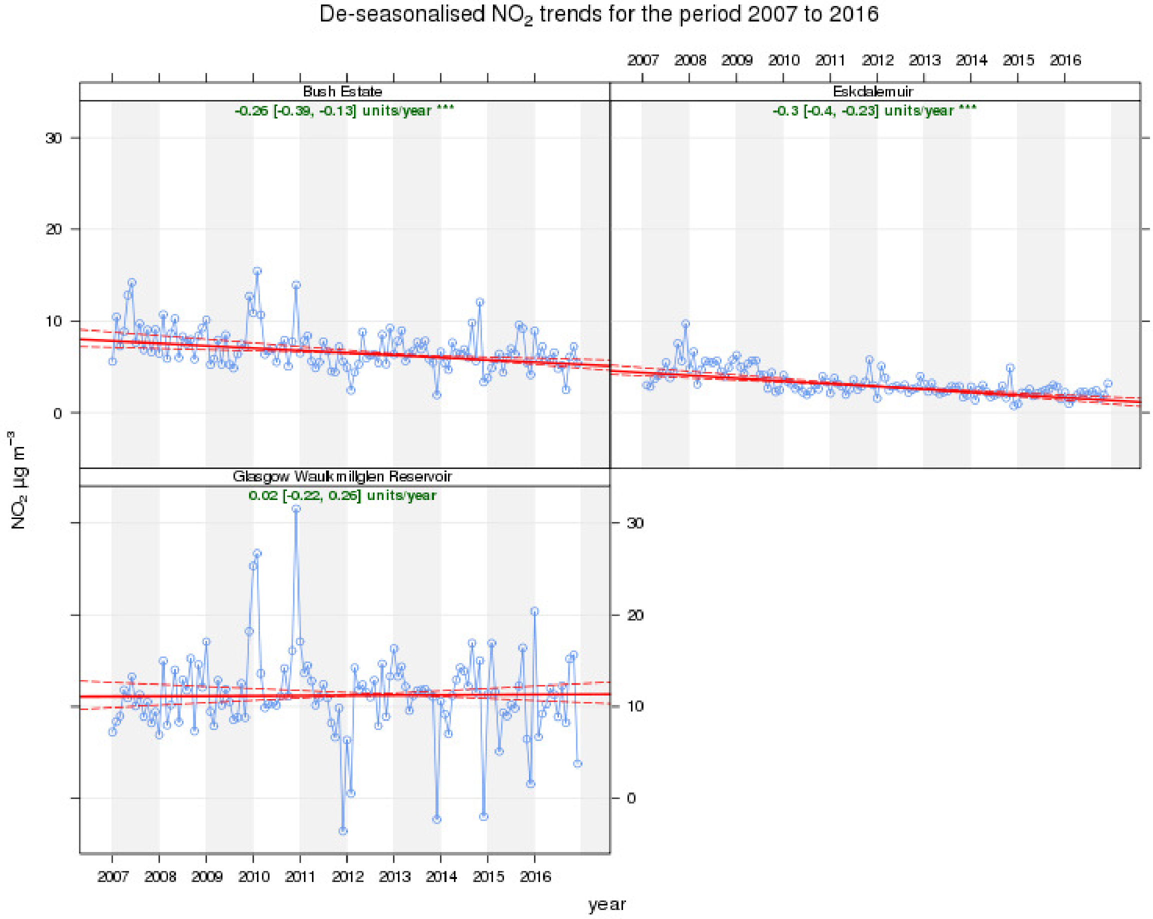
In the previous report in this series (the 2015 edition), trend analysis for urban non-roadside sites was based on only three sites: Aberdeen Errol Place, Edinburgh St Leonards and Grangemouth. The inclusion this year of Fort William and Glasgow Anderston has provided additional information, and in particular the upward trend at Fort William shows that NO_2 concentrations are not decreasing at all urban non-roadside locations.

8.1.2 NO_2 at Rural Sites

There are three long-running rural sites which have monitored oxides of nitrogen for the past 10 years: Bush Estate (to the south of Edinburgh close to the Pentland Hills Regional Park), Eskdalemuir and Glasgow Waukmillglen Reservoir. Figure 8-2 shows trends in NO_2 concentration at these sites.

The sites at Bush Estate and Eskdalemuir showed small but highly significant downward trends. However, this was not the case for Glasgow Waukmillglen Reservoir, where – by contrast - concentrations were increasing very slightly year-on-year, though the trend was not significant.

Figure 8-2 Trends in NO_2 Concentration at Three Rural Sites, 2007 – 2016



8.1.3 NO_2 at Traffic-related Urban Sites

Recent years have seen a substantial increase in the number of monitoring stations at urban traffic-related sites in Scotland. There are now 19 roadside or kerbside monitoring stations that have been in operation for 10 years or more, and are still in operation. These are as follows:

- Aberdeen Anderson Drive
- Aberdeen Union Street
- Dumfries
- Dundee Lochee Road
- Dundee Seagate
- Dundee Whitehall Road
- East Dunbartonshire Bearsden
- East Dunbartonshire Bishopbriggs

- Edinburgh Gorgie Road
- Edinburgh Queen Street
- Edinburgh St John's Road
- Fife Cupar
- Falkirk Hope Street
- Glasgow Byres Road
- Glasgow Kerbside (Hope Street)
- Inverness
- Perth Atholl Street
- Perth High Street
- West Dunbartonshire Clydebank.

This is a large number of sites, so for the purposes of this report we have selected nine of the above long-running sites which have measured exceedances of the Air Quality Strategy objective for annual mean NO_2 (40 µg m^{-3}) in recent years (though not necessarily 2016). These are as follows: Aberdeen Union Street, Dundee Lochee Road, Dundee Seagate, Edinburgh Gorgie Road, Edinburgh St John's Road, Glasgow Byres Road, Glasgow Kerbside (Hope Street), East Dunbartonshire Bearsden and Perth Atholl Street.

Figure 8-3 shows the trend plot. Six of the nine sites (Aberdeen Union Street, Dundee Lochee Road, Edinburgh Gorgie Road, Edinburgh St John's Road, Glasgow Kerbside and Perth Atholl Street) showed downward trends in NO_2 concentration which were highly significant (at the 0.001 level). However, this was not the case at every site – at Glasgow Byres Road the trend was significant only at the 0.05 level; and Dundee Seagate and East Dunbartonshire Bearsden showed no significant trends.

Trends over the most recent five complete years, 2012 – 2016, have also been examined for these sites. These are shown in Figure 8-4. Comparing the ten-year and five-year trends, the patterns differ from site to site: Aberdeen Union Street, Dundee Lochee Road, Dundee Seagate, Edinburgh Gorgie Road and Glasgow Byres Road show downward trends that have become greater, more statistically significant, or both, during the past five years. However, by contrast the other four sites – East Dunbartonshire Bearsden, Edinburgh St John's Road, Glasgow Kerbside and Perth Atholl Street – downward trends have become smaller or less statistically significant during this more recent period. And in the case of East Dunbartonshire Bearsden and Edinburgh St John's, the trend has changed from negative to positive (although not statistically significant at either site). It is therefore not valid to assume that NO_2 is continuing to improve at all sites; there are clearly some at which it has levelled off.

Figure 8-3 Trends in NO_2 Concentration at Nine Long-running Urban Traffic Sites with Exceedances, 2007-2016

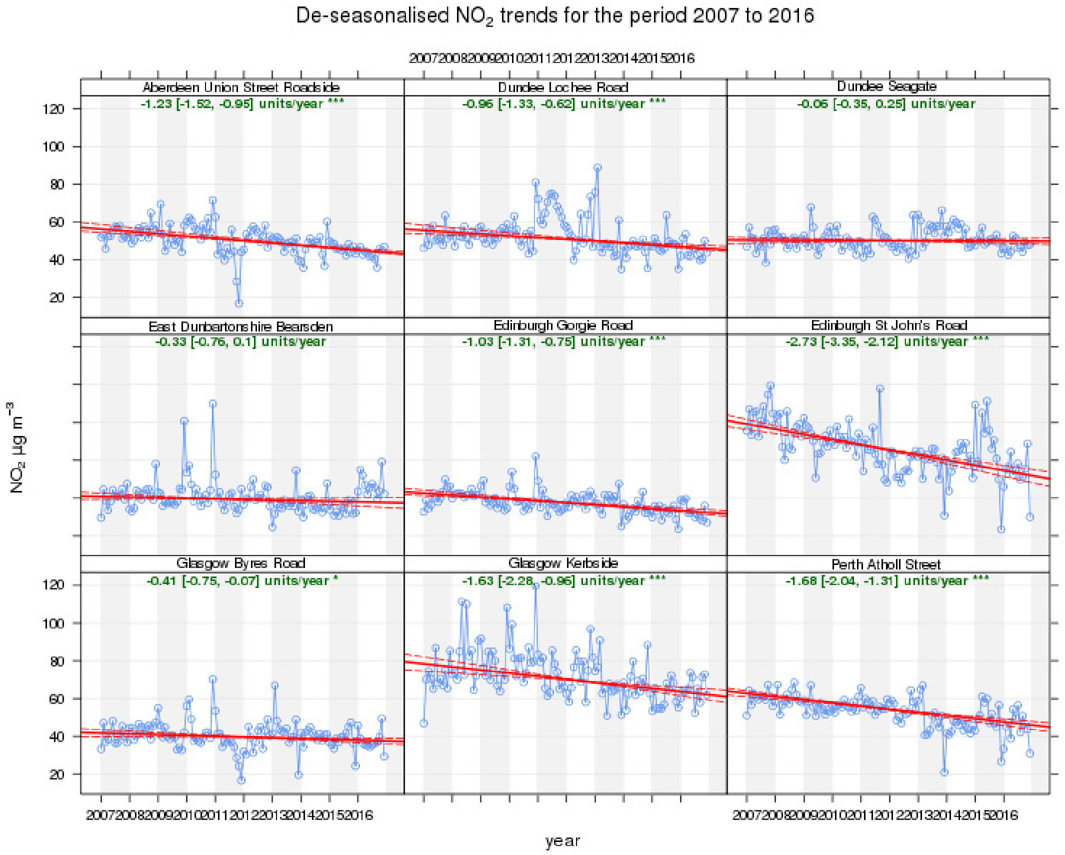
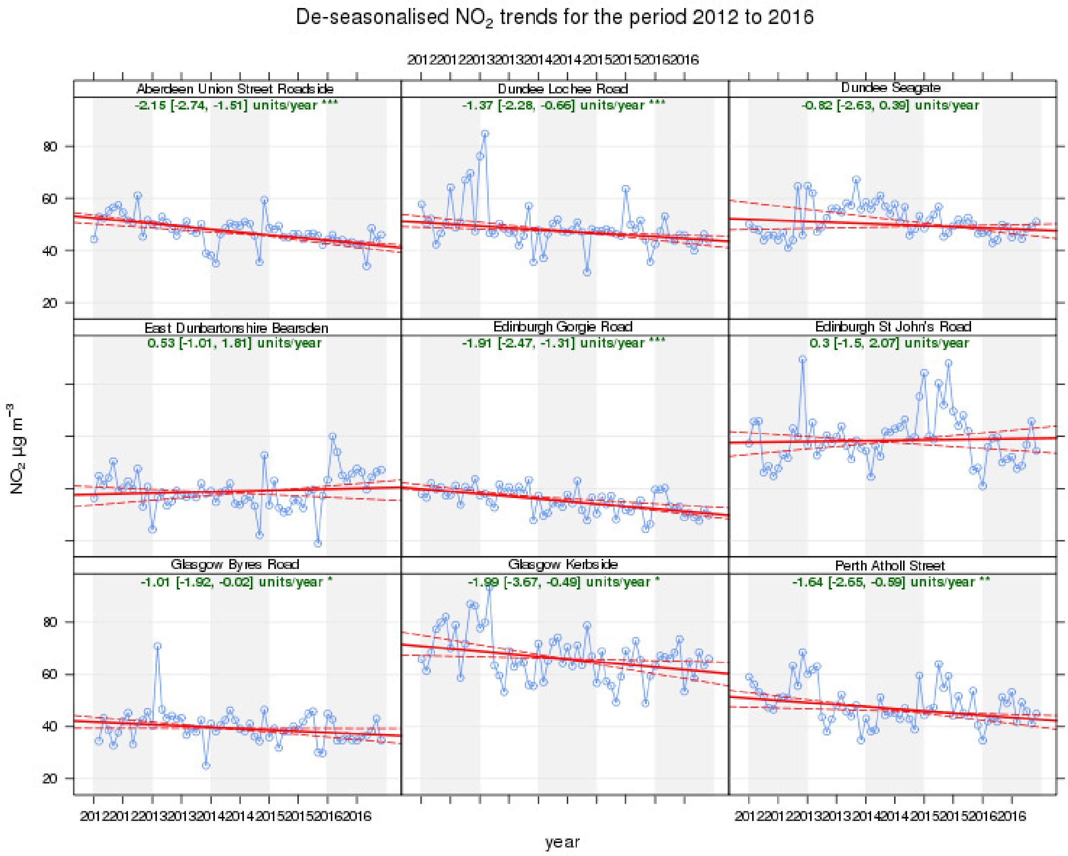


Figure 8-4 Recent Trends in NO_2 Concentration at Nine Long-running Urban Traffic Sites with Exceedances, 2012-2016



8.2 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 value.

