Scottish Air Quality Database

Annual Report 2015

Report for Scottish Government

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 2013-2016.

This report presents the activities undertaken during the ninth year of the project – April 2015 to March 2016. In addition to the core work undertaken under the project, there has been significant additional activity and further developments during the year. These have included; Scottish Government funded Clear the Air – Programme study packs for secondary schools; implementation of Inspire Based Open Data Web Services to the Scottish Air Quality Database and website; $PM_{2.5}$ monitoring network evaluation; Investigation of concentrations and ratios of $PM_{2.5}$ and PM_{10} across Scotland to help inform potential changes to objectives and air quality management.

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 $PM_{2.5}$ objectives with the WHO guideline value of 10 µg m^{-3} and to include this in legislation. The Air Quality (Scotland) Amendment Regulations introduced 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 92 automatic monitoring sites throughout Scotland are available in the database for all or part of 2015. 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.

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, 15 local authorities in Scotland have declared a total of 37 AQMAs.

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).

NO_2 Maps for 2014

The NO_2 maps indicate that there were three modelled exceedances of the Scottish annual mean NO_2 objective of 40 µg m^{-3} at background locations in 2014. These three exceedances are located close to Aberdeen Harbour and are linked to emissions from shipping.

The Scotland-specific model predicted that at roadside locations (trunk roads and A roads) the Scottish annual mean NO_2 air quality objective was exceeded along 54 road links (63 km of road). The majority of exceedances were predicted to occur in the Glasgow Urban Area where exceedances were modelled for 34 road links (41 km of road). Overall exceedances of the Scottish annual mean NO_2 air quality objective were modelled in four of the six zones and agglomerations in Scotland.

PM_{10} Maps for 2014

Exceedances of the Scottish annual mean PM_{10} objective of 18 µg m^{-3} were modelled at 71 1 km^2 grid squares in Scotland. 29 exceedances in background concentrations of PM_{10} occur in the vicinity of Edinburgh. 41 exceedances are located close to Aberdeen. The causes of exceedances modelled in these areas are varied and relate to a combination of quarrying and industry, the contribution of road transport emissions to background, or shipping close to Aberdeen Harbour.

72 road links (84 km of road) were identified as exceeding the Scottish annual mean PM_{10} air quality objective. Exceedances of the Scottish annual mean PM_{10} objective were modelled on 15 road links (24.7 km of road) in North East Scotland, 12 road links (9.5 km of road) in Central Scotland and 9 road links in the Edinburgh Urban Area (12.8 km of road).

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.

In terms of concentrations of oxides of nitrogen (NO_x), the longest-running urban background monitoring site in Scotland is Aberdeen, Errol Place (in operation from late 1999 onwards). NO_x concentrations at this site increased slightly in its earlier years of operation but have shown a general decrease since 2002. The pattern for NO_2 is in some respects similar to that observed for NO_x, in that it peaks around 2002 with a subsequent decrease: however, NO_2 appears to show more variation.

Three urban non-roadside sites have been monitoring NOx since 2004 or earlier; Aberdeen Errol Place, Edinburgh St Leonards, and Grangemouth. All three sites show a positive trend (i.e. decreasing NO_x). The actual decrease year-on-year is small; however, the trend is statistically highly significant at Aberdeen Errol Place, and significant at Edinburgh St Leonards. In the case of NO_2 all sites again show a slight negative trend, though the year-on-year decrease is even smaller than for total NO_x.

Three long-running rural sites have monitored NO_x since 2005 or earlier: Bush Estate, Eskdalemuir and Glasgow Waulkmillglen Reservoir. While the sites at Bush Estate and Eskdalemuir show small but highly significant downward trends, this is not the case for Glasgow Waulkmillglen Reservoir, where – by contrast - concentrations are increasing (though the trend is not significant).

At Scotland's longest running traffic-related urban site, Glasgow Kerbside, there is considerable fluctuation in NOx at this site, but some indication of an overall downward trend. By contrast, in the case of NO_2, there is no apparent downward trend over this period.

Looking at a subset of nine long-running sites at urban traffic locations (Aberdeen Anderson Drive, Dumfries, East Dunbartonshire Bishopbriggs, Edinburgh Gorgie Road, Glasgow Byres Road, Glasgow Kerbside, Inverness, Perth Atholl Street and Perth High Street). Seven of the sites show a downward trend in NO_x, however, both Aberdeen Anderson Drive and Inverness show slight upward trends (statistically significant in the case of Aberdeen Anderson Drive).

In the case of NO_2, five of the sites (Dumfries, East Dunbartonshire Bishopbriggs, Edinburgh Gorgie Road, Perth Atholl Street and Perth High Street) show statistically significant downward trends. Inverness shows a small but statistically significant upward trend and the remaining three show no significant trend at all. This is similar to the previous two years reports and indicating that trends depend greatly on local conditions. This may be illustrated by data from Dundee, where four urban traffic monitoring sites have been measuring NO_2 since 2006. Even though all these sites are at roadside locations, and in the same city, they show different trends in NO_2 concentration.

PM_{10}

The longest-running Scottish urban background PM_{10} monitoring site is Aberdeen Errol Place (since 1999). This shows no clear trend in the early years, followed by a significant decrease from around 2004 until 2015.

Looking at a subset of longest running urban non roadside sites (Aberdeen Errol Place, Dundee Mains Loan, Edinburgh St Leonards and Grangemouth), all sites show a negative trend significant at 0.001.

In terms of long term traffic related sites. A subset of the longest running sites all show a statistically significant downward trend, indicating a year on year decrease.

Since Glasgow Kerbside ceased monitoring PM_{10} in 2014, the longest-running urban traffic PM_{10} monitoring site is now Inverness (which began monitoring this pollutant in 2001). This site too shows a highly significant downward trend, significant at the 0.001 level.

$PM_{2.5}$

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

When Glasgow Kerbside is compared to other similar sites in the UK, it appears that downward trends in $PM_{2.5}$ concentrations are now being observed at roadside locations around the UK. However, this is not consistent at all sites and there is still a considerable variation. It is possible that this variation reflects differing trends in relevant factors influencing localised $PM_{2.5}$ concentrations (such as traffic flow)

Ozone

For all long running rural ozone sites (Bush Estate, Eskdalemuir and Strath Vaich), though fluctuating considerably, plots show a small but statistically significant upward trend. In contrast to the pattern observed at rural sites, both these urban background sites show decreasing trends in ozone concentration in the years since 2004. The trends are statistically significant at both sites.

Emissions of Pollution Species

Scotland's NO_x emissions have declined by 67% since 1990 and in 2013 accounted for 9% (94kt) of the UK total. Road transport combustion and power generation represent the main sources of decline in NO_x emissions.

Since 2009 the decreasing trend in NO_x emissions appears to have slowed in all sectors with the exception of transport sources. Energy sources is shown to have 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.

Emissions of PM_{10} have declined by 53% since 1990 and in 2013 accounted for 11% (14kt) of the UK total. At 35%, emissions from commercial, domestic and agricultural combustion were the main source of PM_{10} in 2013. The percentage emissions from this source appears to have increased since 2000. Emissions from energy industries which accounted for 25% of total emissions in 1990 have significantly reduced to 6% in 2013. This reduction is primarily due to abatement at coal fired stations, and the reduction in coal fired energy generation in place of natural gas (which has negligible PM_{10} emissions), nuclear and renewable sources.

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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 and evaluate Scottish air quality policies. 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 results of this study are discussed in the Pilot Study Report. 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 2015 in the on-going project tasks and also highlights the considerable new work undertaken during 2015.

Section 2 provides information on the Air Quality in Scotland website (which was re-launched in March 2014), with Section 3 providing a brief summary of the Annual Air Quality in Scotland seminar which took place in March 2016. Section 2 explains the legislation and policy behind air quality requirements in Scotland and the UK. This section will focus more specifically on the introduction of the Cleaner Air for Scotland Strategy in November 2015 and the associated introduction of the $PM_{2.5}$ objectives in April 2016.

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 pollutions 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.

The corresponding QA/QC programmes have expanded and adapted to encompass these additions. 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 2015.

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 data such as Poly-aromatic Hydrocarbon and metals networks.

In 2009, a pilot mapping exercise 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. The Scottish pollution climate mapping work carried out in 2015 is described in Section 7.

Section 8 provides a discussion of trends in pollutant concentrations across Scotland, based on the latest available data. 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.

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. This data has been updated for 2012 and this report also includes a section on emissions in Scotland with data from both the National Atmospheric Emissions Inventory (NAEI) and the SEPA SPRI (Section 9).

2 Legislation and Policy

Air quality management is based on a series of statutory requirements and policy programmes originating from Europe, the UK and Scotland.

The foundations of Scotland's air quality management system are based on the following air quality directives adopted by all Member States of the European Union:

- Directive 2008/50/EC on ambient air quality and cleaner air for Europe (the Air Quality Directive).
- Directive 2004/107/EC (the Fourth Daughter Directive) relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons (PAH) in ambient air.

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

Further legislation is also in place to control emissions of air pollutants, with the main legislation being the UNECE Gothenburg Protocol. The Protocol was originally adopted by the executive body in 1999 to abate acidification, eutrophication and ground-level ozone and sets emission ceilings for 2010 for sulphur, NO_x, volatile organic compounds (VOCs) and ammonia. Similar ceilings have since been set in European law under the 2001 National Emission Ceilings Directive (2001/81/EC), which was subsequently made into UK law as the National Emission Ceilings Regulations 2002. The Protocol has since been amended in 2012 to include national emission reduction commitments to be achieved in 2020 and beyond. Further information on the protocol is available at http://www.unece.org/env/lrtap/multi_h1.html.

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. Standards are concentrations of pollutants that are considered safe for humans and the environment. 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 are set out in the European 2008 Ambient Air Quality Directive (2008/50/EC) and transposed into Scottish legislation by the Air Quality Standards (Scotland) Regulations 2010. It is the responsibility of EU Member States to achieve the limit and target values.

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

Table 2.1: Scottish Local Air Quality Management Objectives

Pollutant	Air Quality Objective		Date to be achieved by
	Concentration	Measured as	
Benzene	16.25 µg/m^3	Running annual mean	31.12.2003
	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	0.5 µg/m^3	Annual mean	31.12.2004
	0.25 µg/m^3	Annual mean	31.12.2008
Nitrogen dioxide	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
Particles (PM_{10}) (gravimetric)	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
Particles ($PM_{2.5}$) (gravimetric)	10 µg/m^3	Annual mean	2020
Sulphur dioxide	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

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 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

CAFS considers the impact of air quality on health and looks at the estimated costs as well as the premature deaths associated with poor air quality. It has been estimated that 2,000 premature deaths and around 22,500 lost life-years across the Scottish population are linked to fine particulate air pollution[1].

The document sets out the main objectives and actions required to achieve improvements in Air Quality.

A summary of the six main objectives and the 40 actions stated in CAFS are set out below:

i. TRANSPORT

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

This will be achieved by:

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

ii. HEALTH

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 $PM_{2.5}$.

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

iii. LEGISLATION and POLICY

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

This will be achieved by:

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

iv. PLACEMAKING

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

This will be achieved by:

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

v. COMMUNICATION

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

This will be achieved by:

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

vi. CLIMATE CHANGE

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

This will be achieved by:

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

Updated $PM_{2.5}$ objective

As outlined in CAFS, the Scottish government decided to replace the existing provisional Scottish $PM_{2.5}$ objectives with the WHO guideline value of 10 ug m^{-3}. This was introduced into legislation by the Air Quality (Scotland) Amendment Regulations 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).

Additionally, to refocus the Local Air Quality Management system, new guidance documents from Defra and the Scottish Government were published in April 2016.

2.3 Local Air Quality Management

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

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

The Scottish Government Policy Guidance and UK wide Technical Guidance on LAQM were updated in April 2016. The newly published Defra and devolved administrations' 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. One of the main changes is to the LAQM reporting process. An Annual Progress Report (APR) will replace the previous 3-year cyclical process. The LAQM Policy and Technical Guidance's are available at http://www.scottishairquality.co.uk/air-quality/legislation.

3 Air Quality Seminar and Newsletter

As part of the Scottish Air Quality Database project, Ricardo Energy & Environment organise, on behalf of Scottish Government, an annual air quality seminar. The latest Scottish Government Annual Air Quality Seminar was held in the IET Glasgow, Teacher Building, 14 St Enoch Square, Glasgow, on Tuesday 22nd March 2016. The event was attended by over 60 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; Removing the Effects of Weather from Trends – Improving Insights for Air Pollution Data Analysis by Dr David Carslaw (Ricardo Energy & Environment & University of York); Remote Sensing Real Driving Emission in Aberdeen by Dr James Tate (Leeds Institute for Transport Studies); PM Ration and Network Design by Stephen Stratton (Ricardo Energy & Environment); Developing the Data Analysis and Visualisation Tools within the Scottish Air Quality Database by Dr Colin Gillespie (SEPA). 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 the legislative and policy background to air quality control 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 26th March 2015

The Scottish Government

RICARDO

SCOTTISH AIR QUALITY DATABASE AND WEBSITE ANNUAL SEMINAR

Thursday 22 March 2016

IET Glasgow Teacher Building, 14 St Enoch Square, Glasgow G1 4DB

Agenda

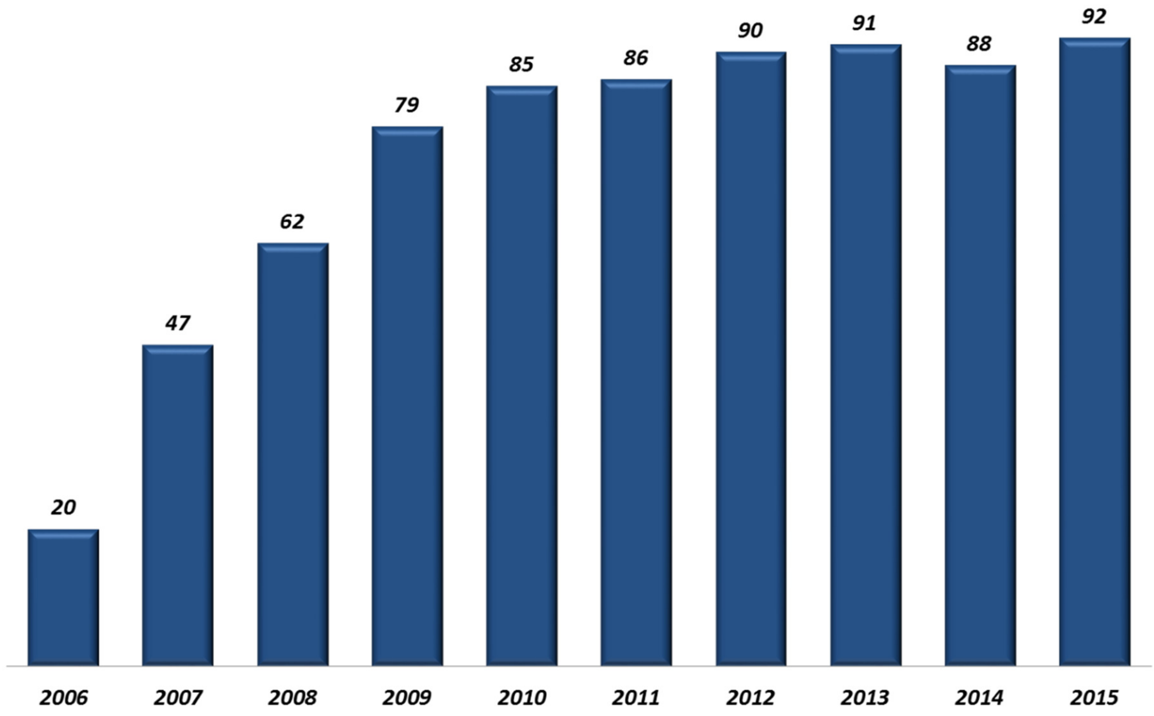
09:15	Registration	
10:00	Welcome and Introduction	Andrew Taylor – Scottish Government
10:20	Removing the Effects of Weather from Trends – Improved Insights for Air Pollution Data Analysis	Dr David Carslaw – University of York / Ricardo Energy & Environment
10:50	Tea/Coffee Break	
11:05	Remote Sensing Real Driving Emissions in Aberdeen	Dr James Tate – Leeds Institute for Transport Studies
11:35	PM Ratio and Network Design	Stephen Stratton - Ricardo Energy & Environment
12:05	Lunch	
12:50	Background Air Quality Network Monitoring at High and Low Temporal Resolution: Data Uses and Future Challenges	Dr Christine Braban – Centre for Ecology and Hydrology
13:20	Developing the Data Analysis and Visualisation Tools within the Scottish Air Quality Database	Dr Colin Gillespie – Scottish Environment Protection Agency
13:50	Sensor Observatory Service	Tony Bush – Apertum
14:20	Innovative Technologies	Dr Justin Lingard - Ricardo Energy & Environment
14:50	Tea/Coffee Break	
15:05	Clear the Air	Jennifer Simpson - Ricardo Energy & Environment
15:35	Breathe Scotland	Dr Geeta Puri – Environmental Protection Scotland
16:00	Q&A – Session Close	

4 Data Availability 2015

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

At the end of 2015 the Scottish Air Quality Database contained data for a total of 92 automatic monitoring sites. In total, four new monitoring sites were incorporated into the database during 2015: Alloa A907, Angus Forfar Glamis Rd, Falkirk Grangemouth Zetland Park and Glasgow High St. Two monitoring sites; Alloa and East Ayrshire John Finnie St were decommissioned during 2015. Figure 4.1 shows the growth of the SAQD from 20 sites in 2006 pilot study to 92 sites during 2015.

Figure 4.1 Number of Monitoring Sites within the Scottish Air Quality Database Network 2006 - 2015



For the 19 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 2015, 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 2015

Site Name	Type	East	North	Pollutants	Network	Start Year[#]	Data in 2015
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}	SAQD	2008	Jan – Dec
Alloa*	RS	288750	693150	PM_{10}	SAQD	2010	Jan
Alloa A907+	RS	288689	693068	NO_2 PM_{10}	SAQD	2015	Feb – Dec
Angus Forfar Glamis Road+	RS	345248	750385	PM_{10}	SAQD	2015	Oct – Dec
Auchencorth Moss	R	322167	656123	13BD BENZ O_3 PM_{10} $PM_{2.5}$ TOL XYL	AURN	2006	Jan – Dec
Bush Estate	R	324626	663880	NO_2 O_3	AURN	1986	Jan – Dec
Dumbarton Roadside	RS	240234	675193	NO_2	AURN	2010	Jan – Dec
Dumfries	RS	297012	576278	NO_2	AURN	2001	Jan – Dec
Dundee Broughty Ferry Road	RS	341970	730997	PM_{10} SO_2	SAQD	2006	Jan – Dec
Dundee Lochee Road	KS	330773	738861	NO_2 PM_{10}	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 – Dec
Dundee Whitehall Street	KS	330155	740279	NO_2	SAQD	2006	Jan – Dec
East Ayrshire Kilmarnock John Finnie St*	RS	242691	638095	NO_2 PM_{10}	SAQD	2010	Jan – Jun
East Ayrshire Kilmarnock St Marnock St	RS	242742	637705	NO_2 PM_{10}	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
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 – Dec
Edinburgh Queensferry Road	RS	318734	674931	NO_2 PM_{10}	SAQD	2011	Jan – Dec
Edinburgh Salamander St	RS	327621	676342	NO_2 PM_{10}	SAQD	2009	Jan – Dec
Edinburgh St John's Road	KS	320100	672890	NO_2	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 Banknock^	RS	277247	679026	PM_{10} $PM_{2.5}$	SAQD	2013	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	2015	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}	SAQD	2007	Jan – Dec
Fife Cupar	RS	337401	714572	NO_2 PM_{10}	SAQD	2005	Jan – Dec
Fife Dunfermline	RS	309912	687738	NO_2 PM_{10}	SAQD	2007	Jan – Dec
Fife Kirkcaldy	RS	329143	692986	NO_2 PM_{10}	SAQD	2011	Jan – Dec
Fife Rosyth^	RS	311752	683515	NO_2 PM_{10} $PM_{2.5}$	SAQD	2008	Jan – Dec

Site Name	Type	East	North	Pollutants	Network	Start Year#	Data in 2015
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
Glasgow Dumbarton Road	RS	255030	666608	NO_2 PM_{10}	SAQD	2012	Jan – Dec
Glasgow Kerbside	KS	258708	665200	NO_2	AURN	1997	Jan – Dec
Glasgow Great Western Road	RS	258007	666650	NO_2	AURN	2015	Jan – Dec
Glasgow High Street+	RS	260014	665348	NO_2 PM_{10} $PM_{2.5}$	AURN	2015	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}	SAQD	2015	Mar - Dec
Inverness	RS	265720	845680	NO_2 $PM_{10}$$PM_{2.5}$	AURN	2001	Jan – 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	2015	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 St^	KS	232142	638892	NO_2 PM_{10} $PM_{2.5}$	SAQD	2009	Jan – Dec
Paisley Glasgow Airport	A	248296	666544	NO_2	SAQD	2004	Jan – Jul
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
Shetland Lerwick~	R	445337	1139683	NO_2 SO_2	SAQD	2012	-
South Ayrshire Ayr Harbour	RS	233617	622749	NO_2 PM_{10}	SAQD	2012	Jan – Dec
South Ayrshire Ayr High St	RS	233725	622120	NO_2 PM_{10}	SAQD	2007	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 Rutherglen	RS	261113	661690	NO_2 PM_{10}	SAQD	2012	Jan – Dec
South Lanarkshire Uddingston^	RS	269657	660305	NO_2 PM_{10}, $PM_{2.5}$	SAQD	2013	Jan – Dec
Stirling Craigs 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 2015
* Sites closed during 2015
^Changes in number of measured pollutants or monitoring method during 2015
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 2015

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

Sites opened during 2015:

• Alloa A907	NO_2, PM_{10}	from 14/01/2015
• Angus Forfar Glamis	PM_{10}	from 23/10/2015
• Falkirk Grangemouth Zetland Pk	SO_2	from 06/05/2015
• Glasgow High St	NO_2 PM_{10} $PM_{2.5}$	from 27/01/2015

Sites closed during 2015:

• Alloa	PM_{10}	on 13/01/2015
• East Ayrshire Kilmarnock John Finnie St	NO_2, PM_{10},	on 08/06/2015

Sites changes during 2015:

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

- Aberdeen Market St 2 on 30/09/2015
- Falkirk Banknock on 28/01/2015
- Fife Rosyth on 12/07/2015
- North Ayrshire Irvine High St on 16/04/2015
- West Dunbartonshire Clydebank on 13/03/2015

Monitoring of $PM_{2.5}$ and PM_{10} using a FIDAS analyser in addition to NO_2 at the following sites:

- South Lanarkshire Lanark on 10/04/2015
- South Lanarkshire Uddingston on 04/03/2015

Glasgow Anderston and Paisley Glasgow Airport were off during 2015 due to electrical power issues.

4.2 Volatile Correction Model

4.2.1 Background

The EU Directive on Ambient Air Quality[2] and the UK Air Quality Strategy[3] set targets and limit values 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

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

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

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 inter-comparison data obtained in Edinburgh, has also been widely used.

The results of the formal UK PM_{10} Equivalence Study[4] carried out in 2006, showed that data from the TEOM could not be considered as equivalent to the EU reference method, whether or not a correction 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 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 130km of an FDMS TEOM can be corrected with data from that analyser.

KCL developed aweb portal (http://www.volatile-correction-model.info/Default.aspx), to enable the model to be applied in a step-by-step approach. The model enables the user to input daily or hourly-average pressure, temperature measurements and purge measurements (volatile measurements) from Filter Dynamics Measurement System (FDMS) analysers. The measured volatile fraction is then added to the TEOM measurements giving the corrected data.

4.2.2 Use of the VCM in Scotland

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

However, additional refinement of the VCM model has been undertaken and hourly meteorological data for all parameters has been sourced. As a result, VCM correction of the 2009 to 2015 datasets has been undertaken on an hourly basis. This also brings into line the processing of the Scottish local authority data with that of the AURN.

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

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

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

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

For the 2015 corrections, temperature and pressure data from Edinburgh Airport meteorological monitoring stations were utilised. This site was selected as a good representation 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. Table 4.2 lists the sites used for correcting hourly TEOM data from Central Scotland and Aberdeen. A total of 32 FDMS sites were used for correcting hourly average TEOM data.

Any outliers in the FDMS purge measurements were identified using Grubbs' Test[5] on daily average data. All hourly data within a day identified as an outlier were then removed from the data set and the average of each hourly purge measurement from the FDMS sites was calculated and used in the VCM calculations.