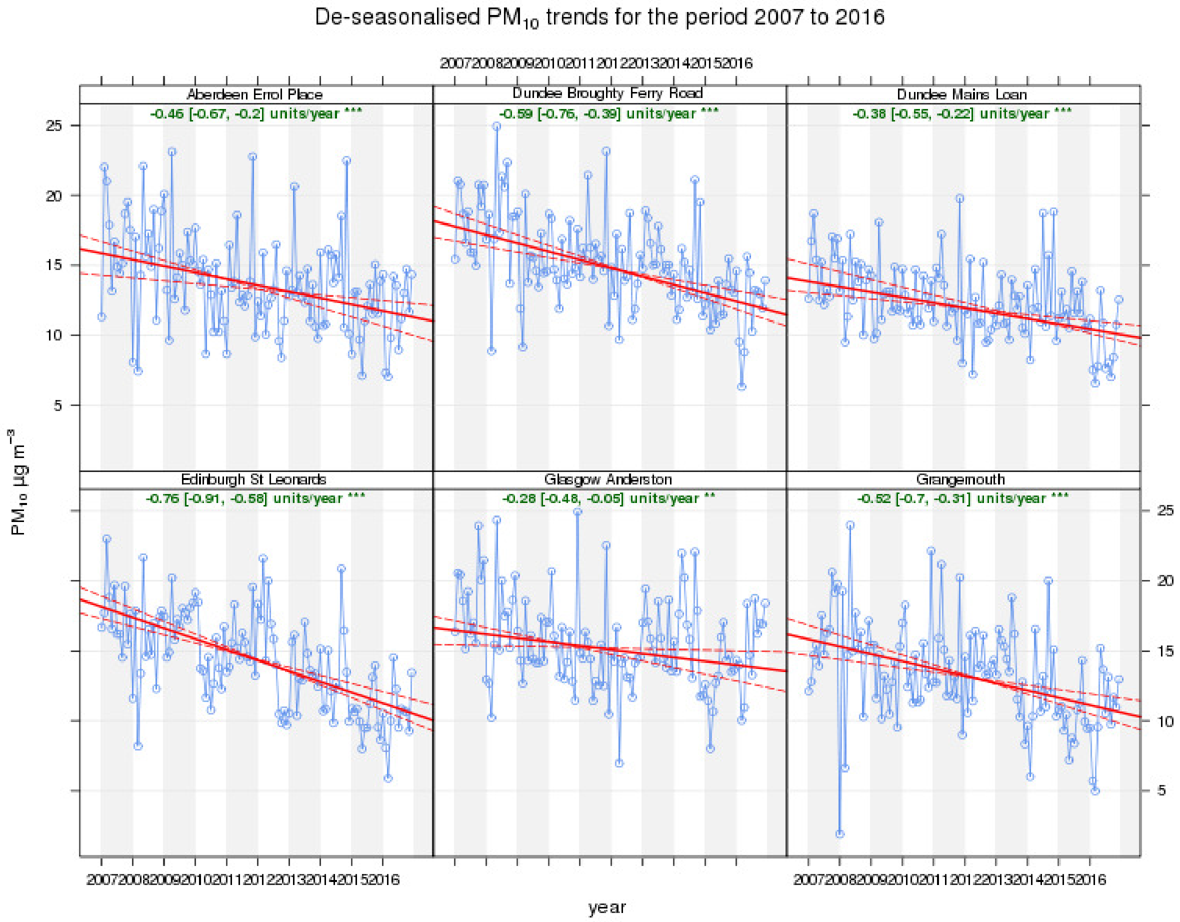
Many of Scotland's monitoring sites use the Tapered Element Oscillating Microbalance (TEOM) to monitor PM_{10}. For the reasons discussed in Section 4, it is necessary to correct TEOM data for possible evaporation of the volatile component (due to the high operating temperature of the TEOM, necessary to prevent condensation on the filter). For a number of years up to and including 2008 the conventional way of doing this was to apply a factor of 1.3 to the data, and the data presented here for those years have been adjusted in this way. However, in 2009 a better correction method became available: The King's College Volatile Correction Model (VCM), which can be found at http://www.volatile-correction-model.info/ . This model uses measurements from nearby FDMS-TEOM instruments (which measure both the volatile and non-volatile fraction) to calculate and apply a correction to the daily or hourly dataset. This is now the recommended method, and has been used for the data presented here for years 2009 onwards, from sites where the TEOM is used.

8.2.1 PM_{10} at Urban Background Sites

There are now six urban non-roadside sites in Scotland that have been monitoring PM_{10} for ten years or longer. These are: Aberdeen Errol Place (TEOM, converted to FDMS in 2009), Dundee Broughty Ferry Road (TEOM, data VCM corrected), Dundee Mains Loan (TEOM, data VCM corrected) Edinburgh St Leonards (FDMS since 2007), Glasgow Anderston (FDMS since 2011), and Grangemouth (FDMS since 2009). Dundee Broughty Ferry Road and Grangemouth are urban industrial; the rest are urban background.

Figure 8-5 shows trends in de-seasonalised monthly mean PM_{10} at this subset of long-running sites. All six sites showed a negative trend, significant at the 0.001 level for all except Glasgow Anderston where it was significant at the 0.01 level.

Figure 8-5 Trends in PM_{10} Concentration at Six Long-Running Urban Background and Urban Industrial Sites, 2007 – 2016



8.2.2 PM_{10} at Urban Traffic Sites

Trends in de-seasonalised monthly mean PM_{10} concentrations for nine traffic-related sites in operation since 2007 or earlier are shown in Figure 8-6. These are the long-running Aberdeen Anderson Drive, Aberdeen Union Street, East Dunbartonshire Bearsden, East Dunbartonshire Bishopbriggs, Edinburgh Queen Street, Fife Cupar, Glasgow Byres Road, Perth Atholl Street and Perth High Street. (West Dunbartonshire Clydebank started up in 2007 but has not been included because it has no PM_{10} data between 2012 and mid-2015.) All nine sites showed 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.

Trends in de-seasonalised monthly mean PM_{10} concentrations for the same nine sites, for the most recent five complete years 2012 – 2016, are shown in Figure 8-7. At four of the nine sites (the two in Aberdeen, plus Fife Cupar and Perth Atholl Street) the downward trend is stronger or more significant over this more recent period: however, in the remaining five, the downward trend has weakened or become insignificant. As in the case of NO_2, ongoing, targeted efforts are therefore still needed to ensure air quality continues to improve where necessary.

Figure 8-6 Trends in PM_{10} Concentration at Nine Long-Running Urban Traffic Sites, 2007 – 2016

De-seasonalised PM_{10} trends for the period 2007 to 2016

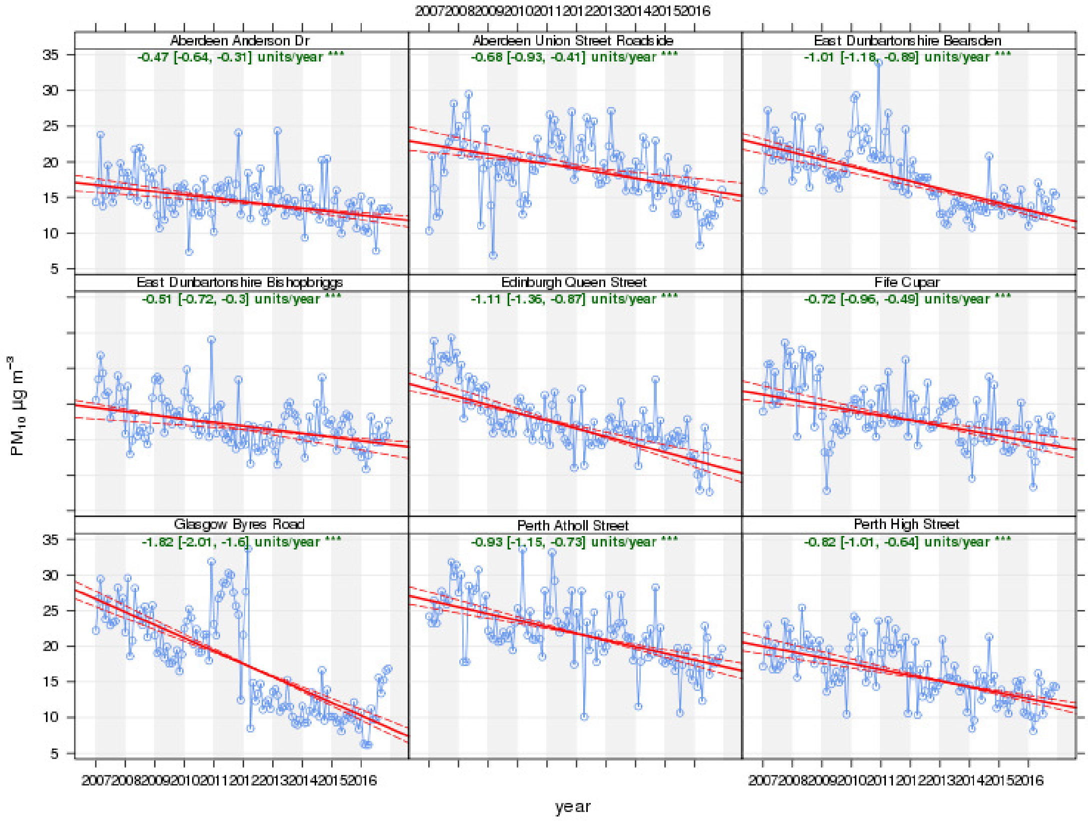
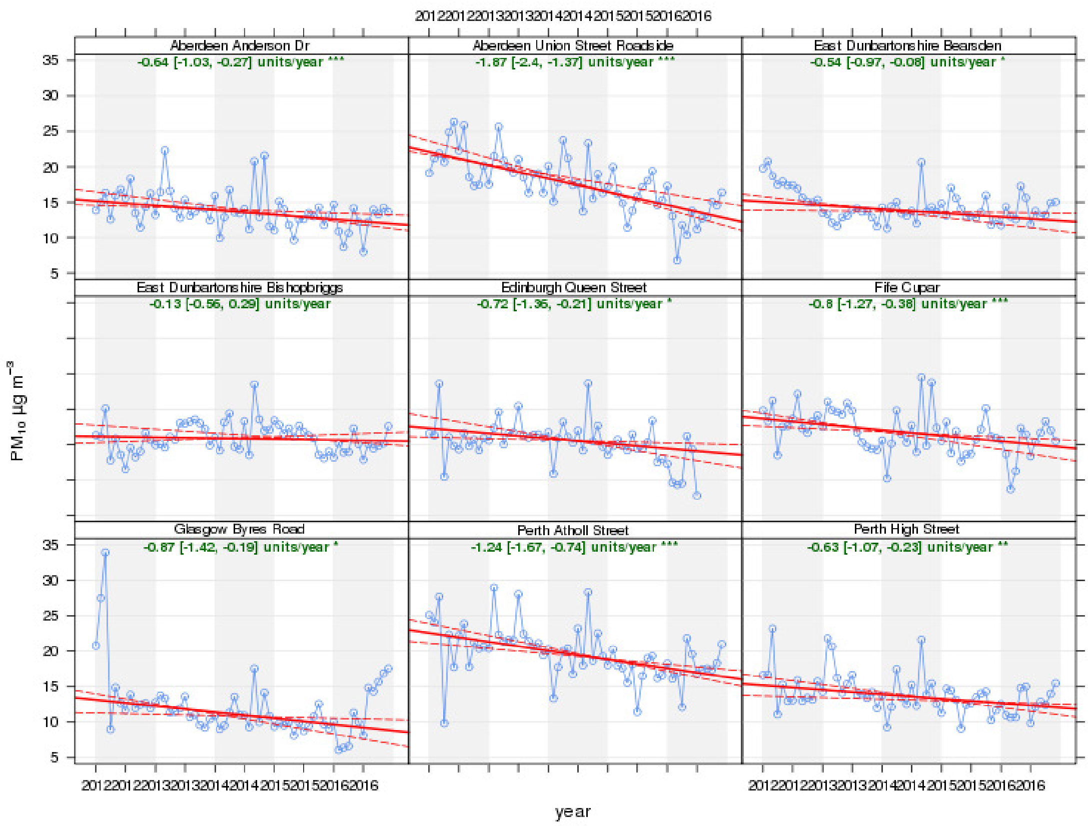


Figure 8-7 Recent Trends in PM_{10} Concentration at Nine Long-Running Urban Traffic Sites, 2012 – 2016

De-seasonalised PM_{10} trends for the period 2012 to 2016



8.2.3 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 2016 there were five 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), Grangemouth (urban industrial) and Inverness (roadside). The trend plot for the first four of these five sites is shown in Figure 8-8: the Inverness data have been plotted separately in Figure 8-9, because this site uses the Partisol gravimetric sampler and therefore only takes daily measurements, not hourly like the other sites. (For Inverness, the full period of $PM_{2.5}$ measurements, from 2008 onwards, is shown in Figure 8-9).

All five of the long-running $PM_{2.5}$ monitoring sites showed a downward trend in this pollutant. However, it was only statistically significant at three of them - Edinburgh St Leonards, Grangemouth and the non-automatic Inverness site. In all three cases, the level of significance was high (0.001 level).

Figure 8-8 Trends in $PM_{2.5}$ Concentration at Four Long-Running Monitoring Sites, 2009 – 2016

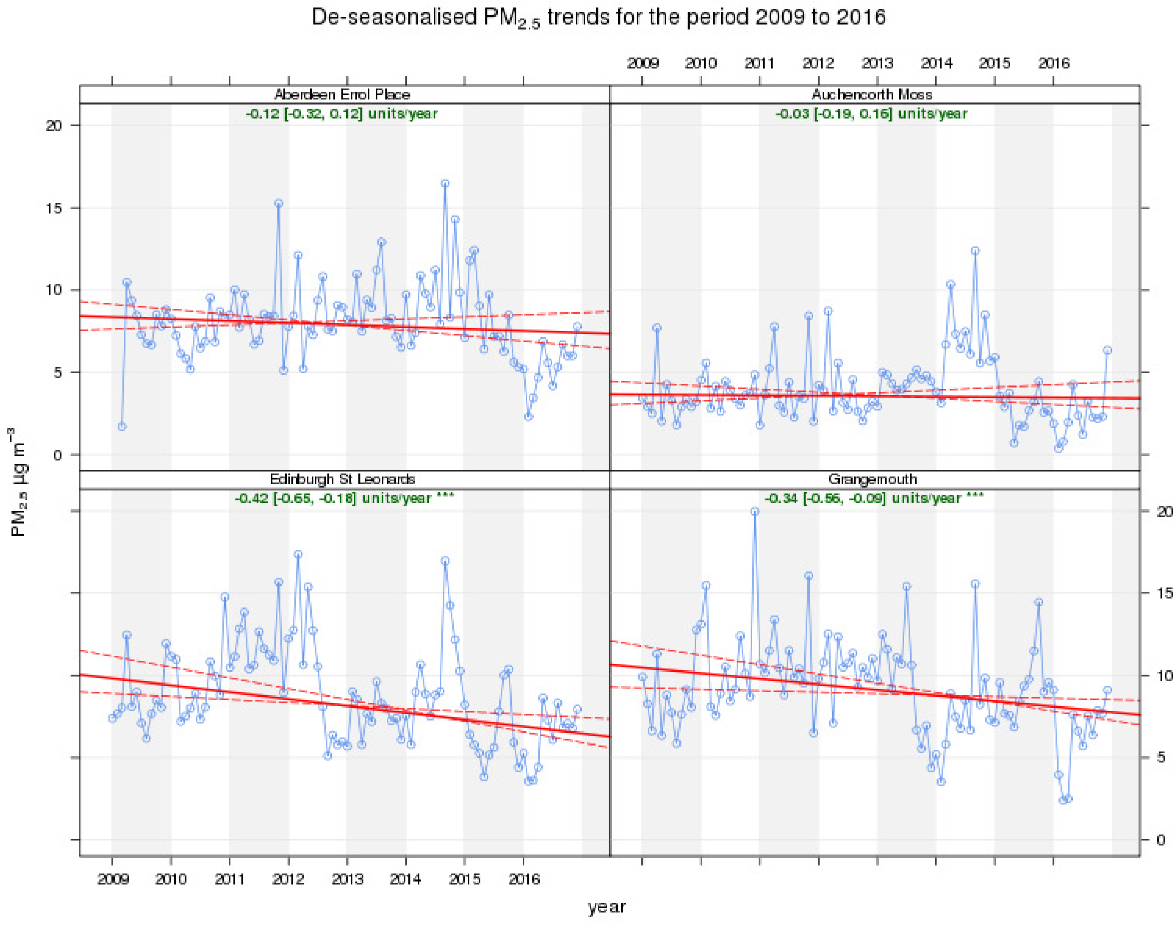
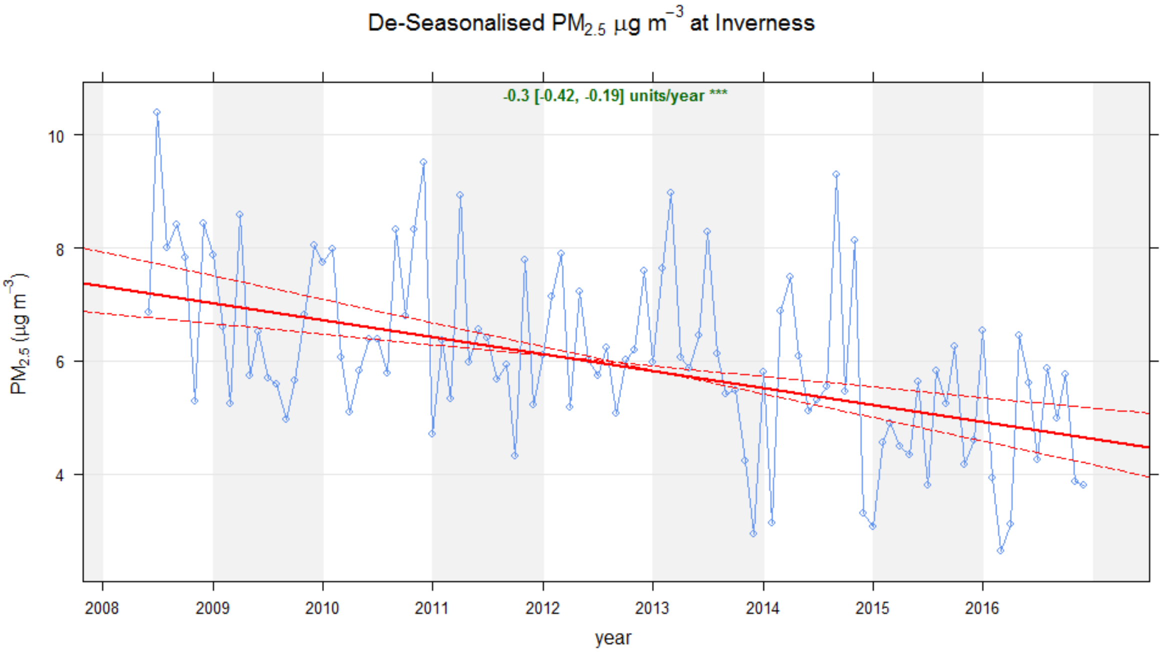


Figure 8-9 Trends in $PM_{2.5}$ Concentration at Inverness (Partisol site), 2008 – 2016



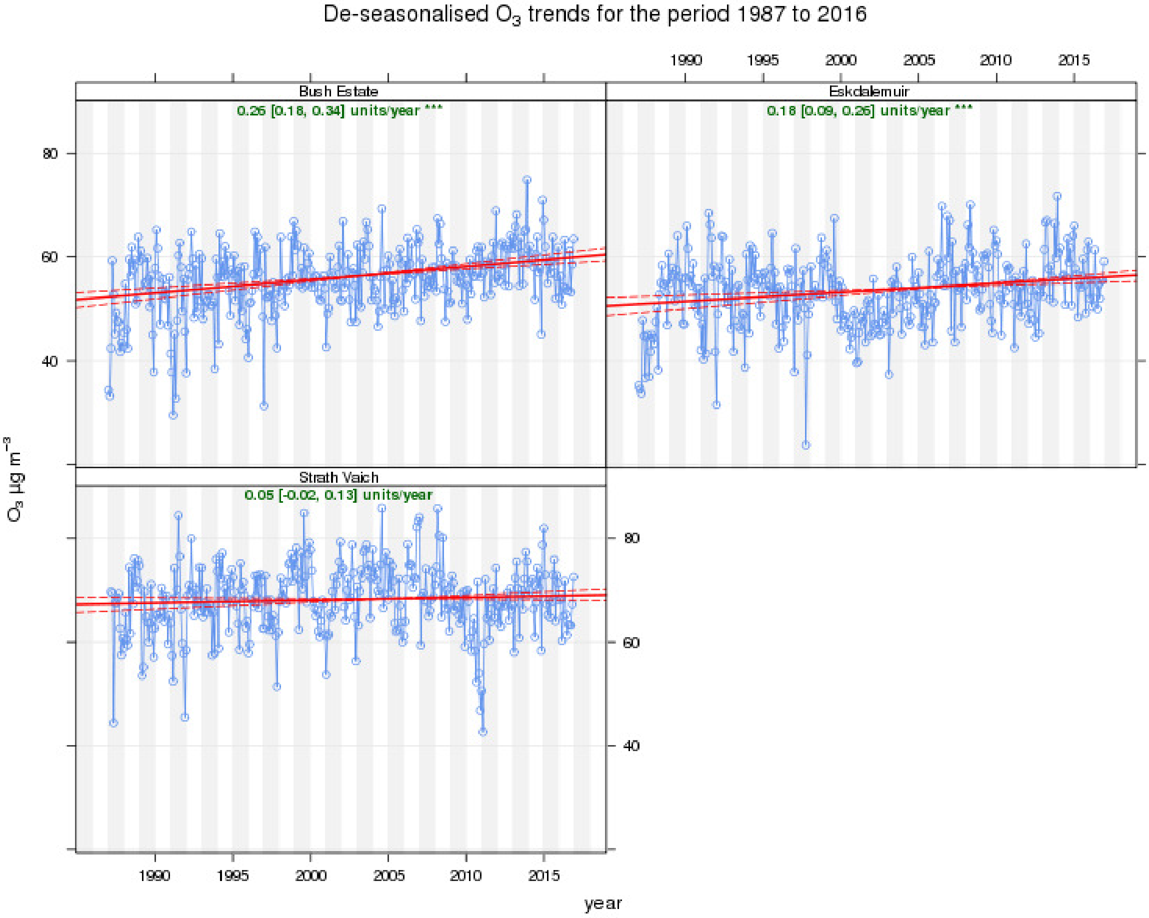
8.3 Ozone

8.3.1 Rural Ozone

Three of Scotland's rural air quality monitoring stations have been monitoring ozone for 30 years, 1987 – 2016. These are Bush Estate, Eskdalemuir and Strath Vaich. Figure 8-10 shows long-term trends in de-seasonalised monthly mean ozone (O_3) concentrations at these three exceptionally long-running rural monitoring sites. All three sites showed a small upward trend in monthly mean rural ozone concentrations over this period. For Bush Estate and Eskdalemuir this trend was statistically significant at the 0.001 level. For Strath Vaich the trend was smaller and was not statistically significant. The charts also show considerable fluctuation; this may reflect the fact that ozone is formed by reactions involving other pollutant gases, in the presence of sunlight. Thus, ozone concentrations depend substantially on weather conditions. There is also evidence that the "hemispheric background" concentration of O_3 has increased since the 1950s due to the contribution from human activities.[11]

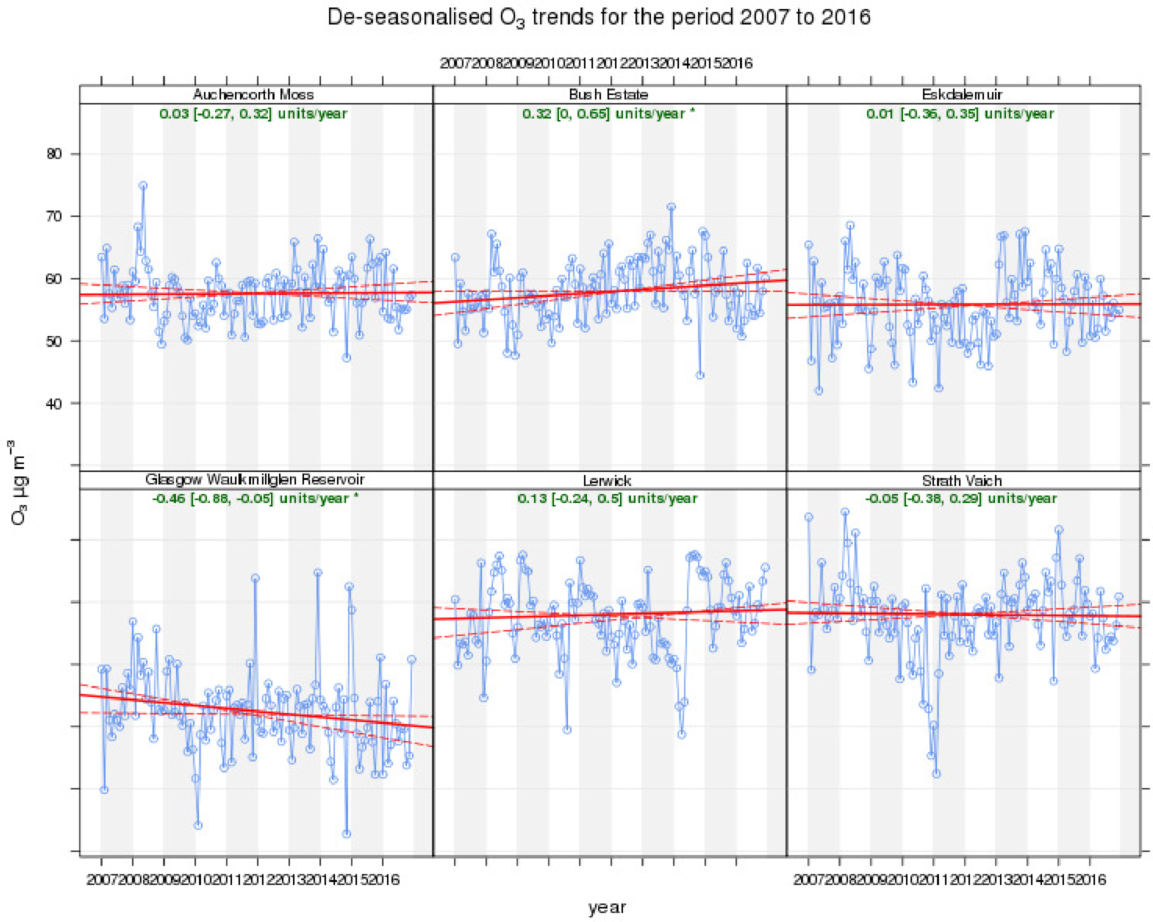
[11] See the APIS webpage "Ozone" at http://www.apis.ac.uk/overview/pollutants/overview_O3.htm

Figure 8-10 Trends in O_3 Concentrations at Long-Running Rural Sites, 1987 – 2016



A larger number of sites have been in operation since 2007 or earlier (i.e., a minimum of 10 years). These are the above three sites, plus Auchencorth Moss, Glasgow Waukmillglen Reservoir and Lerwick. Trends in ozone concentration at these six sites are shown in Figure 8-11. In contrast to the 30-year trends, the 10-year trends were less consistent. Four of the sites showed increasing trends while the other two showed decreasing trends. Only two of the sites showed statistically significant trends over this most recent ten years: positive in the case of Bush Estate, and negative in the case ofGlasgow Waukmillglen Reservoir.

Figure 8-11 Trends in O_3 Concentrations at Six Long-Running Rural Sites, 2007 – 2016



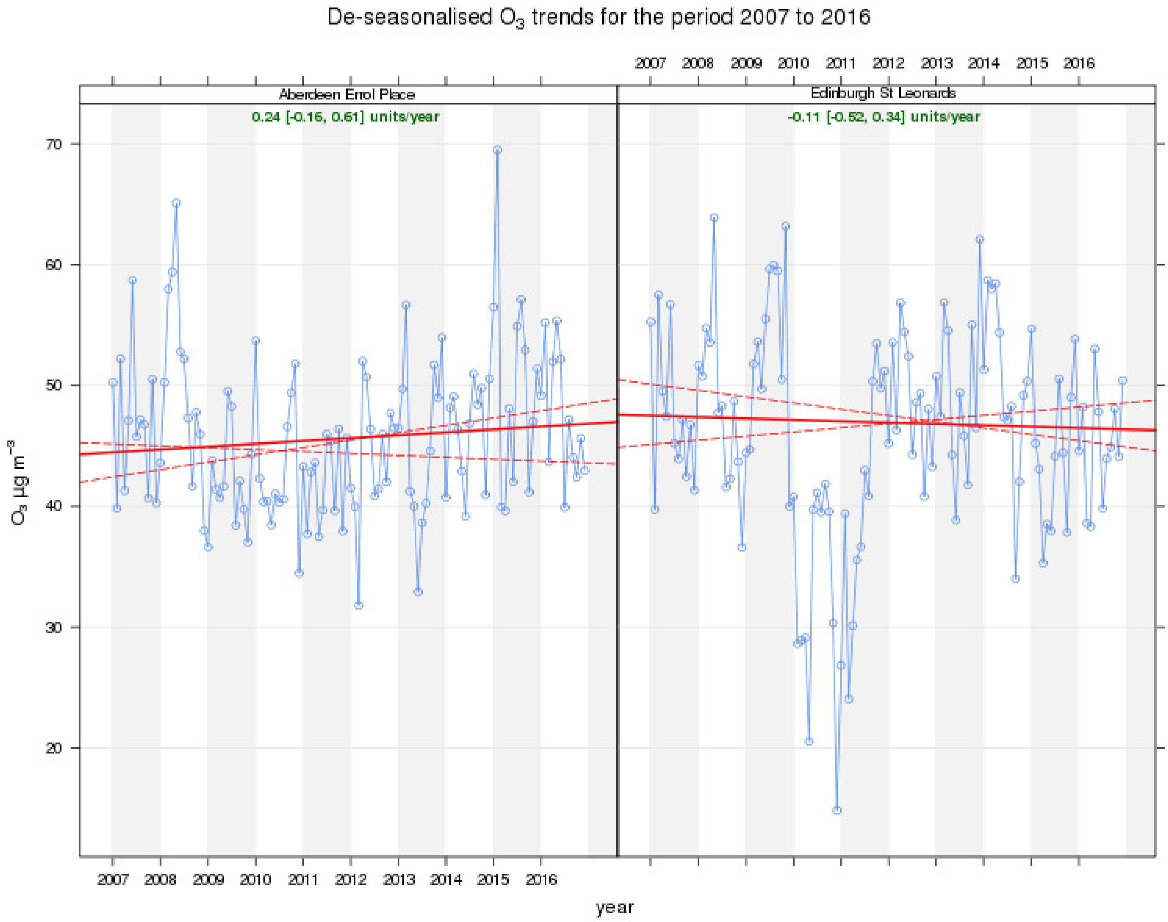
8.3.2 Urban Background Ozone

Figure 8-12 shows trends in de-seasonalised monthly mean ozone concentrations at the two Scottish urban background monitoring sites which have been monitoring ozone for the past 10 years, 2007-2016: Edinburgh St Leonards and Aberdeen Errol Place.