The corrected data for 2015 and calculated summary statistics have been provided to the local authorities. In addition, the SAQD website database now shows all ratified TEOM data for 2015 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 2015 SAQD TEOM data is shown in Figure 4.2. However, note 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 4.2 FDMS Monitoring Sites used for VCM Correcting TEOM Data 2015

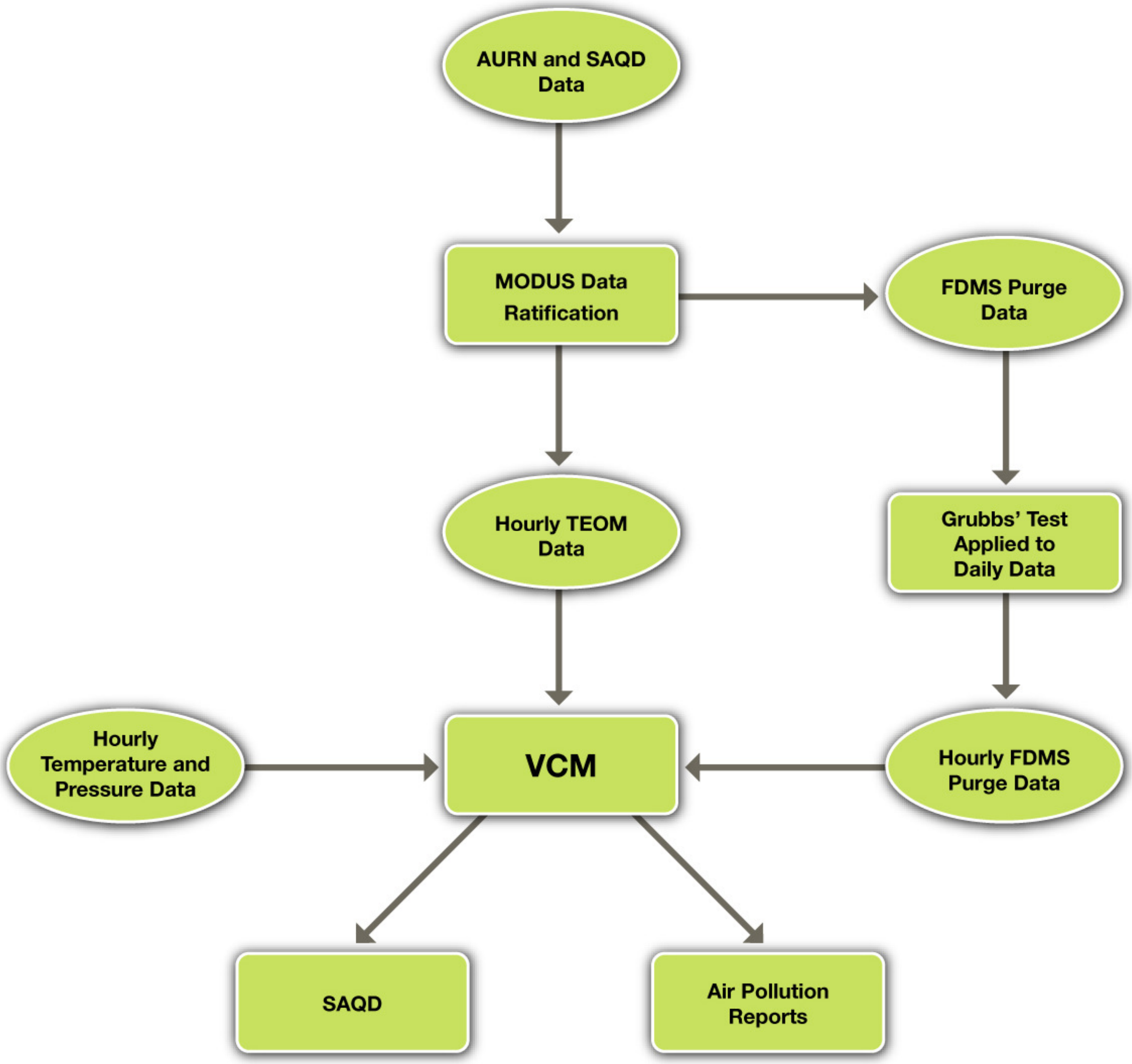
FDMS Sites used in VCM	Monitoring Network
Aberdeen	AURN
Alloa A907	SAQD
Angus Forfar Glamis Rd	SAQD
Auchencorth Moss	AURN
East Ayrshire Kilmarnock John Finnie St	SAQD
East Dunbartonshire Kirkintilloch	SAQD
East Dunbartonshire Milngavie	SAQD
Edinburgh Queensferry Road	SAQD
Edinburgh St Leonards	AURN
Fife Cupar	SAQD
Fife Dunfermline	SAQD
Fife Kirkcaldy	SAQD
Fife Rosyth	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

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

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

FDMS Sites used in VCM	Monitoring Network
Paisley St James St	SAQD
Perth Muirton	SAQD
South Ayrshire Ayr Harbour	SAQD
South Ayrshire Ayr High St	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 4.2 Process used for VCM Correcting SAQD TEOM Data



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 6-months, daily automatic data collection and validation and data ratification in 3-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. Inter-calibration 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.

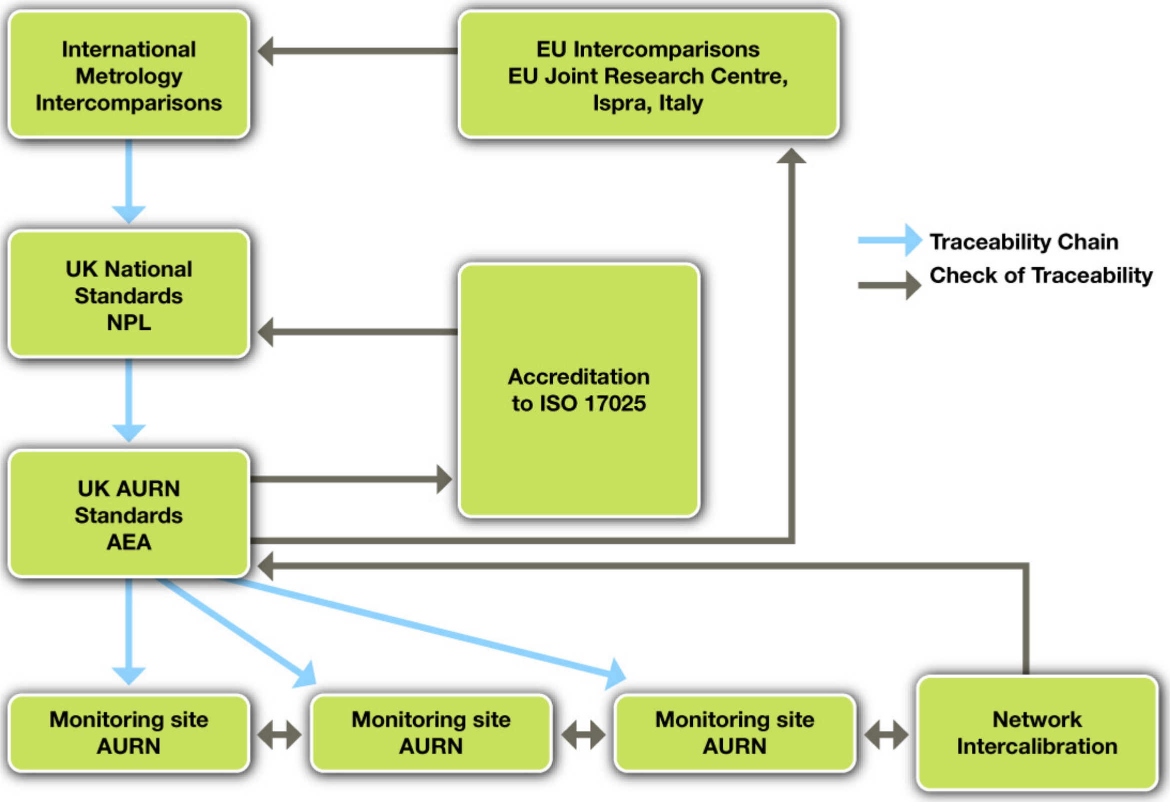
The assessment of the on-site calibration cylinder concentrations against accredited and traceable Ricardo Energy & Environment gas standard cylinders provides the essential final link in the measurement traceability chain (Fig 5.1). This process ensures that all monitoring stations in Scotland are traceable 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 inter-calibration 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 are routinely performed and these are integrated into the streamlined automatic data management system. Data are retrieved automatically from the Scottish air quality monitoring stations (*data acquisition*). The data are then rapidly processed by applying the latest available calibration factors (*data scaling*) and carefully screened using specifically developed computer algorithms to identify suspect data or equipment faults (*data validation*). These validated data are then appended to the site database and uploaded to the Scottish Database and Website. These operations are carried out automatically by computer systems, with all output manually checked by data management experts.

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

5.3 Data Ratification

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

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

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

Data ratification of the Scottish local authority station data is undertaken on a 3-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 2015

As discussed above, site inter-calibrations and audit visits are undertaken at 6-monthly intervals. However, where a site joins the database part way through a year then it is possible that only one audit will be conducted during the year. Table 5.2 shows the full list of inter-calibrations and audits undertaken on air quality sites in the Scottish Database during 2015.

The majority of analysers and sites were found to be operating satisfactorily during the audits. However, inevitably some problems were identified at some sites, these are summarised in Table 5.

Table 5.1 Monitoring site faults identified during the 2015 audits

Fault	Number of Monitoring Sites Winter 2014/15	Number of Monitoring Sites Summer 2015
TEOM** and TEOM FDMS k_0 out by > 2.5%	3	4
Particulate Analyser*** flow out by >10%	9	2
NO_x analyser converter <97% efficiency	8	7
NO cylinder out by >10%	5	9
SO_2 cylinder out by >10%	2	1
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 typical faults that are found during audit and inter-calibration exercises and as can be seen from the 2015 figures.

In many cases, the results from the audit and inter-calibration 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 2015, where the period Winter 2014/15 corresponds to Dec-14 to Mar-15 and Summer 2015 corresponds to Jun-14 to Aug-15.

5.4.1 Data Ratification

With the renewal of the Scottish Air Quality Database and Website contract in 2013, data ratification was brought in line with the AURN schedule and is now undertaken at 3-monthly intervals. Hence, as with the inter-calibrations and audits, if the site joins the database part way through a year then data can only be ratified from the date of the site joining the database.

All ratified data for 2015 have now been uploaded to the Scottish Air Quality website and Table 5.3 summarises the ratification undertaken during 2015. 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 inter-calibration and audits conducted during 2015

Site Name	Winter 2014/15	Summer 2015	Site Name	Winter 2014/15	Summer 2015
Aberdeen Anderson Dr	✓	✓	Glasgow Abercromby Street	✓	✓
Aberdeen Errol Place	✓	✓	Glasgow Anderston	-	-
Aberdeen King Street	✓	✓	Glasgow Broomhill	✓	✓
Aberdeen Market Street 2	✓	✓	Glasgow Burgher Street	✓	✓
Aberdeen Union St	✓	✓	Glasgow Byres Road	✓	✓
Aberdeen Union Street Roadside	✓	✓	Glasgow Dumbarton Road	✓	✓
Aberdeen Wellington Road	✓	✓	Glasgow Kerbside	✓	✓
Alloa	✓	-	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	✓	✓	Lerwick	✓	✓
Dundee Seagate	✓	✓	N Lanarkshire Chapelhall	✓	✓
Dundee Union Street	✓	✓	N Lanarkshire Coatbridge Whifflet	✓	✓
Dundee Whitehall Street	✓	✓	N Lanarkshire Croy	✓	✓
East Ayrshire Kilmarnock John Finnie	✓	✓	N Lanarkshire Kirkshaws	✓	✓
East Ayrshire Kilmarnock St Marnock	✓	✓	N Lanarkshire Moodiesburn	✓	✓
East Dunbartonshire Bearsden	✓	✓	N Lanarkshire Motherwell	✓	✓
East Dunbartonshire Bishopbriggs	✓	✓	N Lanarkshire Shawhead Coatbridge	✓	✓
East Dunbartonshire Kirkintilloch	✓	✓	North Ayrshire Irvine High St	✓	✓
East Dunbartonshire Milngavie	✓	✓	Paisley Glasgow Airport	✓	✓

Site Name	Winter 2014/15	Summer 2015	Site Name	Winter 2014/15	Summer 2015
East Lothian Musselburgh N High St	✓	✓	Paisley Gordon Street	✓	✓
Edinburgh Currie	✓	✓	Paisley St James St	✓	✓
Edinburgh Glasgow Road	✓	✓	Peebles	✓	✓
Edinburgh Gorgie Road	✓	✓	Perth Atholl Street	✓	✓
Edinburgh Queen Street	✓	✓	Perth Crieff	✓	✓
Edinburgh Queensferry Road	✓	✓	Perth High Street	✓	✓
Edinburgh Salamander St	✓	✓	Perth Muirton	✓	✓
Edinburgh St John's Road	✓	✓	Shetland Lerwick	✓	✓
Edinburgh St Leonards	✓	✓	South Ayrshire Ayr Harbour	✓	✓
Eskdalemuir	✓	✓	South Ayrshire Ayr High St	✓	✓
Falkirk Banknock	✓	✓	South Lanarkshire East Kilbride	✓	✓
Falkirk Grangemouth MC	✓	✓	South Lanarkshire Hamilton	✓	✓
Falkirk Grangemouth Zetland Park	-	✓	South Lanarkshire Lanark	✓	✓
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	✓	✓

Table 5.3 Data Ratification undertaken during 2015

Site Name	Q1	Q2	Q3	Q4	Site Name	Q1	Q2	Q3	Q4
Aberdeen Anderson Dr	✓	✓	✓	✓	Glasgow Abercromby Street	✓	✓	✓	✓
Aberdeen Errol Place	✓	✓	✓	✓	Glasgow Anderston	-	-	-	-
Aberdeen King Street	✓	✓	✓	✓	Glasgow Broomhill	✓	✓	✓	✓
Aberdeen Market Street 2	✓	✓	✓	✓	Glasgow Burgher Street	✓	✓	✓	✓
Aberdeen Union St	✓	✓	✓	✓	Glasgow Byres Road	✓	✓	✓	✓
Aberdeen Union Street Roadside	✓	✓	✓	✓	Glasgow Dumbarton Road	✓	✓	✓	✓
Aberdeen Wellington Road	✓	✓	✓	✓	Glasgow Kerbside	✓	✓	✓	✓
Alloa	✓	-	-	-	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	✓	✓	✓	✓	Lerwick	✓	✓	✓	✓
Dundee Seagate	✓	✓	✓	✓	N Lanarkshire Chapelhall	✓	✓	✓	✓
Dundee Union Street	✓	✓	✓	✓	N Lanarkshire Coatbridge Whifflet	✓	✓	✓	✓
Dundee Whitehall Street	✓	✓	✓	✓	N Lanarkshire Croy	✓	✓	✓	✓
East Ayrshire Kilmarnock John Finnie	✓	✓	-	-	N Lanarkshire Kirkshaws	✓	✓	✓	✓
East Ayrshire Kilmarnock St Marnock	✓	✓	✓	✓	N Lanarkshire Moodiesburn	✓	✓	✓	✓
East Dunbartonshire Bearsden	✓	✓	✓	✓	N Lanarkshire Motherwell	✓	✓	✓	✓
East Dunbartonshire Bishopbriggs	✓	✓	✓	✓	N Lanarkshire Shawhead Coatbridge	✓	✓	✓	✓
East Dunbartonshire Kirkintilloch	✓	✓	✓	✓	North Ayrshire Irvine High St	✓	✓	✓	✓
East Dunbartonshire Milngavie	✓	✓	✓	✓	Paisley Glasgow Airport	✓	✓	✓	-
East Lothian Musselburgh N High St	✓	✓	✓	✓	Paisley Gordon Street	✓	✓	✓	✓
Edinburgh Currie	✓	✓	✓	✓	Paisley St James St	✓	✓	✓	✓
Edinburgh Glasgow Road	✓	✓	✓	✓	Peebles	✓	✓	✓	✓
Edinburgh Gorgie Road	✓	✓	✓	✓	Perth Atholl Street	✓	✓	✓	✓
Edinburgh Queen Street	✓	✓	✓	✓	Perth Crieff	✓	✓	✓	✓
Edinburgh Queensferry Road	✓	✓	✓	✓	Perth High Street	✓	✓	✓	✓