Neither one of these two urban background sites showed a statistically significant trend in ozone concentration over this period.

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

Figure 8-12 Trends in O_3 Concentration at Two Long-Running Urban Background Sites, 2007 – 2016



8.4 Sites with Significant Increasing Trends

The Scottish Environment Protection Agency (SEPA) provides a range of advanced air quality data analysis tools which are available via the Air Quality in Scotland website at http://analysistools.scottishairquality.co.uk/advanced.html . These have been used to identify *any* monitoring stations which have statistically significant increasing trends in nitrogen dioxide or particulate matter concentration (the tools do not at present provide trend analysis for ozone).

These trends are summarised in Table 8-1 below. The table only shows active sites (as of the end of 2016) and only shows those that had been in operation for at least five years, as of the end of 2016. (Five years is usually considered the minimum length of time needed to assess long-term trends in air quality). Trends have been calculated from the beginning of 2006 at the earliest (this being the earliest the SEPA trend analysis tools go back to), or from when the site started up, if that was later.

Table 8-1 Monitoring Stations with Significant Increasing Trends in Pollutant Concentration

Site Name	Site type	Pollutant	Trend	Period	Significance level	Units/year
Dundee Mains Loan	Urban Background	NO_2	Increasing	29/03/2011-31/12/2016	0.05	0.34
Dundee Lochee Road	Kerbside	PM_{10}	Increasing	03/04/2011-31/12/2016	0.05	0.46
Inverness	Roadside	NO_2	Increasing	01/01/2006-31/12/2016	0.01	0.31
South Lanarkshire Rutherglen	Roadside	NO_2	Increasing	01/01/2012-31/12/2016	0.001	2.05

The sites identified, using the SEPA tools, as having significant upward trends in one or more pollutants are as follows

- Dundee Mains Loan: an urban background monitoring station. In recent years, annual mean NO_2 concentrations have been in the range 10-13 µg m^{-3}, so well below the objective of 40 µg m^{-3}. At the current rate of increase, it would take nearly 80 years for the objective to be exceeded.
- Dundee Lochee Road: a kerbside monitoring station where the Scottish objective of 18 µg m^{-3} for annual mean PM_{10} is exceeded and has been since 2014. The small but significant positive trend in PM_{10} concentrations indicates that the situation is not improving.
- Inverness: a roadside monitoring station that does not currently exceed the objective for NO_2. Recent annual mean NO_2 concentrations have been in the low twenties of µg m^{-3}.
- South Lanarkshire Rutherglen: a roadside monitoring site that began operation at the start of 2012. Prior to 2016 the annual mean NO_2 concentrations were close to the AQS objective but did not exceed. There was however a large increase in 2016, with an annual mean of 48 µg m^{-3}. Initial investigations into this increase have identified that the probable cause is due to extensive works being carried out on the M74 causing commuters to take alternative routes through Rutherglen.

Note: although NO_2 at Fort William showed a small upward trend for the period 2007-2016 as discussed in Section 8.1.1, the trend from its start-up in 2006 was not statistically significant so is not included in Table 8-1 above.

8.5 Summary of Trends

Over the past 10 years 2007 – 2016, the following trends have been observed in the measurements from Scottish air quality monitoring stations:

1. Nitrogen dioxide concentrations at Scotland's five long-running urban non-roadside (i.e. urban background and urban industrial) sites showed a mixture of trends. At three of the sites (all urban background) there has been a highly significant decrease but at one (the urban industrial Grangemouth) there was no significant trend and at one (the suburban Fort William) there was a significant increasing trend.
2. Nitrogen dioxide concentrations at Scotland's three long-running rural sites also showed a mixture of trends. Bush Estate and Eskdalemuir showed small but highly significant downward trends. However, Glasgow Waukmillglen Reservoir showed no statistically significant trend.
3. Scotland now has a large number of urban traffic (roadside and kerbside) monitoring sites monitoring NO_2, of which 19 have now been operating for at least 10 years. This trend analysis therefore focussed on nine of these sites that have operated for 10 years and have reported exceedances of the objective in recent years. All of these sites showed downward trends; the trends were significant in seven cases and six of these were at the 0.001 level.

4. Examination of trends at the same nine sites over the most recent five complete years (2012 – 2016) indicates that, at some of these, the decreasing trends have continued but at others they have weakened or levelled off. Ongoing, targeted effort is therefore necessary to ensure that improvements in air quality continue.
5. PM_{10} concentrations at Scotland's six long-running urban non-roadside sites showed a significant or highly significant downward trend in all cases.
6. PM_{10} concentrations at Scotland's nine long-running urban traffic (roadside and kerbside) sites showed statistically significant downward trends at all sites (at the 0.001 level in all but one case).
7. Examination of trends in PM_{10} at the same nine sites over the most recent five complete years (2012 – 2016) indicates that, at some of these, the decreasing trends have continued but at others they have weakened or levelled off. As in the case of NO_2, ongoing, targeted effort is therefore necessary to ensure that reductions in particulate air pollution continue.
8. The measurement of $PM_{2.5}$ in Scotland has a shorter history, and there are not yet any (automatic) monitoring sites with 10 years' data. There are however five sites that have measured $PM_{2.5}$ since 2009 or earlier. Three of these (Edinburgh St Leonards, Grangemouth and Inverness) showed highly significant downward trends in $PM_{2.5}$: the other two (Aberdeen Errol Place and Auchencorth Moss) showed downward trends but they were not significant.
9. Ozone has been measured at three rural sites in Scotland (Bush Estate, Eskdalemuir and Strath Vaich) for 30 years. All three sites showed small positive trends over this very long period, highly statistically significant at two of the three sites.
10. Ozone has been measured for the past 10 years at six rural sites. Over this more recent period there are only two sites which show significant trends - one positive and one negative – so trends over this more recent period are less consistent.
11. Ozone concentrations showed no significant trends at either of the two urban background sites which have monitored this pollutant for the past 10 years.
12. Three of Scotland's current monitoring sites with at least five years of data show a statistically significant upward trend in NO_2 concentration. Of these, two (Dundee Mains Loan and Inverness) are well below the AQS annual mean NO_2 objective, but the third, South Lanarkshire Rutherglen, exceeded this objective in 2016.
13. Dundee Lochee Road shows a significant upward trend in PM_{10} concentration. This site already exceeds the Scottish objective for annual mean PM_{10} and the trend indicates that this situation is not improving.

9 Emissions of pollutant species

In this chapter we provide information on emissions of pollutants into the atmosphere in Scotland. The UK National Atmospheric Emissions Inventory (NAEI) calculates total emissions for the UK from a comprehensive range of sources including industry, domestic, transport etc. The UK inventory is now disaggregated into the UK constituent countries[12]. The inventory covers a wide range of pollutants, but in this report will mainly focus on NO_x and PM_{10}. Information on other pollutants can be found at www.naei.org.uk.

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

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

Information provided in Section 9.1 of this report on the main industrial emissions of NO_x and PM in Scotland have been compiled from the information presented on SEPA's SPRI, with permission from SEPA. The data provided is up to 2015, which is the most recent data available at the time of writing this report.

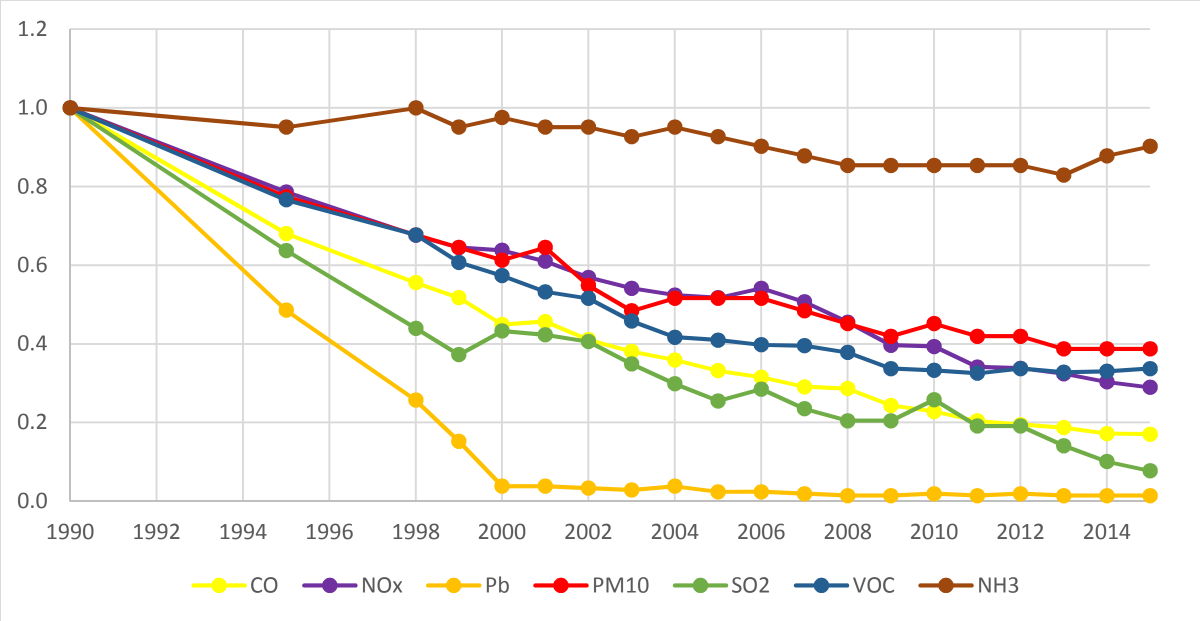
9.1 NAEI data for Scotland

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

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

[12] Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 1990 – 2015
http://naei.beis.gov.uk/reports/reports?report_id=895

Figure 9.1 Scotland normalised trends for all monitored pollutants



Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 1990 – 2015

9.1.1 Scotland NO_x Inventory by NFR Sector, 1990 – 2015

Table 9-1 and Figure 9.2 provides a Summary of NOx emission estimates for Scotland by category. The detailed data are available in the report and website cited in the introduction to this Chapter.

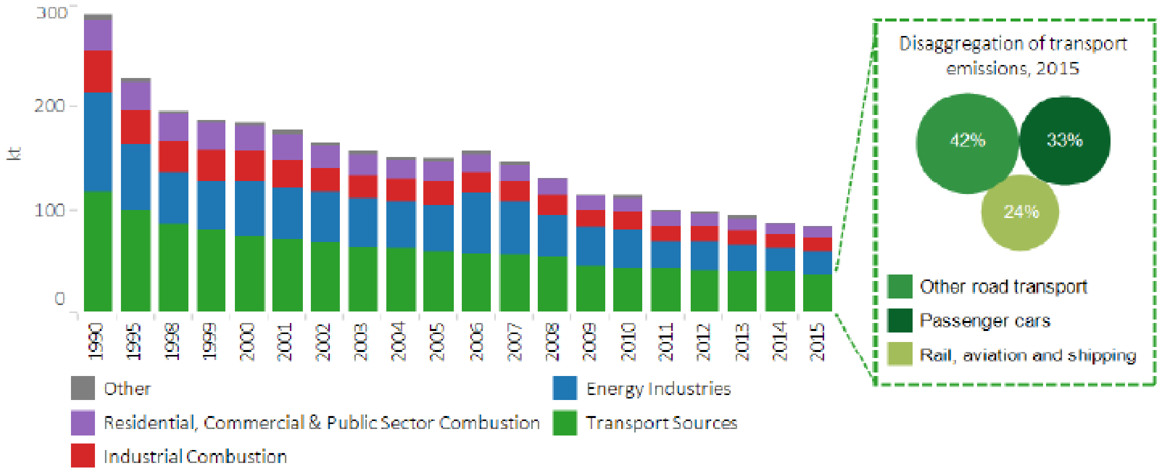
Table 9-1 Summary of NOx emission estimates for Scotland (1990 – 2015)

Category	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005
Energy Industries	96.6	64.9	51	48.5	54.9	50.4	49.2	46.3	44.8	44.5
Industrial Combustion	39.7	32.5	30	28.8	28.4	28.4	23.2	22.4	22.9	23.6
Transport Sources	118	98.8	85.6	81.1	74.3	70.6	68.2	64.7	62.2	60.3
Other	5.4	3.2	2.4	2.9	2.8	3.0	2.6	2.7	2.7	2.6
Residential & other combustion	29.8	28.2	26.8	26.1	24.7	24.3	21.9	20.8	19.5	18.7
Total:	**289.5**	**227.6**	**195.8**	**187.4**	**185.1**	**176.7**	**165.1**	**156.9**	**152.1**	**149.7**

Category	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Energy Industries	56.9	50.2	40.1	35.8	36.9	28.8	30.1	27.9	26	23.6
Industrial Combustion	21.8	22	19.8	16.4	16.5	14.2	13.6	13.1	12.7	12.1
Transport Sources	58.5	56.7	53.8	46.2	43.8	41.5	39.9	38.5	37.4	36.4
Other	2.6	2.5	2.4	2.2	2.3	2.4	2.1	2.2	1.6	1.7
Residential & other combustion	16.9	15.4	16	14.2	14.4	12.4	12.4	11.8	10.2	10.1
Total:	**156.7**	**146.8**	**132.1**	**114.8**	**113.9**	**99.3**	**98.1**	**93.5**	**87.9**	**83.9**

Units: kilotonnes
Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 1990 – 2015

Figure 9.2 Time series of Scotland NO_x emissions 1990-2015



Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 1990 – 2015

Scotland's NOx emissions have declined by 71% since 1990 and in 2015 accounted for 9% (91kt) of the UK total. This decline is driven by the continued introduction of tighter emission standards over the last decade.