Edinburgh Salamander St	✓	✓	✓	✓	Perth Muirton	✓	✓	✓	✓
Edinburgh St John's Road	✓	✓	✓	✓	Shetland Lerwick	✓	✓	✓	✓
Edinburgh St Leonards	✓	✓	✓	✓	South Ayrshire Ayr Harbour	✓	✓	✓	✓
Eskdalemuir	✓	✓	✓	✓	South Ayrshire Ayr High St	✓	✓	✓	✓
Falkirk Banknock	✓	✓	✓	✓	South Lanarkshire East Kilbride	✓	✓	✓	✓
Falkirk Grangemouth MC	✓	✓	✓	✓	South Lanarkshire Hamilton	✓	✓	✓	✓
Falkirk Grangemouth Zetland Park	-	✓	✓	✓	South Lanarkshire Lanark	✓	✓	✓	✓
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	✓	✓	✓	✓

6 Air Pollution in Scotland 2015

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 2015.

- Section 6.2 - Other pollutants covered by the Air Quality Strategy – PAH (benzo[a]pyrene), Benzene, 1,3-butadiene and lead - summary statistics for 2014 or 2015 depending on the availability of data.

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

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

Tables 6.1.1 – 6.1.7 show the 2015 annual average data statistics for NO_2, PM_{10}, $PM_{2.5}$ CO, SO_2 and O_3 respectively, for the ratified automatic data from monitoring sites included in the Scottish Air Quality Database. These are shown along with the corresponding data capture for the year.

These data will have been used by local authorities to assess air quality within their area as part of the review and assessment process. Where any of the Air Quality Objectives for Scotland have been exceeded, at locations where there is relevant exposure of the general public, then the authority will need to carry out a Detailed Assessment as an addendum to their Annual Progress Report to confirm the exceedance and estimate its extent. Where the exceedance is confirmed then the authority will declare an Air Quality Management Area (AQMA). At the time of writing, 15 local authorities in Scotland have declared a total of 39 AQMAs (see http://www.scottishairquality.co.uk/laqm/aqma). Based on the data in the database, a brief summary of the air quality situation throughout Scotland, along the lines of that already provided in the Newsletter, is given under each table.

6.1.1 Nitrogen Dioxide

Table 6.1.1 Ratified data annual average concentration and data capture for NO_2 in 2015 for monitoring sites in the Scottish Air Quality Database

Site Name	Type	Annual Average NO_2 2015 ($\mu g\ m^{-3}$)	No. hours >200 $\mu g\ m^{-3}$	Data capture NO_2 2015 (%)
Aberdeen Anderson Drive	RS	22	0	64
Aberdeen Errol Place	UB	23	1	99
Aberdeen King St	RS	28	0	99
Aberdeen Market Street 2	RS	36	0	94
Aberdeen Union Street	RS	46	3	94
Aberdeen Wellington Road	RS	40	0	93
Bush Estate	R	6	0	99

Site Name	Type	Annual Average NO_2 2015 ($\mu g\ m^{-3}$)	No. hours >200 $\mu g\ m^{-3}$	Data capture NO_2 2015 (%)
Dumbarton Roadside	RS	17	0	96
Dumfries	RS	30	1	98
Dundee Lochee Road	RS	48	6	87
Dundee Mains Loan	UB	10	0	96
Dundee Meadowside	RS	38	0	83
Dundee Seagate	KS	50	0	100
Dundee Union Street	KS	28	0	100
Dundee Whitehall Street	KS	36	0	96
East Ayrshire Kilmarnock John Finnie St	RS	32	0	43
East Ayrshire Kilmarnock St Marnock St	RS	25	0	90
East Dunbartonshire Bearsden	RS	34	5	98
East Dunbartonshire Bishopbriggs	RS	27	0	99
East Dunbartonshire Kirkintilloch	RS	29	0	95
East Dunbartonshire Milngavie	RS	23	1	94
East Lothian Musselburgh N High St	RS	19	0	85
Edinburgh Currie	UB	7	0	95
Edinburgh Glasgow Road	RS	26	0	99
Edinburgh Gorgie Road	RS	32	0	89
Edinburgh Queen Street	RS	27	0	98
Edinburgh Queensferry Road	RS	41	0	93
Edinburgh Salamander St	RS	28	0	99
Edinburgh St John's Road	KS	65	42	89
Edinburgh St Leonards	UB	26	0	98
Eskdalemuir	R	2	0	98
Falkirk Grangemouth MC	UB	18	0	89
Falkirk Haggs	RS	30	0	90
Falkirk Hope St	RS	21	0	100
Falkirk West Bridge Street	RS	35	0	70
Fife Cupar	RS	27	0	97
Fife Dunfermline	RS	25	0	99
Fife Kirkcaldy	RS	18	0	100
Fife Rosyth	RS	23	0	93
Fort William	S	12	0	91
Glasgow Burgher St	RS	27	0	99
Glasgow Byres Road	RS	38	0	98
Glasgow Dumbarton Road	KS	41	0	97
Glasgow Great Western Road	RS	31	0	99
Glasgow High St	RS	32	0	75
Glasgow Kerbside	KS	60	4	99
Glasgow Townhead	UB	26	0	95
Glasgow Waulkmillglen Reservoir	R	9	0	81
Grangemouth	UI	15	0	95
Grangemouth Moray	UB	15	0	94
Inverclyde Greenock A8	RS	28	0	97
Inverness	RS	28	0	74
Lerwick	R	5	0	65
N Lanarkshire Chapelhall	RS	32	0	68
N Lanarkshire Croy	RS	19	0	99
N Lanarkshire Kirkshaw	RS	25	0	97
N Lanarkshire Moodiesburn	RS	18	0	99
N Lanarkshire Shawhead Coatbridge	RS	36	0	93
North Ayrshire Irvine High St	KS	28	1	94
Paisley Glasgow Airport	A	18	0	53
Paisley Gordon Street	RS	27	0	94
Peebles	S	6	0	90

Site Name	Type	Annual Average NO_2 2015 (µg m^{-3})	No. hours >200 µg m^{-3}	Data capture NO_2 2015 (%)
Perth Atholl Street	RS	49	0	92
Perth Crieff	RS	23	0	97
Perth High Street	RS	22	0	98
Renfrew Cockels Loan	RS	36	0	96
South Ayrshire Ayr Harbour	RS	10	0	91
South Ayrshire Ayr High St	RS	18	0	93
South Lanarkshire East Kilbride	RS	33	5	98
South Lanarkshire Hamilton	RS	35	0	99
South Lanarkshire Lanark	RS	21	0	86
South Lanarkshire Rutherglen	RS	37	0	92
South Lanarkshire Uddingston	RS	29	0	96
Stirling Craigs Roundabout	RS	29	0	34
West Dunbartonshire Clydebank	RS	18	0	96
West Lothian Broxburn	RS	27	0	99
West Lothian Linlithgow High Street 2	RS	33	0	93
West Lothian Newton	RS	21	0	98

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

Table 6.1.1 shows nitrogen dioxide data for 78 sites utilising automatic monitoring during 2015. Although, data for 8 of these are only available for part of the year with the overall data capture less than 75%. These include sites which opened or closed during the year, sites which were closed for part of the year due to instrument problems.

Of the remaining 70 sites with more than 74% data capture, 8 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 Edinburgh St John's Road; a Kerbside site.

The highest annual average concentrations were measured at Edinburgh St John's Road, with a measured concentration of 65 µg m^{-3}. The greatest number of exceedances of the hourly mean objective was measured at Edinburgh St John's Road with 42 exceedances.

6.1.2 Particulate Matter – PM_{10}

Table 6.1.2 Ratified data annual average concentration and data capture for PM_{10} in 2015 for monitoring sites in the Scottish Air Quality Database

Site Name	Type	PM_{10} Analyser Type*	Annual Average PM_{10} 2015 (µg m^{-3})	No. Days > 50 µg m^{-3}	Data Capture (%)
Aberdeen Anderson Dr	RS	TEOM (VCM)	13	2	89
Aberdeen Errol Place	UB	FDMS	12	4	97
Aberdeen King St	RS	BAM (unheated inlet)	17	8	93
Aberdeen Market St 2	RS	BAM (heated inlet)	19	12	96
Aberdeen Union St	RS	FDMS	17	4	61
Aberdeen Wellington Road	RS	TEOM (VCM)	20	16	93
Alloa	RS	FDMS	17	2	27
Auchencorth Moss	R	Partisol	6	0	97
Auchencorth Moss PM10 PM25	R	FDMS	7	0	72
Dundee Broughty Ferry Road	RS	TEOM (VCM)	13	2	99

Site Name	Type	PM_{10} Analyser Type*	Annual Average PM_{10} 2015 ($\mu g\ m^{-3}$)	No. Days > 50 $\mu g\ m^{-3}$	Data Capture (%)
Dundee Lochee Road	K	BAM (unheated inlet)	20	5	92
Dundee Mains Loan	UB	TEOM (VCM)	12	1	97
Dundee Meadowside	RS	BAM (unheated inlet)	16	4	97
Dundee Seagate	K	BAM (unheated inlet)	14	3	97
Dundee Union Street	K	BAM (unheated inlet)	17	7	96
East Ayrshire Kilmarnock John Finnie St	RS	FDMS	18	2	24
East Ayrshire Kilmarnock St Marnock St	RS	BAM (unheated inlet)	14	0	24
East Dunbartonshire Bearsden	RS	Eberline (heated inlet)	14	0	91
East Dunbartonshire Bishopbriggs	RS	Eberline (heated inlet)	15	1	23
East Dunbartonshire Kirkintilloch	RS	FDMS	17	4	83
East Dunbartonshire Milngavie	RS	FDMS	13	0	98
East Lothian Musselburgh N High St	RS	BAM (unheated inlet)	12	1	89
Edinburgh Currie	UB	TEOM (VCM)	9	0	77
Edinburgh Glasgow Road	RS	TEOM (VCM)	15	1	97
Edinburgh Queen Street	RS	TEOM (VCM)	15	2	98
Edinburgh Queensferry Road	RS	FDMS	16	1	87
Edinburgh Salamander St	RS	TEOM (VCM)	20	8	90
Edinburgh St Leonards	UB	FDMS	11	0	45
Falkirk Banknock	UB	TEOM (VCM)	11	4	95
Falkirk Grangemouth MC	UB	TEOM (VCM)	13	0	90
Falkirk Haggs	RS	TEOM (VCM)	15	1	98
Falkirk West Bridge St	RS	TEOM (VCM)	15	2	80
Fife Cupar	RS	FDMS	17	2	80
Fife Dunfermline	RS	FDMS	16	2	87
Fife Kirkcaldy	RS	FDMS	13	2	100
Fife Rosyth	RS	FDMS	14	3	90
Glasgow Abercromby Street	RS	FDMS	14	1	97
Glasgow Broomhill	RS	FDMS	15	2	99
Glasgow Burgher St	RS	FDMS	16	3	96
Glasgow Byres Road	RS	FDMS	10	0	90
Glasgow Dumbarton Road	RS	TEOM (VCM)	17	3	99
Glasgow High St	RS	FDMS	16	2	91
Glasgow Kerbside	K	FDMS	16	0	15
Glasgow Nithsdale Road	RS	FDMS	14	1	93
Glasgow Townhead	UB	FDMS	12	0	44
Glasgow Waulkmillglen Reservoir	R	TEOM (VCM)	11	0	82
Grangemouth	UI	FDMS	12	1	67
Inverclyde Greenock A8	RS	TEOM (VCM)	15	2	96
Inverness	RS	Partisol	9	0	95
N Lanarkshire Chapelhall	RS	TEOM (VCM)	17	0	49
N Lanarkshire Coatbridge Whifflet	UB	TEOM (VCM)	12	1	94
N Lanarkshire Croy	RS	TEOM (VCM)	12	1	97
N Lanarkshire Kirkshaws	RS	TEOM (VCM)	13	1	93