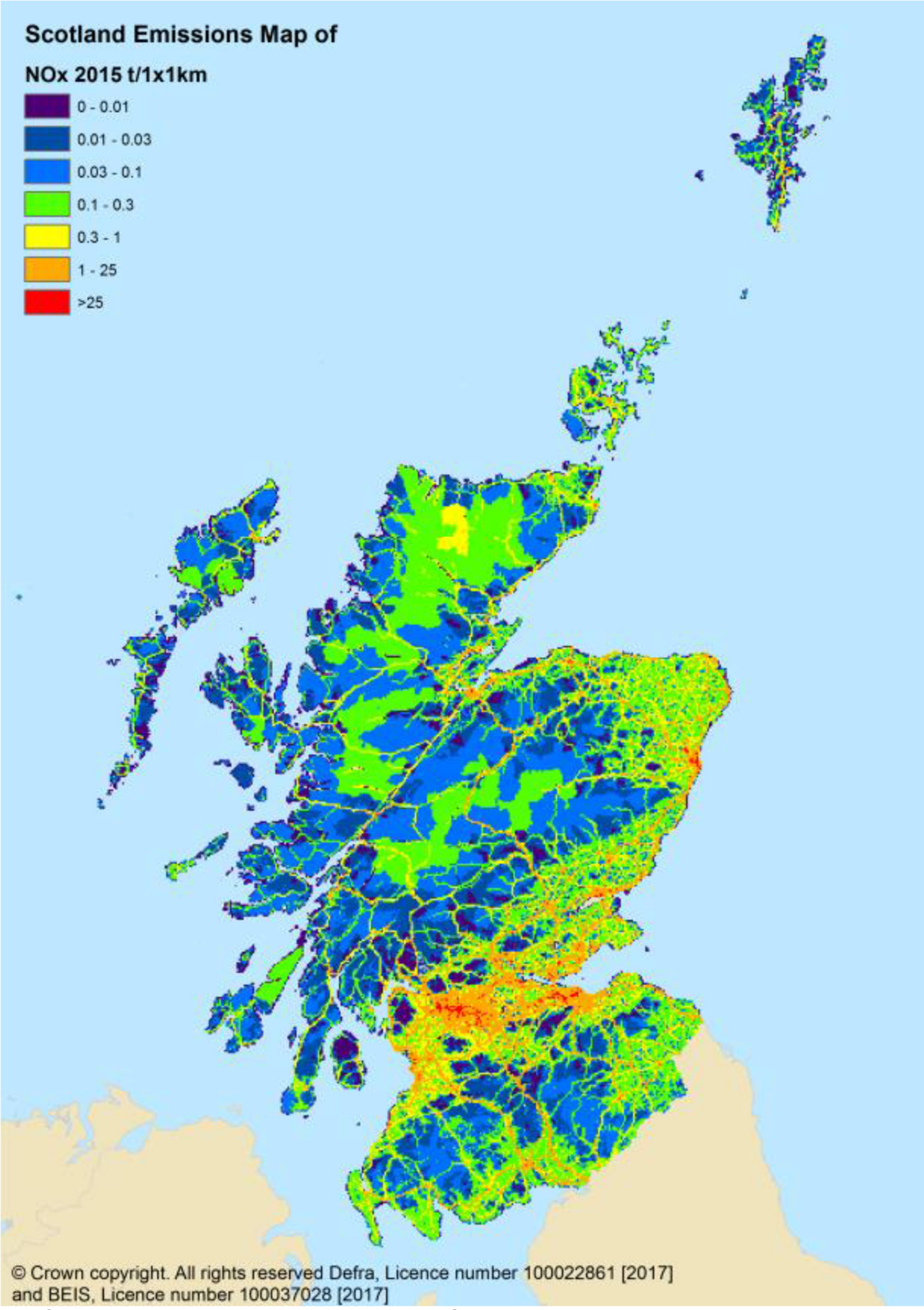
Since 2008, emissions from passenger cars have further decreased, which is mainly driven by the assumption on improvements in catalyst repair rates made in the NAEI to take into account of the introduction of Regulations Controlling Sale and Installation of Replacement Catalytic Converters and Particle Filters for Light Vehicles for Euro 3 (or above) light duty vehicles. However, the increasing number of diesel cars within the fleet offsets these emissions reductions, because diesel cars emit higher NOx relative to their petrol counterparts.

The peak in NOx emissions in 2006 was due to a significant increase in coal-fired power generation at Longannet in that year. As can be seen in figure 9.2 energy sources increased in 2012 as global coal and gas prices fluctuations led to a UK-wide shift in power generation fuel mix from gas to coal in that year. The decline in NOx emissions since 2007 is also linked to the power sector, as Boosted Over-Fire Air (BOFA) abatement systems were fitted to all four of Longannet's units, to reduce NOx emissions from coal-fired generation by up to 25%. BOFA systems were also fitted at Cockenzie power station which then closed in 2013.

It should be noted that, since 2010 the decreasing trend in NOx emissions appears to have slowed across all sectors.

Figure 9.3 shows a map of Scotland's NO_X emissions in 2015.

Figure 9.3 Map of NO_X Emissions in Scotland, 2015



Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 1990 – 2015

9.1.2 Scotland PM_{10} Inventory by NFR Sector 1990 – 2015

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

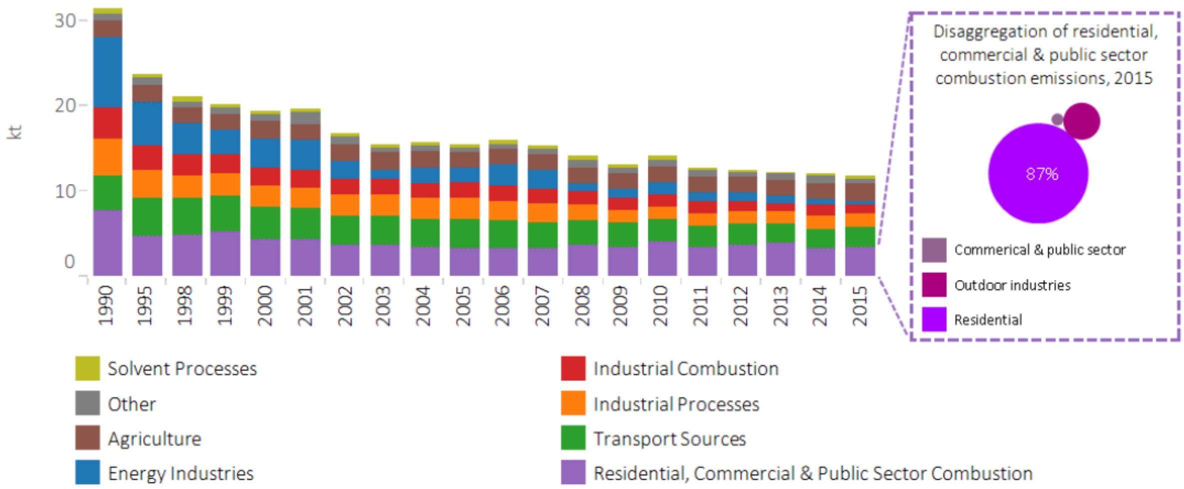
Table 9-2 Summary of PM_{10} emission estimates for Scotland (1990 – 2015)

Category	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005
Agriculture	2	2	1.9	1.8	2	1.9	2	1.9	2	1.9
Energy Industries	8.2	5.1	3.7	3	3.6	3.4	2.1	1.1	1.8	1.7
Industrial Combustion	3.6	3	2.3	2.3	2.1	2	1.8	1.8	1.8	1.8
Transport Sources	4	4.3	4.2	4.2	3.7	3.6	3.6	3.4	3.4	3.3
Industrial Processes	4.4	3.2	2.8	2.6	2.4	2.5	2.4	2.6	2.4	2.5
Solvent Processes	0.7	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.4
Other	0.7	0.7	0.6	0.7	0.7	1.5	0.8	0.6	0.7	0.6
Residential & other combustion	7.8	4.8	4.9	5.2	4.4	4.3	3.6	3.6	3.4	3.3
Total:	**31.4**	**23.6**	**20.9**	**20.3**	**19.4**	**19.6**	**16.7**	**15.4**	**15.9**	**15.5**

Category	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Agriculture	1.9	1.9	1.9	1.8	1.9	1.9	1.9	1.9	1.9	1.9
Energy Industries	2.5	2.3	1	1	1.4	1	1	0.7	0.6	0.4
Industrial Combustion	1.8	1.7	1.6	1.4	1.4	1.3	1.2	1.1	1.1	1.2
Transport Sources	3.2	3	2.9	2.8	2.7	2.5	2.4	2.3	2.2	2.2
Industrial Processes	2.3	2.2	1.9	1.5	1.6	1.5	1.4	1.4	1.6	1.6
Solvent Processes	0.5	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Other	0.6	0.6	1	0.6	0.8	0.8	0.6	0.8	1	0.7
Residential & other combustion	3.3	3.3	3.6	3.5	4	3.4	3.7	3.8	3.3	3.5
Total:	**16.1**	**15.4**	**14.3**	**12.9**	**14.1**	**12.7**	**12.5**	**12.3**	**12**	**11.8**

Units: kilotonnes
Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 1990 – 2015

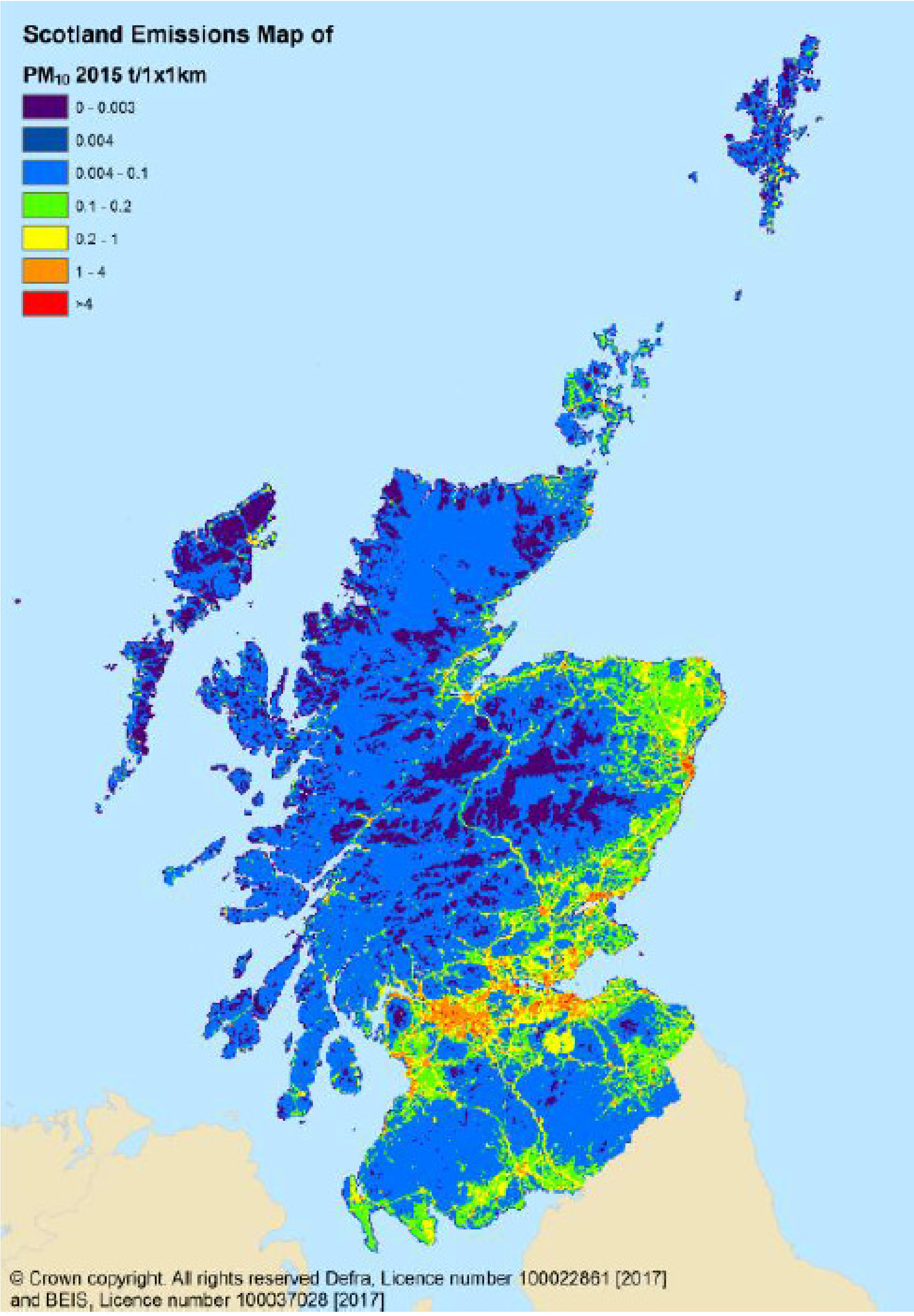
Figure 9.4 Time series of Scotland's PM_{10} emissions 1990-2015



Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 1990 – 2015

Emissions of PM_{10} have declined by 63% since 1990 and in 2015 accounted for 8% (12kt) of the UK total. Emissions from energy industries have had the most significant decline over the period shown, due to the abatement methods in place at coal fired stations. This is further impacted due to the increase in nuclear and renewable energy sources and the increased use of gas in the place of coal for energy generation. However, emissions from Residential and Other Combustion sector has increased since 2005. The increase has been attributed to an increased quantity of wood fuel use, primarily in the domestic sector. In addition, almost all other emissions sources have remained stable since 2009. Though PM_{10} emissions have reduced since 1990, mainly due to the reduced emissions from industry, overall there has been no significant reduction in PM_{10} emissions since 2002. Figure 9.4 shows a map of PM_{10} emission in Scotland for 2015.

Figure 9.1 Map of PM_{10} Emissions in Scotland, 2015



Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 1990 – 2015

10 Developments and Website Usage Statistics

10.1 Expansion of the $PM_{2.5}$ Network

As outlined in CAFS, the Scottish Government decided to replace the existing non statutory Scottish $PM_{2.5}$ annual objective of 12 µg m^{-3} with a statutory objective of 10 µg m^{-3}, in line with the World Health Organisation (WHO) guideline value. This came into force on the 1st April 2016. The full revised legislation and its extended series of associated technical annexes can be found on the Scottish Government website (http://www.scottishairquality.co.uk/air-quality/legislation). These moves by the Scottish Government has resulted in Scotland being one of the leading countries in Europe and the rest of the world in terms of the monitoring and mitigation of the pollutant $PM_{2.5}$.

A resulting effect of this new legislation has been the relatively rapid expansion of the $PM_{2.5}$ monitoring network within the Scottish air quality database. In 2016 there were 11 new $PM_{2.5}$ sites added to the network bring a total of 26 sites across Scotland. Figure 10.1 illustrates the location of these new sites. As part of the 2016/17 funding support for local authorities to assist with LAQM monitoring and modelling work, awards were made to fund 13 (Figure 10.1) new $PM_{2.5}$ monitoring stations. At the time of writing this report there are 31 sites monitoring $PM_{2.5}$ in 15 separate local authorities. This compares with 2013 when there were only 7 sites measuring the pollutant.

As the monitoring network has expanded, the Scottish Air Quality Database and Website has in turn expanded and developed to cope with the influx of new data.

Figure 10.1: Locations of the new $PM_{2.5}$ monitoring site introduced in 2016

10.2 Scottish Environment Protection Agency – Spotfire Tools

New visualisation and data analysis tools have been incorporated in to the Air Quality in Scottish website. The tools utilise the TIBCO Spotfire® software, pulling data from the monitoring network database, incorporating both GIS-based software, pre-set analysis functions and met office data. As additional data becomes available, these tools can be expanded, with additional data being pulled and visualised alongside air quality data, such as traffic and modelled information. The tools and the webpages were developed and are maintained by SEPA at the request from Scottish Government as improvements to the existing website. The pages went live in January at the Scottish Air Quality Database and Website Annual Seminar and are currently available as beta test web pages.

The Air Quality in Scottish website now has a new landing page for all the data analysis tools, including Openair and the Spotfire tools. The website continues to provide local authorities and the general public with a single landing page that allows them to analyse the data provided by the monitoring network.

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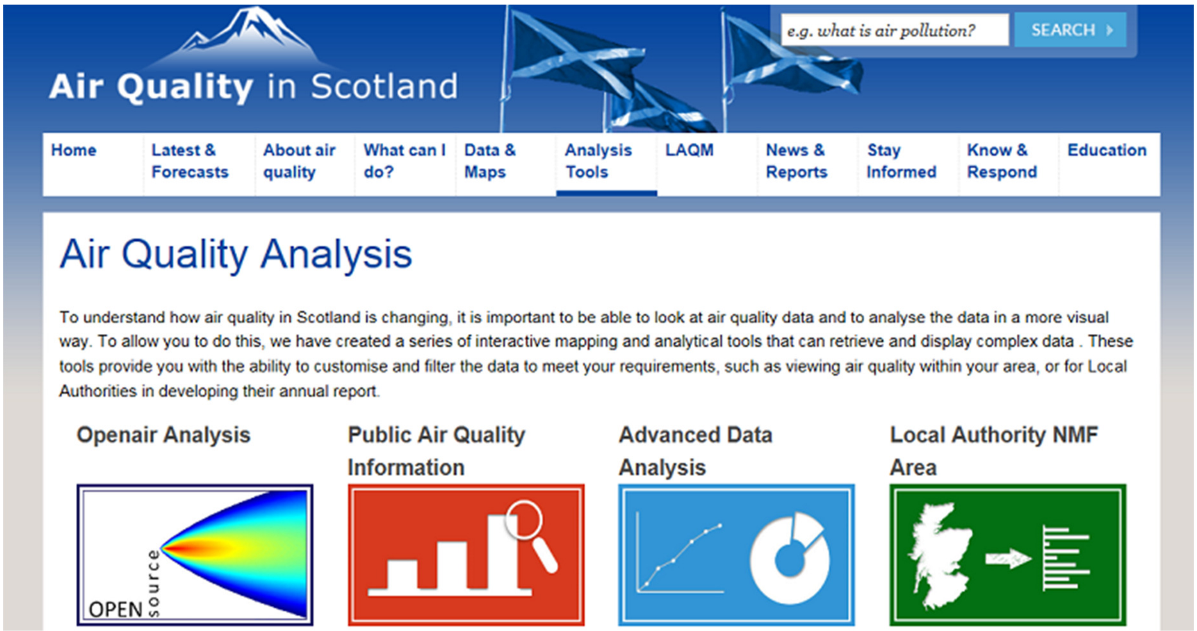
Figure 10.2 new homepage for the air quality analysis tools on the Air Quality in Scotland website

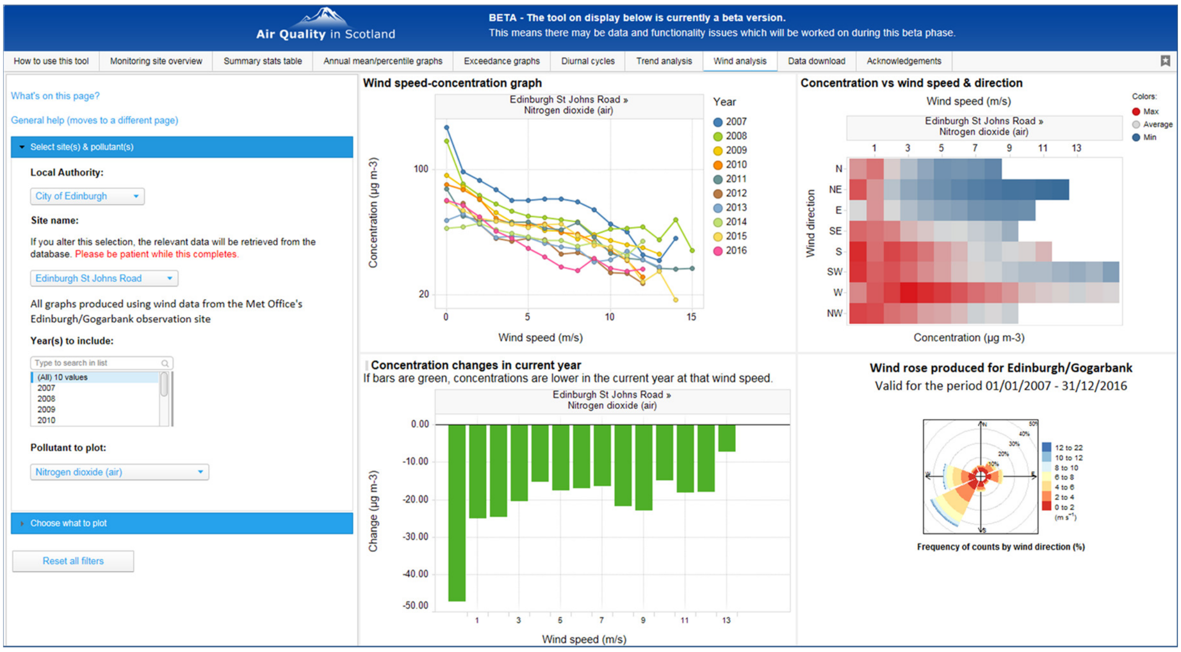


The aim of the new analysis and visualisation tools are to:

- Provide the public with pre-filtered data that allows them to access the monitoring network in a simple and meaningful way without being faced with the difficulty of interrogating the data;
- Allow those that are looking for more advanced analysis of the data, bring together other data sources and utilising visual functionalities to interrogate and report on the network;
- Provide local authorities with pre-set analysis tools for reporting purposes;
- Link with international data to help identify and visualise the movement of transboundary pollution as it crosses Scotland, through features such as a time-series function that shows changes in the monitoring data across the full network and links individual stations to local weather information.

The new tools were developed to support Scottish Governments delivery within CAFS through informing, engaging and empowering to improve air quality.

Figure 10.3: Example of the visulisation of the data within the SEPA tools



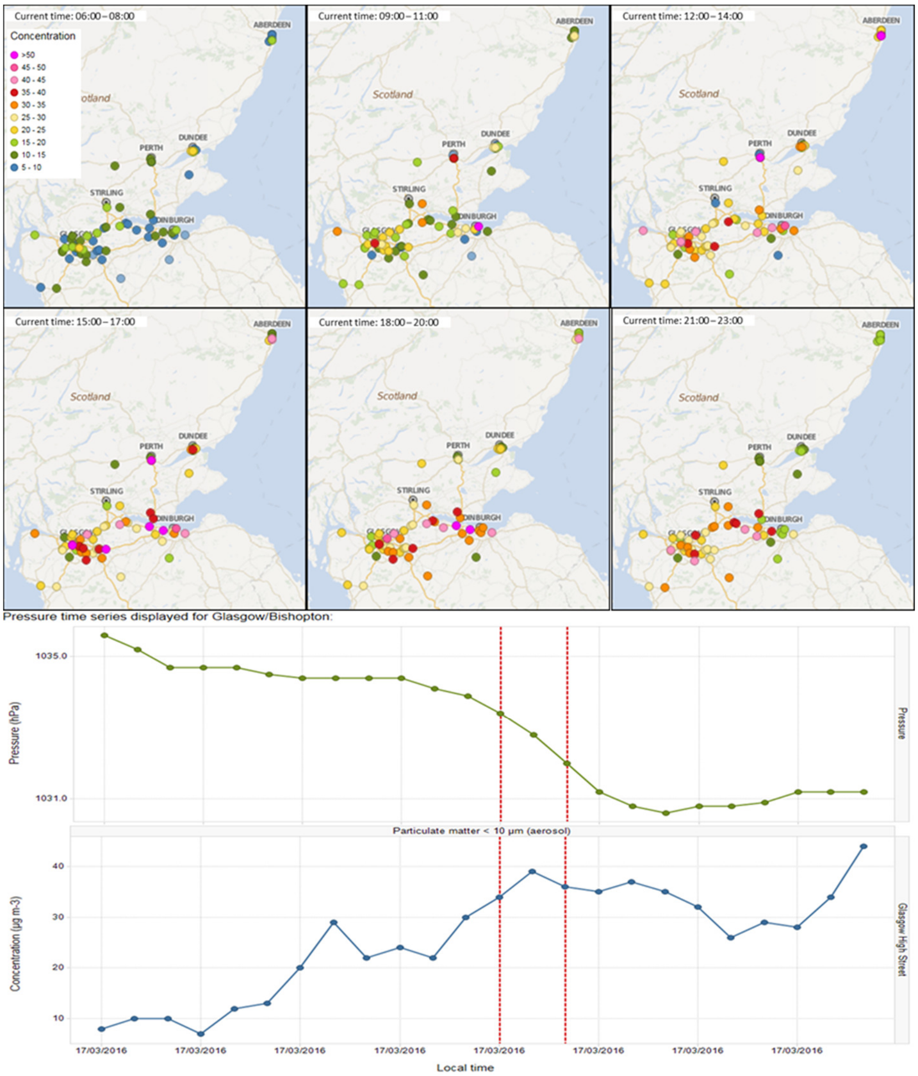
10.2.1 Functions within the new Visualisation and Analysis Tools – Transboundary Anaysis tool

The new SEPA visualisation and analysis tools combine GIS-based information, external data and monitoring data, whilst utilising statistical functions to provide a variety of visual outputs for the user.

One of the functions available can illustrate the impacts of pollution events on the monitoring network, such as the event on the 17th of March, 2016. This event has been summarised in Figure 10.4, which has been extracted from the Transboundary Analysis tool.

The tool takes you through a time series of monitoring data from across the network, linking this to specific weather information. It allows the user to then interrogate the effects such episodes have on individual monitoring stations, such as the example here, Glasgow High Street. The tools can be used to illustrate the effects transboundary pollution and weather patterns can have on local air quality.

Figure 10.4 Pollution episode identified across the Scottish monitoring network during 17/03/2016.



10.3 SAQD Newsletter

In December 2016, the first edition of the quarterly newsletter was published via the Air Quality Scotland website (http://www.scottishairquality.co.uk/news/). The newsletter, produced by Ricardo Energy and Environment in conjunction with SEPA, is designed to provide regular updates and news regarding the SAQD and local air quality matters to all stakeholders. This includes: updates to the network; new information on air quality issues; updates on changes in policy and procedures; new initiatives and events; technical reports; and how to access data using the Air Quality Scotland website.

Figure 10.5 illustrates the first and second editions of the Air Quality in Scotland Quarterly newsletter.

10.4 Education

Education has been an ongoing 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 (aged 8-11 years old). The second website "Clear the Air" was developed in partnership with a number of secondary schools for pupils in S1 – S3 (aged 12-15 years old). The education packages can be accessed from the Air Quality in Scotland website http://children.scottishairquality.co.uk/

10.4.1 Air Pollution Detectives

Initially launched in 2011, the Air Pollution Detectives has been revised and updated through 2016. 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. The Air Pollution Detectives is available at: http://www.scottishairquality.co.uk/education/.

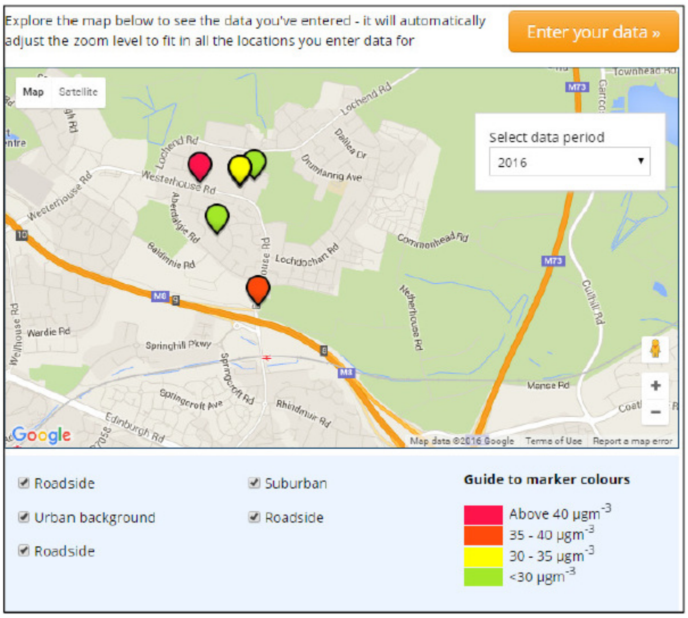
10.4.2 Clear the Air

The Clear the Air web page was developed following the success of the Air Pollution Detectives. The webpage provides an interactive learning experience for air quality and citizen science. 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.

10.4.3 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 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 10.6. The package encourages pupils to discuss the results and the factors influencing the air quality measured within the area. The Clear the Air monitoring pack 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.