Site Name	Type	PM_{10} Analyser Type*	Annual Average PM_{10} 2015 (µg m^{-3})	No. Days > 50 µg m^{-3}	Data Capture (%)
N Lanarkshire Moodiesburn	RS	BAM (unheated inlet)	10	0	83
N Lanarkshire Motherwell	RS	TEOM (VCM)	13	2	67
N Lanarkshire Shawhead Coatbridge	RS	BAM (unheated inlet)	16	1	67
North Ayrshire Irvine High St	K	BAM (unheated inlet)	14	1	97
Paisley Gordon Street	RS	FDMS	14	0	61
Paisley St James Street	RS	FDMS	13	1	91
Perth Atholl Street	RS	TEOM (VCM)	18	6	84
Perth Crieff	RS	BAM (unheated inlet)	14	0	96
Perth High Street	RS	TEOM (VCM)	13	1	98
Perth Muirton	UB	FDMS	9	0	93
Renfrew Cockles Loan	RS	FDMS	14	3	70
South Ayrshire Ayr Harbour	RS	FDMS	13	1	85
South Ayrshire Ayr High St	RS	FDMS	15	1	88
South Lanarkshire East Kilbride	RS	FDMS	16	4	91
South Lanarkshire Hamilton	RS	FDMS	17	3	93
South Lanarkshire Lanark	RS	FIDAS	10	1	72
South Lanarkshire Rutherglen	RS	FDMS	18	5	93
South Lanarkshire Uddingston	RS	FIDAS	11	2	80
Stirling Craigs Roundabout	RS	TEOM (VCM)	12	0	72
West Dunbartonshire Clydebank	RS	FIDAS	10	0	78
West Lothian Broxburn	RS	FDMS	15	2	87
West Lothian Linlithgow High St 2	RS	FDMS	15	2	91
West Lothian Newton	RS	FDMS	16	0	88

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

Table 6.1.2 shows the 2015 gravimetric equivalent particulate matter PM_{10} data from 76 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 59 sites with 75% or greater data capture, 4 sites exceeded the annual average PM_{10} Objective of 18 µg m^{-3} and a further 3 equaled this Objective. Of these sites, Aberdeen Market St 2, Aberdeen Wellington Rd and Edinburgh Salamander St also exceeded the daily mean objective of 50 µg m^{-3} not to be exceeded more than 7 times in a year. The daily mean object was also exceeded at Aberdeen King St, unusually without exceeding the annual mean objective.

The maximum PM_{10} annual mean concentration was measured at Aberdeen Wellington Rd, Dundee Lochee Rd and Edinburgh Salamander St with a measured annual mean concentration of 20 µg m^{-3} and 16, 5 and 8 exceedances of the daily mean objective, respectively. Of the 17 sites with less than 75% data capture East Ayrshire Kilmarnock John Finnie St measured average PM_{10} concentrations equaling than the annual average PM_{10} Objective of 18 µg m^{-3}. No site exceeded the UK AQS Objective of 40 µg m^{-3} for the annual mean PM_{10} and the daily mean objective of no more than 35 exceedances of 50 µg m^{-3}.

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 6.1.2 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 6 µg m^{-3} and 7 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 6.1.3 Ratified data annual average concentration and data capture for $PM_{2.5}$ in 2015 for monitoring sites in the Scottish Air Quality Database

Site Name	Type	$PM_{2.5}$ Analyser Type	Annual Average $PM_{2.5}$ 2015 (µg m^{-3} gravimetric equivalent)	Data Capture (%)
Aberdeen Errol Place	UB	FDMS	8	88
Aberdeen Market St 2	RS	FIDAS	8	25
Aberdeen Union Street	R	FDMS	11	83
Auchencorth Moss	R	Partisol	3	96
Auchencorth Moss PM10 PM25	R	FDMS	3	95
Edinburgh St Leonards	UB	FDMS	6	86
Falkirk Banknock	RS	FIDAS	6	85
Fife Rosyth	RS	FIDAS	6	45
Glasgow High St	RS	FDMS	8	91
Glasgow Townhead	UB	FDMS	7	93
Grangemouth	UI	FDMS	9	95
Inverness	RS	Partisol	5	94
North Ayrshire Irvine High St	RS	FIDAS	7	69
South Lanarkshire Lanark	RS	FIDAS	6	72
South Lanarkshire Uddingston	RS	FIDAS	6	80
West Dunbartonshire Clydebank	RS	FIDAS	6	78

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

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 kerbside site in Glasgow and 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} being introduced in April 2015, local authorities have introduced $PM_{2.5}$ monitoring. During 2015 $PM_{2.5}$ monitoring started at Fife Rosyth, Falkirk Bankock North Ayrshire Irvine High St, South Lanarkshire Lanark and Uddingston, and West Dunbartonshire Clydebank resulting in a total of 16 $PM_{2.5}$ monitoring sites.

Data capture rates of less than 75% were measured at Aberdeen Market St 2, Fife Rosyth, North Ayrshire Irvine High St and South Lanarkshire Lanark. $PM_{2.5}$ concentrations in excess of the Scottish AQS Objective of 10 µg m^{-3} as an annual mean was measured at Aberdeen Union St with a data capture rate of 83%. Figure 6.1.1 shows the 2015 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 $PM_{2.5}$. A difference in annual mean $PM_{2.5}$ concentrations were measured by the Partisol sampler and FDMS analyser during 2015, with measured annual average $PM_{2.5}$ concentrations of 3 µg m^{-3} by both analysers.

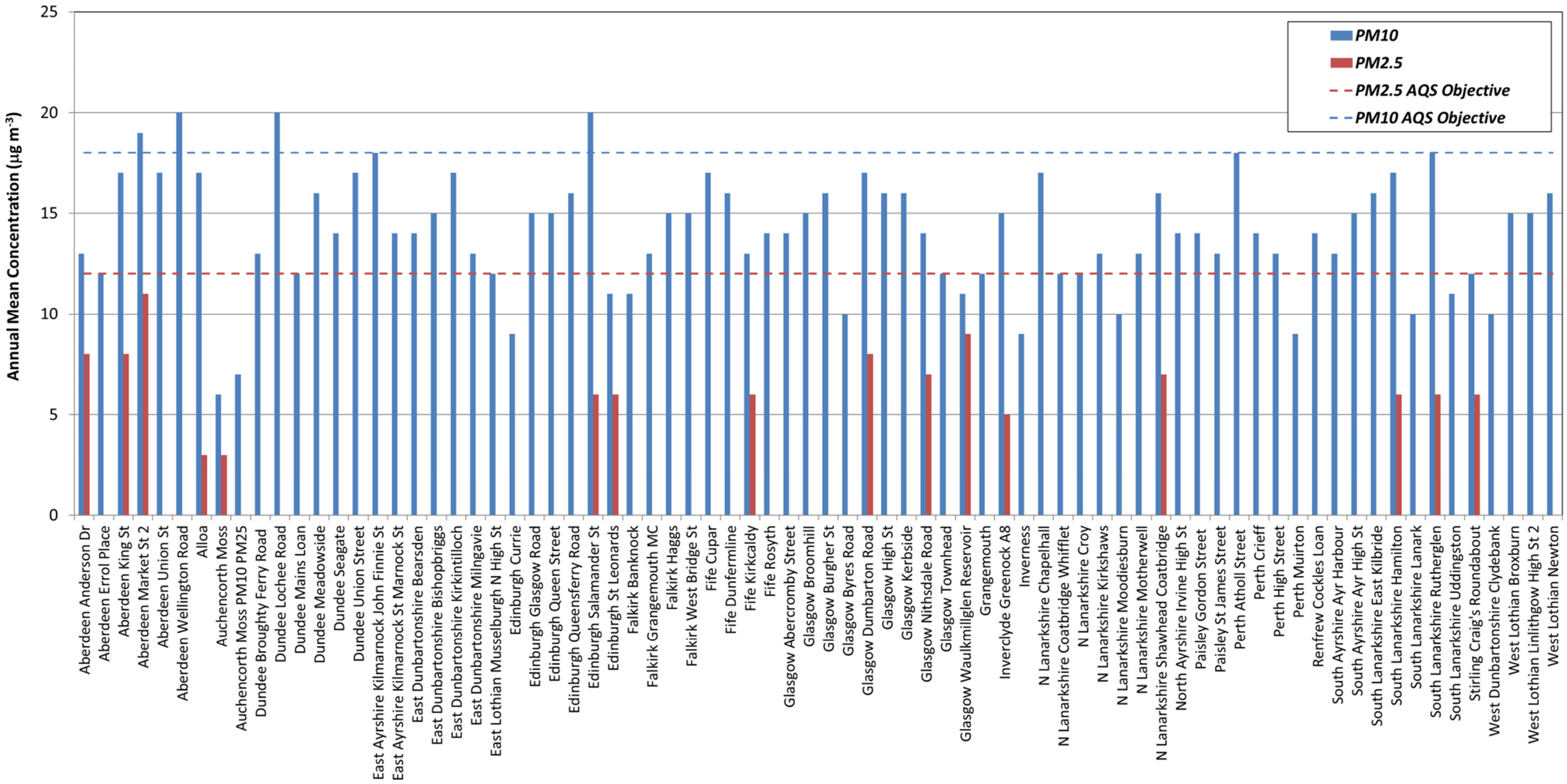
The $PM_{2.5}$/PM_{10} ratios calculated for each site for the years 2009 to 2015 are shown in Table 6.1.4. The highest $PM_{2.5}$/PM_{10} ratios during 2015 for sites with greater than 75% data capture was calculated at Aberdeen Errol Place and Glasgow Kerbside with calculated ratios of 0.69 and 0.70, respectively.

Table 6.1.4 $PM_{2.5}$/PM_{10} ratios for 2009 - 2015 annual average concentrations

Site Name	Annual Average PM_{10} 2015 (µg m^{-3})	Annual Average $PM_{2.5}$ 2015 (µg m^{-3})	Ratio						
			2015	2014	2013	2012	2011	2010	2009
Aberdeen Errol Place	12	8	0.67	0.67	0.69	0.75	0.57	0.54	0.47
Aberdeen Market St 2	19	8	0.42		-	-	-	-	-
Aberdeen Union Street	17	11	0.65	0.72	-	-	-	-	-
Auchencorth Moss	6	3	0.50	0.57	0.57	0.57	0.71	0.50	0.64
Auchencorth Moss PM10 PM25	7	3	0.43	0.88	0.50	0.57	0.50	0.57	0.51
Edinburgh St Leonards	11	6	0.55	0.69	0.57	0.69	0.80	0.64	0.50
Falkirk Banknock	11	6	0.55	-	-	-	-	-	-
Fife Rosyth	14	6	0.43	-	-	-	-	-	-
Glasgow High St	16	8	0.50	-	-	-	-	-	-
Glasgow Townhead	12	7	0.58	0.54	0.50	0.83	1.22	0.79	0.81
Grangemouth	12	9	0.75	0.67	0.64	0.79	0.79	0.79	0.68
Inverness	9	5	0.56	0.55	0.50	0.55	0.50	0.50	0.55
North Ayrshire Irvine High St	14	7	0.50	-	-	-	-	-	-
South Lanarkshire Lanark	10	6	0.60	-	-	-	-	-	-
South Lanarkshire Uddingston	11	6	0.55	-	-	-	-	-	-
West Dunbartonshire Clydebank	10	6	0.60	-	-	-	-	-	-

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

Figure 6.1.1 Annual Average PM_{10} and $PM_{2.5}$ concentrations (µg m^{-3}) for all SAQD sites with more than 75% data capture in 2015*



* $PM_{2.5}$ objective shown was operational prior to April 2016 but did not fall into LAQM regime.

6.1.4 Carbon Monoxide

Table 6.1.5 Ratified data annual average concentration and data capture for CO in 2015 for monitoring sites in the Scottish Air Quality Database

Site Name	Type	Annual Average CO 2015 (mg m^{-3})	Max. Running 8hr Mean CO 2015 (mg m^{-3})	Data Capture (%)
Edinburgh St Leonards	UB	0.2	0.8	95
N Lanarkshire Croy	UB	0.1	0.5	100

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

Table 6.1.5 shows carbon monoxide was monitored using automatic techniques at 2 sites during 2015. All monitoring sites achieved the Air Quality Strategy Objective for this pollutant.

6.1.5 Sulphur Dioxide

Table 6.1.6 Ratified data annual average concentration and data capture for SO_2 in 2015 for monitoring sites in the Scottish Air Quality Database

Site Name	Type	Annual Average SO_2 2015 (µg m^{-3})	No. 15 min SO_2 > 266µg m^{-3} 2015	No. 1 hr SO_2 > 350µg m^{-3} 2015	No. 24 hr SO_2 > 125µg m^{-3} 2015	Data Capture (%)
Dundee Broughty Ferry Road	RS	3	0	0	0	4
Edinburgh St Leonards	UB	2	0	0	0	97
Falkirk Grangemouth MC	UB	3	8	0	0	99
Falkirk Hope St	RS	3	0	0	0	100
Grangemouth	UI	3	1	0	0	97
Grangemouth Moray	UB	3	5	0	0	94
N Lanarkshire Croy	RS	2	0	0	0	99
N Lanarkshire Kirkshaws	RS	1	0	0	0	23
Shetland Lerwick	R	1	0	0	0	63

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

Table 6.1.6 shows sulphur dioxide data from the 9 sites utilising automatic monitoring for 2015. Dundee Broughty Ferry Rd, N Lanarkshire Kirkshaws and Shetland Lerwick were de commissioned on 16/01/15, 25/03/15 and 10/11/15 respectively so data are only available for part of the year. All sites in Scotland met the requirements of the Air Quality Strategy for the 15 minute, 1-hour and 24-hour mean objectives SO_2 in 2015.

6.1.6 Ozone

Table 6.1.7 Ratified data annual average concentration and data capture for O_3 in 2015 for monitoring sites in the Scottish Air Quality Database

Site Name	Type	Annual Average O_3 2015 ($\mu g\ m^{-3}$)	No of days with running 8-hr mean >100 ug m^{-3}	Data capture O_3 2015 (%)
Aberdeen Errol Place	UB	49	0	87
Auchencorth Moss	R	60	8	99
Bush Estate	R	59	7	99
Edinburgh St Leonards	UB	45	3	98
Eskdalemuir	R	57	9	99
Fort William	S	57	7	99
Glasgow Townhead	UB	42	2	99
Glasgow Waulkmillglen Reservoir	R	52	2	97
Lerwick	R	70	8	92
Peebles	S	57	10	98
Strath Vaich	R	70	10	99

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

Table 6.1.7 shows ozone data from 11 sites utilising automatic monitoring for 2015. 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 2015, the Air Quality Strategy Objective of not more than 10 days with a maximum 8 hour running mean greater than 100 $\mu g\ m^{-3}$ was not exceeded at any sites.

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 2014. Where other pollutants are also monitored in these networks, these pollutants are listed, but the data are not provided in this report.

6.2.1 PAH Monitoring Network[6]

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

[6] Conolly C. et al Final Contract Report for the UK PAH Monitoring and Analysis Network (2004-2010) [online] Available at http://uk-air.defra.gov.uk/reports/cat05/1103040911_AEA_PAH_Network_Report_2010_Final_v3.1.pdf [Accessed no 30/05/2012]

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

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

The PAH monitoring sites in Scotland are shown in Table 6.2.1. The sites at Edinburgh and Glasgow are co-located with the Edinburgh St Leonards and Glasgow Townhead AURN sites respectively. The 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 6.2.1 PAH Monitoring Sites in Scotland

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

Annual average concentrations for Benzo(a)pyrene (B(a)P) for 2014 and 2015 are shown in Table 6.2.2. As can be seen the Air Quality Objective for B(a)P of 0.25 ng m^{-3} as an annual average or the EU Directive target value of 1 ng m^{-3} was not exceeded at any site in 2014 or 2015.

Table 6.2.2 Annual Average Benzo(a)Pyrene concentrations for 2014 - 2015 at 4 sites in Scotland

Site	201 Annual Mean B(a)P Concentration (ng m^{-3})	2015 Annual Mean B(a)P Concentration (ng m^{-3})
Auchencorth Moss	0.026	0.022
Edinburgh St Leonards	0.058	0.072
Glasgow Townhead	0.099	0.090
Kinlochleven	0.182	0.218

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 and are co-located with the Grangemouth and Glasgow Kerbside AURN sites. The non-automatic monitoring network provides benzene data for compliance with the EU Air Quality Directive and Scottish objective of 16.25 µg m^{-3} as an annual mean.

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

Results for this site for 2014 and 2015 are provided in Table 6.2.3.

Table 6.2.3 Annual Mean Benzene Concentrations in 2013 and 2015 at 2 sites in Scotland in the UK Non-automatic Hydrocarbon Network

Site Name	Annual Mean benzene for 2014 (µg m^{-3})	Annual Mean benzene for 2015 (µg m^{-3})
Glasgow Kerbside	0.86	0.77
Grangemouth	0.99	0.73

6.2.3 Automatic Hydrocarbon Monitoring

Table 6.2.4 gives the site details for the one automatic hydrocarbon monitoring station in Scotland - Auchencorth Moss; a rural site south of Edinburgh. The data from this site are used both to provide data for ozone precursor hydrocarbon species, in compliance with the EU Air Quality Directive (2008/50/EC). In addition, this site is one of the 2 European Monitoring and Evaluation Programme (EMEP) level II sites (EMEP "supersites") in the UK. The other EMEP supersite is located a Harwell in Oxfordshire. The Harwell site was however decommissioned on the 31st December 2015 and replace with the Chilbolton, Hampshire site. 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 Glasgow Kerbside and Auchencorth Moss can be downloaded from www.scottishairquality.co.uk.

Table 6.2.4 Location of Automatic Hydrocarbon monitoring sites in Scotland

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

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

Table 6.2.5 Annual Average Benzene concentration at Auchencorth Moss in the UK Automatic Hydrocarbon Network, for 2015

Site	2015 Benzene Annual mean concentration (µg m^{-3})	2015 Benzene Maximum running annual concentration (µg m^{-3})	2015 % Data Capture
Auchencorth Moss	0.15	0.15	38

Table 6.2.3 and 6.2.5 indicate that it is unlikely that the EU limit value for benzene of 5 µg m^{-3} was and that 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 2015.

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 6.2.6. Annual Average 1,3-butadiene concentration at Auchencorth Moss in the UK Automatic Hydrocarbon Network, for 2015

Site	2015 1,3-butadiene Annual mean concentration (µg m^{-3})	2015 1,3-butadiene maximum running annual concentration (µg m^{-3})	2015 % Data capture
Auchencorth Moss	0.02	0.02	18

Table 6.2.6 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 2015. 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 www.uk-air.defra.gov.uk. The one urban heavy metal monitoring site in Scotland, named Motherwell South, was decommissioned in in 2013.

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 three rural sites in Scotland are provided in Table 6.2.9 and data for the measurement of lead, nickel, arsenic and cadmium in 2015 are provided in Table 6.2.10. The ***Banchory monitoring site was decommissioned on 04/01/2015.***

Table 6.2.9 Rural Network Metals Monitoring Sites in Scotland

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

Table 6.2.10 Annual Mean metal concentrations 2015 (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	1.23	0.47	0.144	0.0265
Eskdalemuir	0.98	0.37	0.133	0.0236

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)

As discussed in Section 6.2.3 and 6.2.4 the UK Automatic Hydrocarbon Network monitors a wide range of non-methane volatile organic compounds (NMVOC) in addition to the Air Quality Strategy pollutants of Benzene and 1,3-butadiene. At Glasgow kerbside the following pollutants are monitored.

1,3-Butadiene
Benzene
Toluene
Ethylbenzene
(m+p)-Xylene *
o-Xylene

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

Ethane
Ethene
Propane
Propene
Ethyne
2-Methylpropane
n-Butane
trans-2-Butene

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

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

6.3.3 Poly-Aromatic Hydrocarbons (PAH)

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

Benzo(c)phenanthrene
Benzo(a)anthracene
Chrysene
Cyclopenta(c,d)pyrene
Benzo(b)naph(2,1-d)thiophene
5-Methyl Chrysene
Benzo(b+j)fluoranthene
Benzo(k)fluoranthene
Benzo(e)pyrene
Benzo(a)pyrene
Perylene
Indeno(1,2,3-cd)pyrene
Dibenzo(ah.ac)anthracene
Benzo(ghi)perylene
Anthanthrene
Dibenzo(al)pyrene
Dibenzo (ae)pyrene
Dibenzo(ai)pyrene
Dibenzo(ah)pyrene
Coronene
Cholanthrene

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 2015; one in Scotland at Auchencorth Moss.

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

6.3.5 Heavy Metals Network

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

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

Monitoring of the following heavy metals was suspended at Auchencorth Moss on 01/01/2015:

Aluminium (Al), Antimony (Sb), Barium (Ba), Beryllium (Be), Caesium (Cs), Lithium (Li), Mercury (Hg), Molybdenum (Mo), Rubidium (Rb), Scandium (Sc), Strontium (Sr), Tin (Sn), Titanium (Ti), Tungsten (W) and Uranium (U).

6.3.6 United Kingdom Eutrophying & Acidifying Pollutant Network (UKEAP)

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

The UKEAP has four component networks:

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

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

The Precipitation Network (Precip-Net)

There are 38 sites in PrecipNet at which the chemical composition of precipitation (i.e. rainwater) is measured. Six of the sites, Lochnagar, Llyn Llagi, Scoat Tarn, Loch Chon/Tinker, River Etherow, Beaghs Burn and Crai Reservoir (Head of the Valleys) were specifically located within sensitive ecosystems. The network allows estimates of wet deposition of sulphur and nitrogen chemicals.

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

Rural NO_2 Network (NO_2-Net)

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

Triplicate nitrogen dioxide diffusion tube measurements are run at three AURN sites with co-located automatic instruments (Yarner Wood, Harwell and Eskdalemuir). The annual average NO_2 concentration measured at the Eskdalemuir automatic monitoring site was 2 µg m^{-3} in 2015 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 2015 are provided in Table 6.3.1.

Table 6.3.1 NO_2 annual average concentrations 2015 at rural monitoring sites

Site	NO_2 (ug m^{-3})	Data Capture (%)
Allt a'Mharcaidh	1.7	100
Balquhidder 2	2.8	100
Eskdalemuir	3.4	100
Forsinain 2	2.9	100
Glensaugh	3.2	100
Loch Dee	3.2	100
Polloch	1.5	100
Strath Vaich	1.3	100
Whiteadder	5.0	100

Acid Gas and Aerosol Network (AGANET)

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

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

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

National Ammonia Monitoring Network (NAMN)

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

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

7 Air Quality Mapping for Scotland

As part of the Scottish Air Quality Database project, Ricardo Energy & Environment provide mapped concentrations of modelled background air pollutant concentrations on a 1 km x 1 km basis for the whole of Scotland. Modelled roadside air pollutant concentrations are provided for road links in Scotland. The air pollution maps are derived from a combination of (1) measurements from Scotland's network of air quality monitoring stations, and (2) spatially disaggregated emissions information from the UK National Atmospheric Emissions Inventory (NAEI). They provide estimated pollutant concentrations for the whole of Scotland. The methodology for producing the Scottish maps is based on the UK Pollution Climate Mapping (PCM) approach, used for producing air pollution maps for the whole UK for the purposes of annual compliance reporting to the European Commission.

The PCM methodology has been applied to provide pollution maps of Scotland for the Scottish Government for 2014 (the most recent year available) using measurements exclusively from Scottish air quality monitoring sites and Scottish meteorology. The maps provide spatial representation of the annual mean concentrations of:

- PM_{10} (gravimetric equivalent), 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 2011 and are available at:

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

In July 2016, Defra issued an update to UK background maps for Local Air Quality Management Review and Assessment reports calculated using emissions projections from a base year of 2013. In line with this update, we anticipate updating the Scotland specific LAQM maps to a base year of 2013 during 2016.

7.1 Air Quality Maps for Scotland 2014

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

7.1.2 NO_2 maps for 2014

The 2014 annual mean NO_2 concentrations for Scotland were modelled for background and roadside locations. Figure 7.1 and Figure 7.2 show modelled annual mean NO_2 concentrations in Scotland, for background and roadside locations respectively.

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

[8] 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

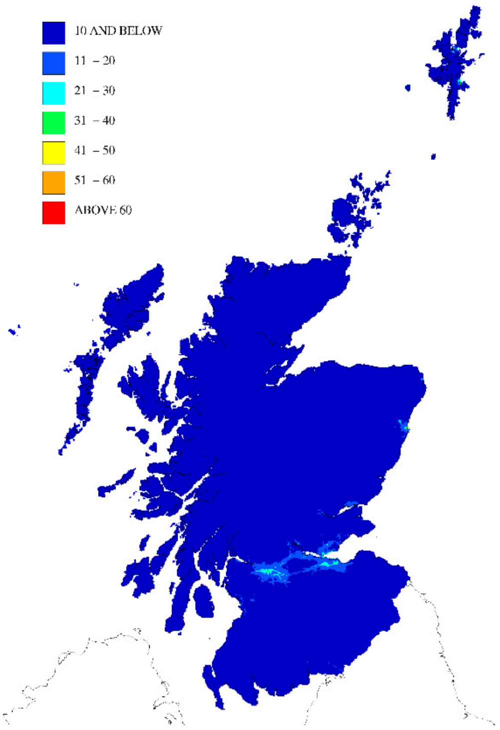
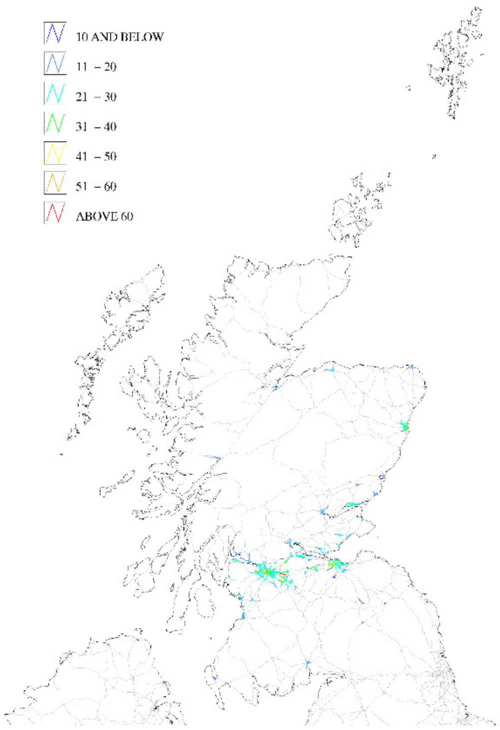
Figure 7.1 Background NO_2 map for 2014, µgm-3 (Scotland specific model)	**Figure 7.2 Roadside NO_2 map for 2014, µgm-3 (Scotland specific model)**
	

Table 7.1 shows that there were three modelled exceedances of the Scottish annual mean NO_2 objective of 40 µg m^{-3} at background locations. These three exceedances are located close to Aberdeen Harbour and are linked to emissions from shipping. Table 7.2 shows that the Scotland-specific model predicted that the Scottish annual mean NO_2 air quality objective was exceeded along 54 road links (63 km of road). The majority of exceedances were predicted to occur in the Glasgow Urban Area where exceedances were modelled for 34 road links (41 km of road). Overall exceedances of the Scottish annual mean NO_2 air quality objective were modelled in four of the six zones and agglomerations in Scotland. In each of the other three Scottish zones and agglomerations there were fewer than 10 road links where exceedances of the Scottish annual mean NO_2 air quality objective were modelled, effecting 5-9 km of roads. No roadside exceedances of the Scottish annual mean NO_2 air quality objective were modelled in the more rural zones and agglomerations of Scotland, i.e. the Highlands and Scottish Borders. More detailed maps showing the roadside annual mean NO_2 concentrations can be found in the Scottish Air Quality Mapping report 2014.