Figure 10.6: Data entry available on each school profile



10.5 Website Usage Statistics

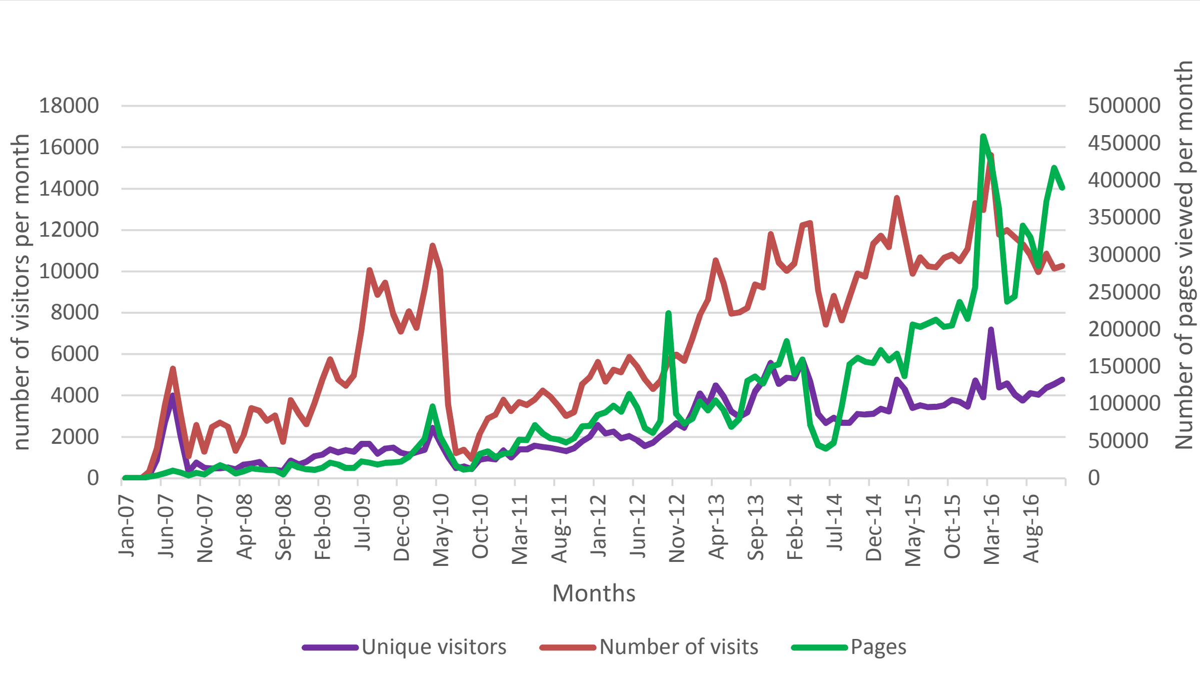
Usage of the website is monitored through the on-line tracking tool "awstats", and statistics can be accessed by clicking the following link: http://www.scottishairquality.co.uk/cgi-bin/usage.pl. Additional to awstats, Google Analytics is also used to track and evaluate website usage. These software tools provide in-depth analysis of the time, date, location and access route of every visit to the website (It does not store any personal information which would require declaring under the Data Protection Act). Figure 10.6 below illustrates how the number of visitors and pages viewed has varied on a monthly basis from April 2007 to December 2016.

The hits will include some automated search engine visits which are required in order to keep the site's rating on Google and Yahoo as high as possible. However, we have endeavoured as far as possible to configure the site security and tracking software to exclude automated web crawlers which may be attempting to scan the site maliciously for personal information to be used in spamming.

Assuming that hits statistics are genuine, figure 10.7 clearly indicates an upward trend in the number of unique visitors and pages viewed since the site was launched in 2007.

Key users of the website include local authorities, the Scottish Government, SEPA, universities, health professionals, environmental consultants and the general public. The vast majority of the users are from the UK (90%) however there is also significant interest from other countries such as the USA (2%), India, Germany and Spain (1% each).

Figure 10.7 Air Quality Website Hits April 2007 December 2016



(Sourced from awstats: http://www.scottishairquality.co.uk/cgi-bin/usage.pl)

10.5.1 Air Quality in Scotland App

The Air Quality in Scotland App was launched in January 2012 and was last updated in March 2015. Since its release the app has been downloaded 947 times. A breakdown of which platforms have download the App is provided in Table 10.1.

Table 10.1 Number of Air Quality in Scotland App Downloads

Platform	Number of Users
Android	306
IOS	641
Total	947

10.6 Website Maintenance/ Updates

On a daily basis the web pages are checked by the Ricardo Energy and Environment IT and air quality team, both manually and using a number of automated software systems, in order to ensure that the website is fully functional with no broken links.

In addition to this, a number of routine maintenance tasks are carried on a daily/weekly/monthly basis as required in order to keep the underlying database up-to-date and fully populated. These include:

- Updates to the Scottish sites are made as required (e.g. If new monitoring instruments come on-line or other sites/instruments are changed for example, South Ayrshire PM_{10} analysers to $PM_{2.5}$ analysers & inclusion of FIDAS analysers (PM1, PM4 and TSP data)).
- New local authority monitoring sites are added to the database once agreement is reached with the local authority, 2016 welcomed Falkirk Grahams Road, Falkirk Bo'ness, Falkirk Bainsford Street and Inverness Queensgate sites to the network.
- The LAQM pages have been updated with any changes to the status of Local Authority Air Quality Management Areas.
- New technical guidance documents and reports (including local authority review and assessment reports) are added to the website when made available.
- Ratified data (or any improved provisional data) load automatically to the website from Ricardo Energy and Environment's data management software on a daily basis.
- Statistics are automatically recalculated every night:
  - Daily, Monthly & Annual Means etc.
  - All exceedance statistics.
- The news section is routinely updated with relevant information provided by the Scottish Government or other website users (e.g. the update to the United Kingdom's 2013 Reference Year Background Maps)
- Site photos are updated as soon as Ricardo Energy and Environment carry out our QA/QC visits, or they are provided by the local authority.

During 2016 there were also a number of significant improvements and changes made to the website to further enhance the performance and usability of the website. These have included;

- Open Data Services went live – These included;
  - Air Quality Spatial Object Register (http://www.scottishairquality.co.uk/data/so/about/)
  - Atom Download Services (http://www.scottishairquality.co.uk/data/atom-dls/)
  - Sensor Observation Services (http://www.scottishairquality.co.uk/data/sos/about/)
- Automatic Annual Monitoring Statistic Data report facility for use by Local authorities in their LAQM annual reporting went live (http://www.scottishairquality.co.uk/laqm/statistics-pdf)
- Integration of the website and database with the SEPA Spotfire data analytical tools (http://analysistools.scottishairquality.co.uk/)
- Enhancement of the Data Selector function
- Addition of the CAFS progress pages (http://www.scottishairquality.co.uk/air-quality/CAFS)
- Addition of the Smoke Control Area Guidance Pages (http://www.scottishairquality.co.uk/laqm/smoke-control-areas)
- Addition of the UKAS certificate of Calibration Pages (http://www.scottishairquality.co.uk/laqm/certificates-calibration)

11 Summary and Conclusions

In April 2007, Ricardo Energy & Environment were commissioned by the Scottish Government to undertake a three-year project (Apr 2007 – Apr 2010) to develop an Air Quality Database and Website for Scotland. This contract has been renewed in recent years, with the latest contract running from 2016-2019.

This report brings together all the Scottish Air Quality Database data for calendar year 2016 and associated work relating to project deliverables including; Data management; QA/QC services; liaison with stakeholders; website development; spatial analysis of air quality data; trend analysis. In addition, the report presents the additional activities and further developments undertaken during the tenth year of the project, July 2016 – June 2017.

Legislation and Policy

The "Cleaner Air for Scotland – The Road to a Healthier Future" (CAFS) strategy was published by the Scottish Government in November 2015. The purpose of CAFS is to provide a national framework which sets out how the Scottish Government and its partner organisations propose to achieve further reductions in air pollution and fulfil their legal responsibilities as soon as possible. CAFS outlines the contribution that better air quality can make to sustainable development whilst improving health and the natural environment and reducing health inequalities for the citizens of Scotland.

As outlined in CAFS, the Scottish Government decided to replace the existing provisional Scottish $PM_{2.5}$ annual objective with the WHO guideline value of 10 µg m^{-3} and to include this in legislation. The Air Quality (Scotland) Amendment Regulations came into force on the 1st April 2016.

The Scottish Government Policy Guidance and the Defra and Devolved Administrations' Technical Guidance documents on LAQM were updated in April 2016. The newly published Technical Guidance on LAQM (TG16) and Scottish Government Policy Guidance (PG(S)16) were amended in line with recommendations which resulted from the 2014 LAQM review.

Air Quality Monitoring in Scotland

All automatic data maintained within the Scottish database are subject to the same QA/QC procedures as at the national network air quality monitoring stations within the UK Automatic Urban and Rural Network. This ensures that all data in the database are quality assured and traceable to UK national calibration standards for the various pollutants.

At the end of 2016 the Scottish Air Quality Database contained data for of 97 automatic monitoring sites. In total, five new monitoring sites were incorporated into the database during 2016: South Lanarkshire Raith Interchange 2, Falkirk Bo'ness, Falkirk Graham's Road, Falkirk Main Street Bainsford and Inverness Academy Road. Two monitoring sites,; Edinburgh Queen Street and Dundee Union Street were decommissioned during 2016.

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

At the time of writing, 14 local authorities in Scotland have declared a total of 39 AQMAs. This is two more than the 2015 total.

The Air Quality in Scotland Websites (www.airqualityscotland.co.uk) and this annual report also contain a summary of data from a wider range of pollutants measured in Scotland as part of several national network monitoring programmes.

Air Quality Mapping of Scotland

Ricardo Energy & Environment provide mapped concentrations of modelled background air pollutant concentrations on a 1 km x 1 km basis for the whole of Scotland. Modelled roadside air pollutant concentrations are provided for road links in Scotland. The air pollution maps are derived from a combination of (1) measurements from Scotland's network of air quality monitoring stations, and (2) spatially disaggregated emissions information from the UK National Atmospheric Emissions Inventory (NAEI).

During 2016/17, and at the time of writing this report, there are two versions of the UK 2015 modelling:

1. Modelling submitted to the European Commission for the UK compliance assessment in September 2016 (version 2015A)
2. Updated modelling for the revised UK NO_2 air quality plans published in July 2017 (version 2015C)

After consultation, the Scottish Government agreed that the best approach for the scheduled 2015 Scottish mapping work would be to use the more up-to-date 2015C modelling undertaken for the revised NO_2 plans, as this incorporates more realistic vehicle emissions. In addition, it is also expected that Defra will provide an update to LAQM data (mapped data for all years from the base year to 2030) based on projections from model version 2015C in due course.

At the time of writing this report, the updates previously stated were not released. As a result, the Scottish Air Quality mapping work has not been completed. Once the relative updates have been released and mapping work completed, this report will be amended as appropriately.

Air Quality Trends for Scotland

Data held within the database covering many years have been used to assess possible trends in air pollution throughout Scotland. Air quality trends have been examined on the basis of individual monitoring sites, and subsets of long-running sites, rather than the composite data set. For this report, smoothed trend and Theil-Sen analysis have been used, utilising the Openair data analysis tools to quantify pollutant trends at individual sites. The trend plots are generally carried out over 10 years, however for traffic based site types five year plots have been produced to see if recent year trends differ.

NO_2

For three of the five longest running Urban Non-Roadside sites (Aberdeen Errol Place, Edinburgh St Leonards and Glasgow Anderston) the 10-year trend plots for NO_2 generally show a significant negative trend, with Grangemouth showing a downward trend but not statically significant. For Fort William the trend is significantly positive.

When considering the three longest running rural sites, Bush Estate and Eskdalemuir showed small but highly significant downwards trends where by contrast Glasgow Waulkmillglen Reservoir site concentrations have increased year on year, though the trend is not significant.

For this report nine of the longest running traffic related urban sites, which have measured exceedances in recent years, were chosen for analysis. 10-year trend plots showed that six of the nine sites (Aberdeen Union Street, Dundee Lochee Road, Edinburgh Gorgie Road, Edinburgh St John's Road, Glasgow Kerbside (Hope Street) and Perth Atholl Street) showed downward trends in NO_2 concentration which were highly significant. However, this was not the case at every site – at Glasgow Byres Road the trend was significant only at the 0.05 level; and Dundee Seagate and East Dunbartonshire Bearsden showed no significant trends.

Comparing the 10-year and five-year trends, the patterns differ from site to site: Aberdeen Union Street, Dundee Lochee Road, Dundee Seagate, Edinburgh Gorgie Road and Glasgow Byres Road show downward trends that have become greater, more statistically significant, or both. By contrast, the other four sites – East Dunbartonshire Bearsden, Edinburgh St John's Road, Glasgow Kerbside and Perth Atholl Street – downward trends have become smaller or less statistically significant. For

East Dunbartonshire Bearsden and Edinburgh St John's Road, the trend has changed from negative to positive. It is therefore not valid to assume that NO_2 is continuing to improve at all sites.

PM_{10}

For PM_{10} Urban sites tend analysis, sites were split into subsets of Urban Background/Industrial and Urban traffic.

For Urban Background and industrial all six sites (Aberdeen Errol Place, Dundee Broughty Ferry Road, Dundee Mains Loan, Edinburgh St Leonards, Glasgow Anderston, and Grangemouth) showed a negative trend, significant at the 0.001 level for all except Glasgow Anderston where it was significant at the 0.01 level.

Over the past 10 years, all nine Urban Traffic sites (Aberdeen Anderson Drive, Aberdeen Union Street, East Dunbartonshire Bearsden, East Dunbartonshire Bishopbriggs, Edinburgh Queen Street, Fife Cupar, Glasgow Byres Road, Perth Atholl Street and Perth High Street) showed 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. For the last five years, trends show that for four of the sites (the two in Aberdeen, plus Fife Cupar and Perth Atholl Street) the downward trend is stronger or more significant. However, in the remaining five, the downward trend has weakened or become insignificant. As in the case of NO_2, ongoing, targeted efforts are therefore still needed to ensure air quality continues to improve where necessary.

$PM_{2.5}$

In 2016 there were five 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), Grangemouth (urban industrial) and Inverness (roadside). All five of the long-running $PM_{2.5}$ monitoring sites showed a downward trend in this pollutant. However, it was only statistically significant at three of them - Edinburgh St Leonards, Grangemouth and the non-automatic Inverness site.

Ozone

Ozone has been measured at three rural sites in Scotland (Bush Estate, Eskdalemuir and Strath Vaich) for 30 years. All three sites showed small positive trends over this very long period, highly statistically significant at two of the three sites. Ozone has been measured for the past 10 years at six rural sites. Over this more recent period there are only two sites which show significant trends - one positive and one negative – so trends over this more recent period are less consistent. Ozone concentrations showed no significant trends at either of the two urban background sites which have monitored this pollutant for the past 10 years.

Sites with Significant Increasing Trends

Three of Scotland's current monitoring sites with at least five years of data show a statistically significant upward trend in NO_2 concentration. Of these, two (Dundee Mains Loan and Inverness) are well below the annual mean NO_2 objective, but the third, South Lanarkshire Rutherglen, exceeded this objective in 2016. Dundee Lochee Road shows a significant upward trend in PM_{10} concentration. This site already exceeds the Scottish objective for annual mean PM_{10} and the trend indicates that this situation is not improving.

Emissions of Pollution Species

Scotland's NOx emissions have declined by 69% since 1990 and in 2015 accounted for 9% (84kt) of the UK total. Since 2008, emissions from passenger cars have further decreased, which is mainly driven by the assumption on improvements in catalyst repair rates made in the NAEI to take into account of the introduction of Regulations Controlling Sale and Installation of Replacement Catalytic Converters and Particle Filters for Light Vehicles for Euro 3 (or above) light duty vehicles. However, the increasing number of diesel cars within the fleet offsets these emissions reductions, because diesel cars emit higher NOx relative to their petrol counterparts. It should be noted that, since 2010 the decreasing trend in NOx emissions appears to have slowed across all sectors.