Table 7.1 Annual mean exceedance statistics for background NO_2 in Scotland based on the Scotland-specific model, 2014.

Zone or agglomeration	Total		>40 µg m^{-3}	
	Area (km^2)	**Population**	**Area (km^2)**	**Population**
Glasgow Urban Area	367	1105095	0	0
Edinburgh Urban Area	134	468399	0	0
Central Scotland	9984	1942272	0	0
North East Scotland	19024	1121019	3	8450

Highland	43514	393586	0	0
Scottish Borders	11400	265466	0	0
Total	**84423**	**5295838**	**3**	**8450**

Table 7.2 Annual mean exceedance statistics for roadside NO_2 in Scotland based on the Scotland-specific model, 2014.

Zone or agglomeration	Total		>40 µg m^{-3}	
	Road links	**Length (km)**	**Road links**	**Length (km)**
Glasgow Urban Area	290	338.7	34	41.0
Edinburgh Urban Area	60	99.5	6	7.4
Central Scotland	239	352.5	10	9.0
North East Scotland	133	233.4	4	5.3
Highland	11	36.6	0	0.0
Scottish Borders	36	47.1	0	0.0
Total	**769**	**1107.8**	**54**	**62.7**

7.1.3 PM_{10} maps for 2014

2014 annual mean PM_{10} concentrations for Scotland were modelled for background and roadside locations. The modelling methodology used to calculate the annual mean PM_{10} concentration was similar to that used in previous years and used a mixture of appropriately scaled PM_{10} monitoring (FDMS, Partisol and VCM corrected TEOM) data. Many of the chemical components of the PM_{10} model are not affected by the Scotland-specific changes to the UK PCM model. This includes the contribution to the total PM_{10} mass from the following components:

- secondary inorganic aerosols (SIA, e.g., sulphate, nitrate, ammonium-based particles)
- secondary organic aerosols (SOA)
- primary particles from long-range transport (e.g., soot particles from biomass burning)
- sea salt aerosol, and
- iron and calcium-based dusts.

Maps of the modelled 2014 annual mean PM_{10} concentrations for Scotland's background and roadside locations are shown in Figures 7.3 and 7.4, respectively.

Figure 7.3 Background PM_{10} map for 2014, µgm^{-3} (Scotland specific model)

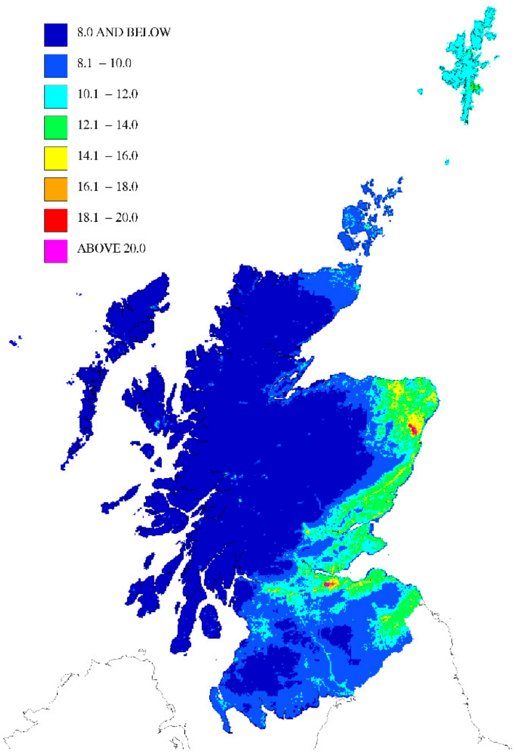
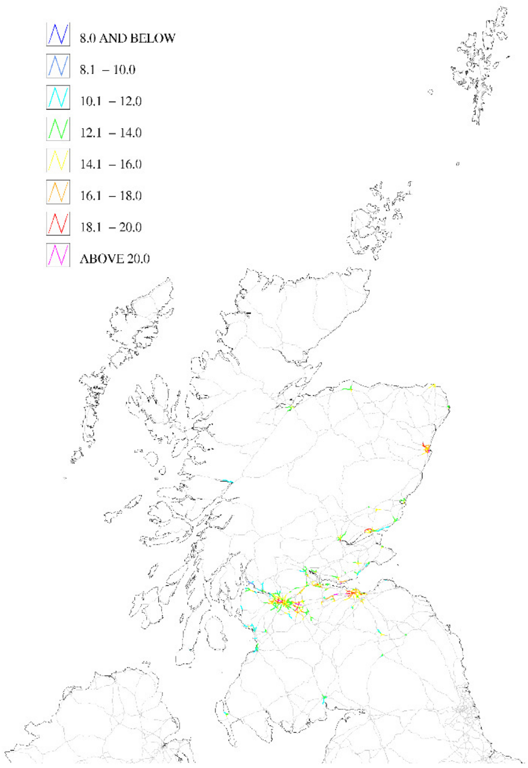


Figure 7.4 Roadside PM_{10} map for 2014, µgm^{-3} (Scotland specific model)



The 2014 Scotland specific model identified exceedances of the Scottish annual mean PM_{10} objective of 18 µg m^{-3} were modelled at 71 1 km^2 grid squares in Scotland, as shown in Table 7.3. 29 exceedances in background concentrations of PM_{10} occur in the vicinity of Edinburgh. The majority of these are located on the western outskirts of Edinburgh close to Edinburgh airport and the M8 corridor. Additional isolated exceedances on the outskirts of Edinburgh and are related to industry and agriculture. 41 exceedances are located close to Aberdeen. The causes of exceedances modelled in these areas are varied and relate to a combination of quarrying and industry, the contribution of road transport emissions to background, or shipping close to Aberdeen Harbour. One further isolated exceedance is located in the Scottish borders and is related to emissions of PM_{10} from agriculture.

72 road links (84 km of road) were identified as exceeding the Scottish annual mean PM_{10} air quality objective, as shown in Table 7.3. Exceedances of the Scottish annual mean PM_{10} objective were modelled on 15 road links (24.7 km of road) in North East Scotland, 12 road links (9.5 km of road) in Central Scotland and nine road links in the Edinburgh Urban Area (12.8 km of road). No roadside exceedances of the Scottish PM_{10} objective were modelled in the Highlands or Scottish Borders.

Table 7.3 Annual mean exceedance statistics for background PM_{10} in Scotland based on the Scotland-specific model, 2014.

Zone or agglomeration	Total		>18 µg m^{-3}	
	Area (km^2)	**Population**	**Area (km^2)**	**Population**
Glasgow Urban Area	367	1105095	0	0
Edinburgh Urban Area	134	468399	0	0
Central Scotland	9984	1942272	29	21560
North East Scotland	19024	1121019	41	7614
Highland	43514	393586	0	0
Scottish Borders	11400	265466	1	0
Total	**84423**	**5295838**	**71**	**29175**

Table 7.4 Annual mean exceedance statistics for roadside PM_{10} in Scotland based on the Scotland-specific model, 2014.

Zone or agglomeration	Total		>18 µg m^{-3}	
	Road links	**Length (km)**	**Road links**	**Length (km)**
Glasgow Urban Area	290	338.7	36	37.0
Edinburgh Urban Area	60	99.5	9	12.8
Central Scotland	239	352.5	12	9.5
North East Scotland	133	233.4	15	24.7
Highland	11	36.6	0	0.0
Scottish Borders	36	47.1	0	0.0
Total	**769**	**1107.8**	**72**	**84.0**

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 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 92 sites in 2015 . 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. This should lead to a more robust assessment. 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.

This section presents trend analysis carried out using Openair: a free, open-source software package of tools for analysis of air pollution data. Openair was developed by King's College London with the University of Leeds: the Openair project is currently led by Dr David Carslaw, of Ricardo Energy & Environment and the University of York. For more information please see https://github.com/davidcarslaw/openair. A range of Openair tools are available on the "Air Quality in Scotland" website: for more information on the tools and how to use them, please see:

http://www.scottishairquality.co.uk/openair/openair.php

The trend analyses in this section 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. (At least 75% data capture is required for a valid monthly mean.) 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.

8.1 Oxides of Nitrogen and Nitrogen Dioxide

In Scotland (as elsewhere in the UK) the largest number of Air Quality Management Areas (AQMAs) has been declared in response to exceedances of objectives for nitrogen dioxide (NO_2). This is also reflected in the number of monitoring stations reporting exceedances for this pollutant (see Section 6 of this report). In particular, the objective of 40 µg m^{-3} for annual mean NO_2 concentration is the most widely exceeded.

It is therefore important to understand how concentrations of this pollutant are varying with time. When investigating trends, both NO_2 and total oxides of nitrogen (NO_x) should be considered. This is because most combustion sources (such as road vehicles, domestic heating and other fuel burning processes) emit a mixture of NO_2 (so-called "direct" NO_2) and NO: the latter is subsequently oxidised to NO_2 in the ambient air. A large proportion of NO_2 is formed from the oxidation of NO emitted from such sources.

8.1.1 NO_x and NO_2 at Urban Background Sites

Historically, the longest-running urban background site in Scotland to have measured NOx concentrations was the former Glasgow City Chambers site (in operation from 1987 to 2012). This closed before the start of 2014 so is not discussed here. For information on trends at Glasgow City Chambers, please see earlier reports in this series, available from

http://www.scottishairquality.co.uk/news/reports?view=technical .

At the time of writing, the longest-running urban background NOx monitoring site in Scotland is Aberdeen, Errol Place (in operation from late 1999 onwards). This site is also part of the UK's national air quality monitoring network (the Automatic Urban and Rural Network or AURN), in which it is referred to simply as "Aberdeen".

Figure 8-1 uses a smoothed trend plot to illustrate the variation in measured annual mean NO_x concentrations at Aberdeen Errol Place, from 1999 to 2015. Figure 8-1 shows that NOx concentrations at this site increased slightly in its earlier years of operation but have shown a general decrease since around 2002.

Figure 8-1 Smoothed Trend Plot of NOx Concentration at Aberdeen, Errol Place: 1999 – 2015