Emissions of PM_{10} have declined by 46% since 1990 and in 2015 accounted for 8% (12kt) of the UK total. Emissions from energy industries have had the most significant decline over the trend shown, due to the abatement methods in place at coal fired stations. However, emissions from Residential and Other Combustion sector has increased since 2005. The increase has been attributed to an increased quantity of wood fuel use, primarily in the domestic sector. Though PM_{10} emissions have reduced since 1990, mainly due to the reduced emissions from industry, overall there has been no significant reduction in PM_{10} emissions since 2002.

Development and Website Usage Statistics

Expansion of the $PM_{2.5}$ Network

A resulting effect of the new $PM_{2.5}$ legislation introduction in April 2016, has been the relatively rapid expansion of the $PM_{2.5}$ monitoring network within the SAQD. In 2016 there were 11 new $PM_{2.5}$ monitoring sites added bringing a total of 27 sites across Scotland. This compares with 2013 when there were only seven sites measuring the pollutant.

SEPA Data Analysis and Visualisation Tools

The new SEPA data analysis and visualisation tools were launched on the 24th January 2017 and are hosted on the Air Quality in Scotland website. The new tools aim to:

- Provide the public with pre-filtered data that allows them to access the monitoring network in a simple and meaningful way without being faced with the difficulty of interrogating the data;
- Allow those that are looking for more advanced analysis of the data, bring together other data sources and utilising visual functionalities to interrogate and report on the network;
- Provide local authorities with pre-set analysis tools for reporting purposes;
- Link with international data to help identify and visualise the movement of transboundary pollution as it crosses Scotland.
- Support Scottish Governments delivery within CAFS through informing, engaging and empowering to improve air quality.

SAQD Newsletter

In December 2016, the first edition of the quarterly newsletter was published via the Air Quality Scotland website (http://www.scottishairquality.co.uk/news/). The newsletter, produced by Ricardo Energy & Environment in conjunction with SEPA, is designed to provide regular updates and news regarding the SAQD and local air quality matters to all website users.

Website Usage

Statistics obtained indicate an upward trend in the number of unique visitors and pages viewed since the site was launched in 2007.

Appendices

Appendix 1 – National Monitoring Networks in Scotland 2016

Table A1.1. AURN Measurement Sites in Scotland 2016

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

Table A1.2 Automatic Hydrocarbon Network Sites in Scotland 2016

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

Table A1.3 Non-Automatic Hydrocarbon Network Sites in Scotland 2016

Site Name	Site Type	Species Measured	Grid Reference
Glasgow Kerbside (Hope Street)$^{\alpha}$	KERBSIDE	Benzene	258708, 665200
Grangemouth	URBAN INDUSTRIAL	Benzene	293840,681032

EU requirement and part of the EMEP long-range transboundary air pollution monitoring programme.
$^{\alpha}$Non-Automatic Monitoring of Benzene started at this site on 01/09/10.

Table A1.3 PAH Monitoring Sites in Scotland 2016

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

Table A1.4 Heavy Metals Monitoring Network Sites in Scotland 2016

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

Table A1.6 Rural Metal Deposition Monitoring sites in Scotland 2016

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

United Kingdom Eutrophying & Acidifying Network (UKEAP)

Table A1.7 The Precipitation Network (PrecipNet) Sites in Scotland 2016

Site Name	Grid Ref	Species included
Shetland	445449,113965	Na^+, Ca^{2+}, Mg^{2+}, K^+, PO_4^{3-}, NH_4^+, NO_3, SO_4^{2-}, Cl^-
Rum	140865,799220	
Halladale	290285,948838	
Strathvaich Dam	234787,875022	
Lagganlia	285684,803720	
Glensaugh	366329,780027	
Edinburgh St Leonards	326265, 673136	
Bush	324626,663880	
Auchencorth Moss	322167, 656123	
Carradale	179870,637801	
Eskdalemuir	323552,603018	

Table A1.8 Acid Gas and Aerosol Network (AGANet) and Ammonia Network (NAMN) Sites in Scotland 2016

Name	Grid Ref	Ammonia	Nitric Acid
Shetland	445449,113965	✓	✓
Halladale	290285,948838	✓	✓
Inverpolly B	218776,908733	✓	
Strathvaich Dam	234787,875022	✓	✓
Ellon Ythan	394500,830400	✓	
Oldmeldrum	383297,827323	✓	
Pitmedden	388300,827800	✓	
Lagganlia	285684,803720	✓	✓
Allt a Mharcaidh	289184,804320	✓	
Rum	140865,799220	✓	✓
Glensaugh	366329,780027	✓	✓
Glenshee Hotel	311187,769916	✓	
Glen Shee	312187,769016	✓	
Tummel	274483,761116	✓	
Rannoch	260380,753315	✓	

Name	Grid Ref	Ammonia	Nitric Acid
Loch Awe	196673,711509	✓	
Edinburgh Johnston Terrace	325389,673404	✓	
Edinburgh Medical School	326388,672605	✓	
Edinburgh St Leonards	326265, 673136	✓	
Bush 2	324789,663804	✓	
Bush 1	324671,663524	✓	✓
Auchencorth Moss	322188,656202	✓	✓
Carradale	179870,637801	✓	✓
Auchincruive B	238478,622899	✓	
Auchincruive 3	237977,623399	✓	
Sourhope	386796,621798	✓	
Eskdalemuir	323588,602997	✓	✓
Dumfries	254679,565792	✓	
Sourhope	386796,621798	✓	

Appendix 2 - Ratification Procedures

A2.1 Intercalibration and Audit procedures

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

The results of the audit exercises form an integral part of the data management system and are fed directly into the data ratification process.

After the audit exercise, data from all the stations visited are traceable to recently calibrated UKAS accredited gas calibration standards (the audit gas).

A2.1.1 Detailed instrumentation checks

The following instrument functional checks are undertaken at an audit:

- Analyser accuracy and precision, as a basic check to ensure reliable datasets from the analysers.
- Instrument linearity, to check that doubling a concentration of gas to the analyser results is a doubling of the analyser signal response. If an analyser is not linear, data cannot be reliably scaled into concentrations.
- Ozone analyser calibration against a traceable ozone photometer;
- Instrument signal noise, to check for a stable analyser response to calibration gases;
- Analyser response time, to check that the analyser responds quickly to a change in gas concentrations;
- Leak and flow checks, to ensure that ambient air reaches the analysers, without being compromised in any way;
- NO_X analyser converter efficiency, via gas phase titration, to ensure reliable operation. The converter must be more than 95% efficient to ensure that the NO_2 data are of the required accuracy;
- TEOM k_0 evaluation. The factor is used to calculate particulate mass concentrations;
- Particulate analyser flowrates. Any error in the flow through these particulate analysers is directly reflected in an error in the final measure of particulate concentration;
- SO_2 analyser hydrocarbon interference; certain hydrocarbons are known to interfere with the SO_2 detector;

- Evaluation of site cylinder concentrations, with reference to the certified audit gas taken to the stations. This procedure allows for the correction of data from stations where the site calibration cylinder concentration is slowly changing and for identification of any unstable cylinders that require replacement;

- Assessing changes in local site environment. During the visit, a record of any changes in the site environment, for example any increased or decreased traffic flow due to road layout changes, construction activity, encroachment of the site by vegetation etc;

- Assessment of station infrastructure and operational procedures. Any deficiencies in site infrastructure or operational procedures, which may affect data quality or safe operation of the site, are noted;

- Ensure Local Site Operators (LSO) understand calibration procedures correctly. It is the calibrations by the LSOs that are used to scale pollution datasets and hence, it is important to check that these are undertaken reliably.

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

A2.1.2 UKAS Accreditation

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

ISO17025 accreditation provides complete confidence that the analyser calibration factors are traceable to national metrology standards, that the calibration methods are sufficient and fit for purpose, and that the uncertainties are appropriate for data reporting purposes.

Ricardo-AEA also holds ISO17025 accreditation for laboratory certification of NO, NO_2, CO and SO_2 gas cylinders.

A2.1.3 Zero air

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

- A zero air cylinder;

- A series of chemical scrubbers, connected to a pumped delivery system;

- A pollutant specific chemical scrubber system to connect directly into the analyser.

A2.1.4 Ozone Photometers

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

A2.2 Data Acquisition and Processing

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

The data are transmitted via MODEM or internet connection, depending on type of logging system used at the site, and automatically appended to the air quality site database.

The results of automatic overnight autocalibration checks are also retrieved and databased.

Appropriate scaling factors, based on the most recent calibration information are applied to the pollutant measurements to produce concentrations in the relevant units.

From the 15-minute values, the hourly averaged results are calculated. This is the averaging period used for the reporting of both validated and ratified data for all pollutants. Additionally, the 15-minute data files are provided for SO_2 to allow direct comparison with the 15-minute objective.

Once the raw data from the stations has been acquired the next step in the data management process is data validation.

A2.2.1 Validation of Data

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

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

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

A2.3 Data Ratification

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

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

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

- Data gaps of more than six hours.

A2.3.1 Ratification tasks and output

When ratifying data the following are closely examined:

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

A2.3.2 Ratified Data Checking

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

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

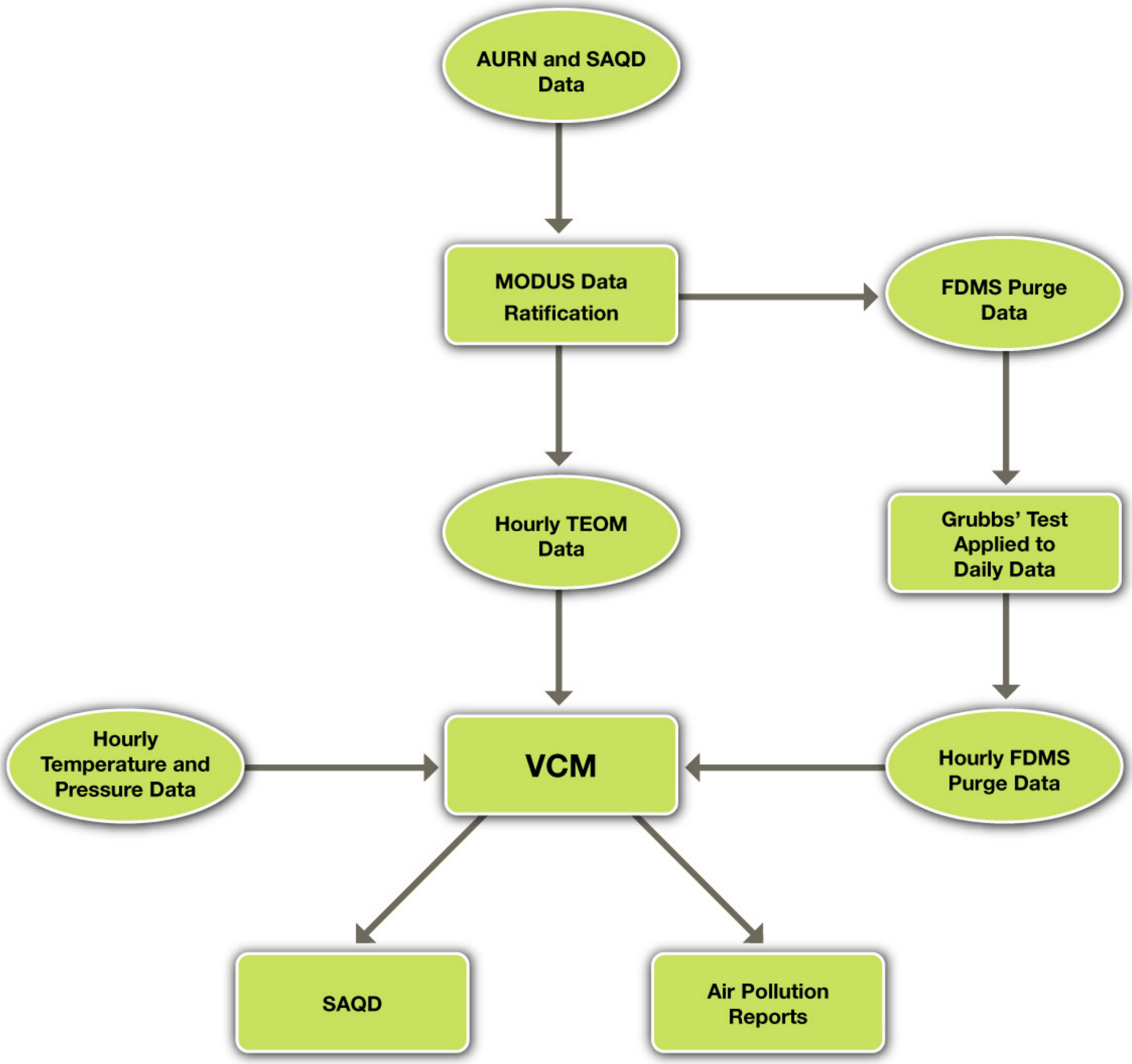
Following the Quality Circle meeting the data are then corrected if required and uploaded as ratified to the database and web site.

Appendix 3 – Volatile Correction Model

Table A3.1 FDMS Monitoring Sites used for VCM Correcting TEOM Data 2016

FDMS Sites used in VCM	Monitoring Network
Aberdeen	AURN
Aberdeen Union Street	SAQD
Alloa A907	SAQD
Angus Forfar Glamis Rd	SAQD
Auchencorth Moss	AURN
East Dunbartonshire Kirkintilloch	SAQD
East Dunbartonshire Milngavie	SAQD
Edinburgh Queensferry Road	SAQD
Edinburgh St Leonards	AURN
Fife Cupar	SAQD
Fife Dunfermline	SAQD
Fife Kirkcaldy	SAQD
Glasgow Anderston	SAQD
Glasgow Abercromby Street	SAQD
Glasgow Broomhill	SAQD
Glasgow Burgher St	SAQD
Glasgow Byres Road	SAQD
Glasgow High St	AURN
Glasgow Nithsdale Road	SAQD
Glasgow Townhead	AURN
Grangemouth	AURN
Paisley Gordon Street	SAQD
Paisley St James St	SAQD
Perth Muirton	SAQD
Renfrew Cockles Loan	SAQD
South Ayrshire Ayr Harbour	SAQD
South Ayrshire Ayr High St	SAQD
South Lanarkshire Cambuslang	SAQD
South Lanarkshire East Kilbride	SAQD
South Lanarkshire Hamilton	SAQD
South Lanarkshire Rutherglen	SAQD
West Lothian Broxburn	SAQD
West Lothian Linlithgow High St 2	SAQD
West Lothian Newton	SAQD

Figure A3.1 Process used for VCM Correcting SAQD TEOM Data



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