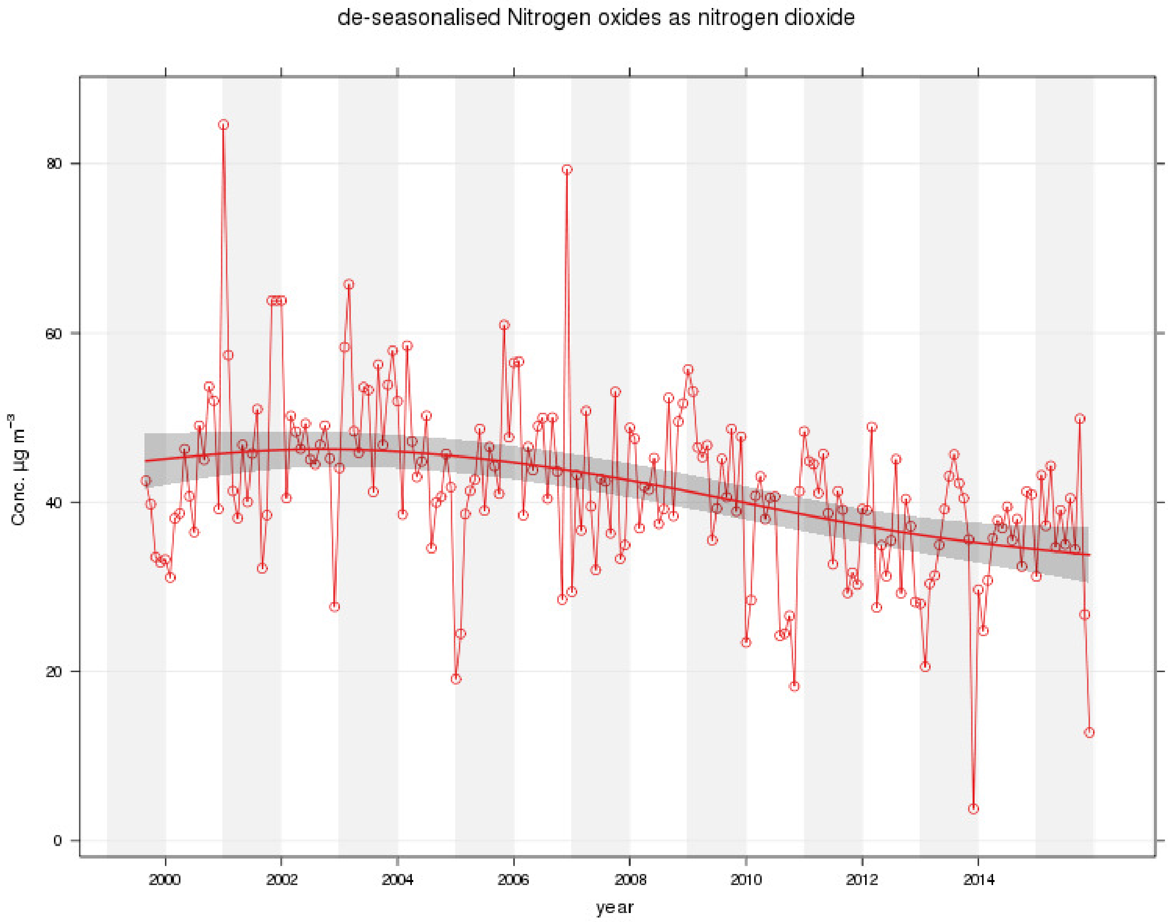
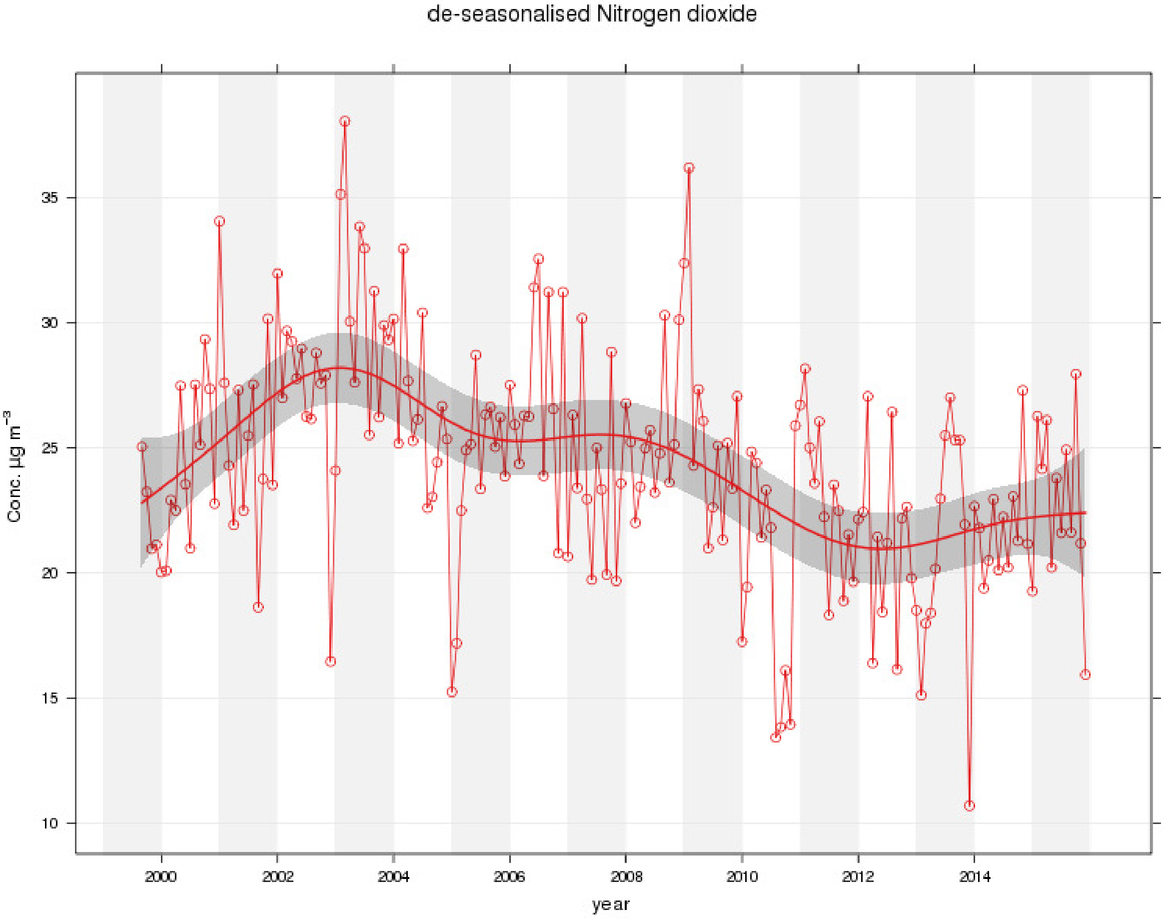


Figure 8-2 shows a smoothed trend plot for NO_2 at the same site and over the same period. (Please note these graphs are plotted on different scales, because concentrations of total NO_x are higher than those of NO_2.) The pattern for NO_2 is in some respects similar to that observed for NO_x, in that it peaks around 2002 with a subsequent decrease: however, NO_2 appears to show more variation.

Figure 8-2 Smoothed Trend Plot of NO_2 Concentration at Aberdeen Errol Place 1999 – 2015



The Openair Theil-Sen function has been used to quantify trends in NO_x and NO_2 in more recent years, when a larger number of sites were operating. Three urban non-roadside sites have been monitoring NO_x since 2004 or earlier; Aberdeen Errol Place, Edinburgh St Leonards, and Grangemouth. Aberdeen Errol Place and Edinburgh St Leonards are classified as 'urban background', while Grangemouth is an 'urban industrial' site.

Trends in NO_x and NO_2 are shown in

Figure 8-3 and

Figure 8-4 respectively, over the period from 2004 to 2015. In these plots the trend line is shown by a solid red line, with 95% confidence intervals for the trend shown by dotted red lines. The trend is given at the top of the plot in green, with confidence intervals shown in square brackets. The trend is given as units (i.e. µg m^{-3}) per year, over the period shown. This may be followed by a number of stars, with * indicating that the trend is statistically significant at the 0.05 level, ** indicating significance at the 0.01 level and *** indicating significance at the 0.001 level. The symbol + indicates that the trend is significant at the 0.1 level.

All three sites show a negative trend (i.e. decreasing NO_x) in

Figure 8-3. The actual decrease year-on-year is small; however, the trend is statistically highly significant (at the 0.001 level) at Aberdeen Errol Place, and significant at the 0.1 level at Edinburgh St Leonards. (Grangemouth does not show a statistically significant trend).

In the case of NO_2 (

Figure 8-4), all sites again show a slight negative trend, though the year-on-year decrease is even smaller than for total NOx. Again, Aberdeen Errol Place and Edinburgh St Leonards show statistically significant negative trends; in the case of Edinburgh St Leonards, the trend is *more* significant for NO_2 than for NO_x.

Figure 8-3 Trends in NOx Concentration at Three Long-running Urban Non-Roadside Sites, 2004-2015

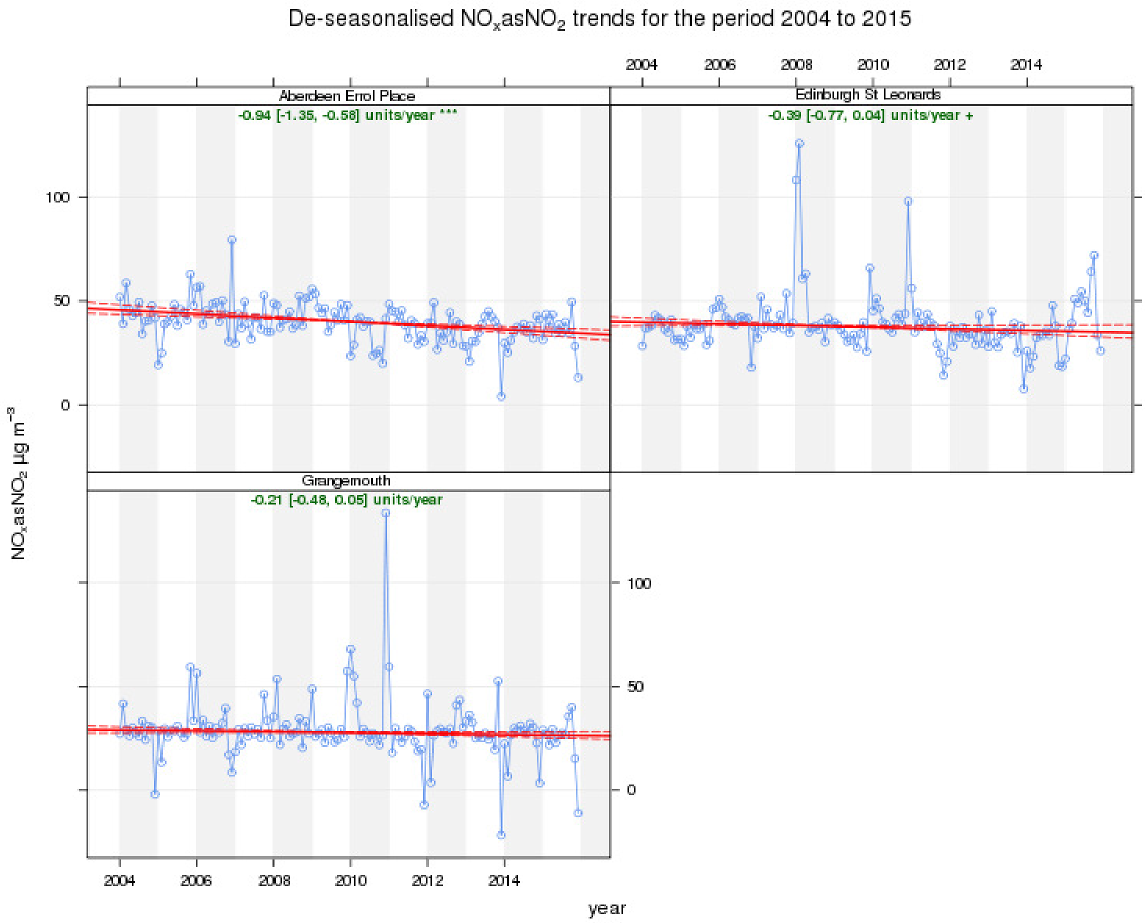
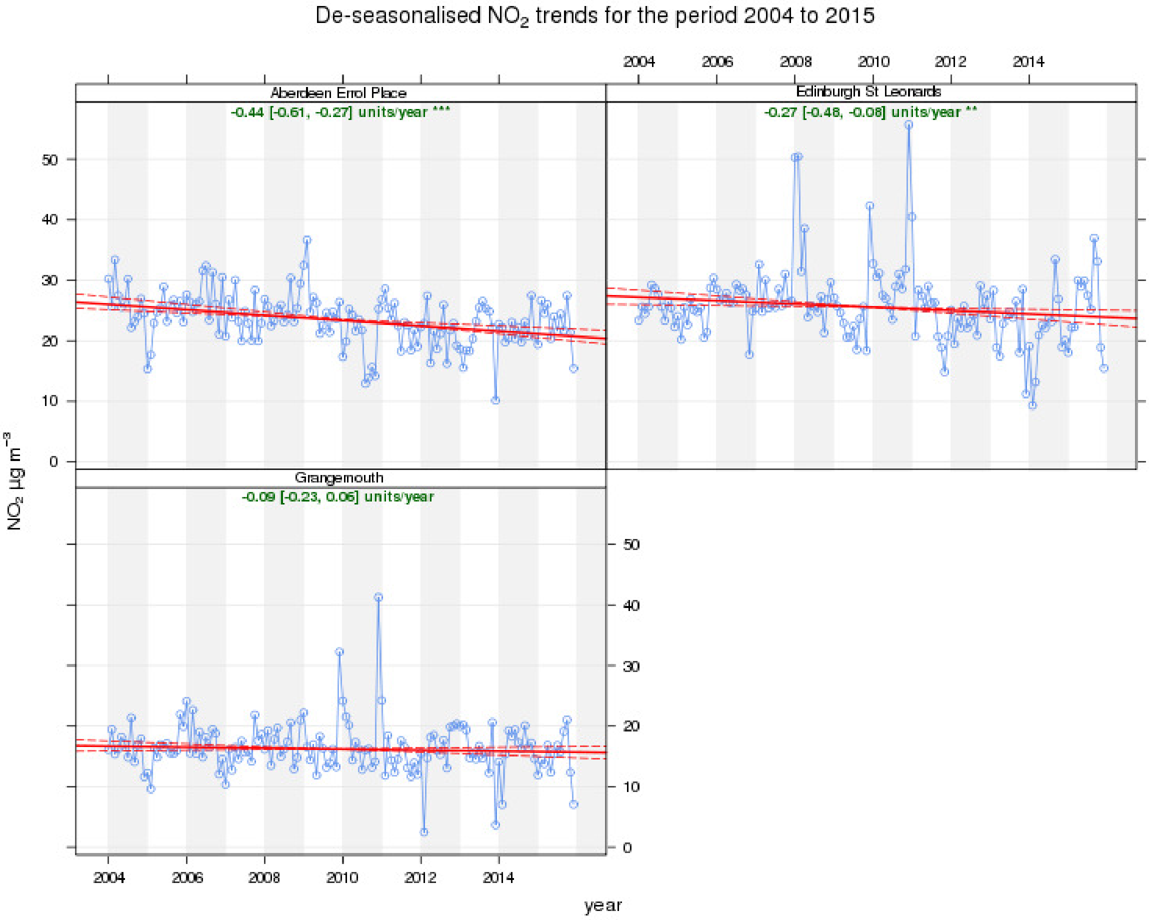


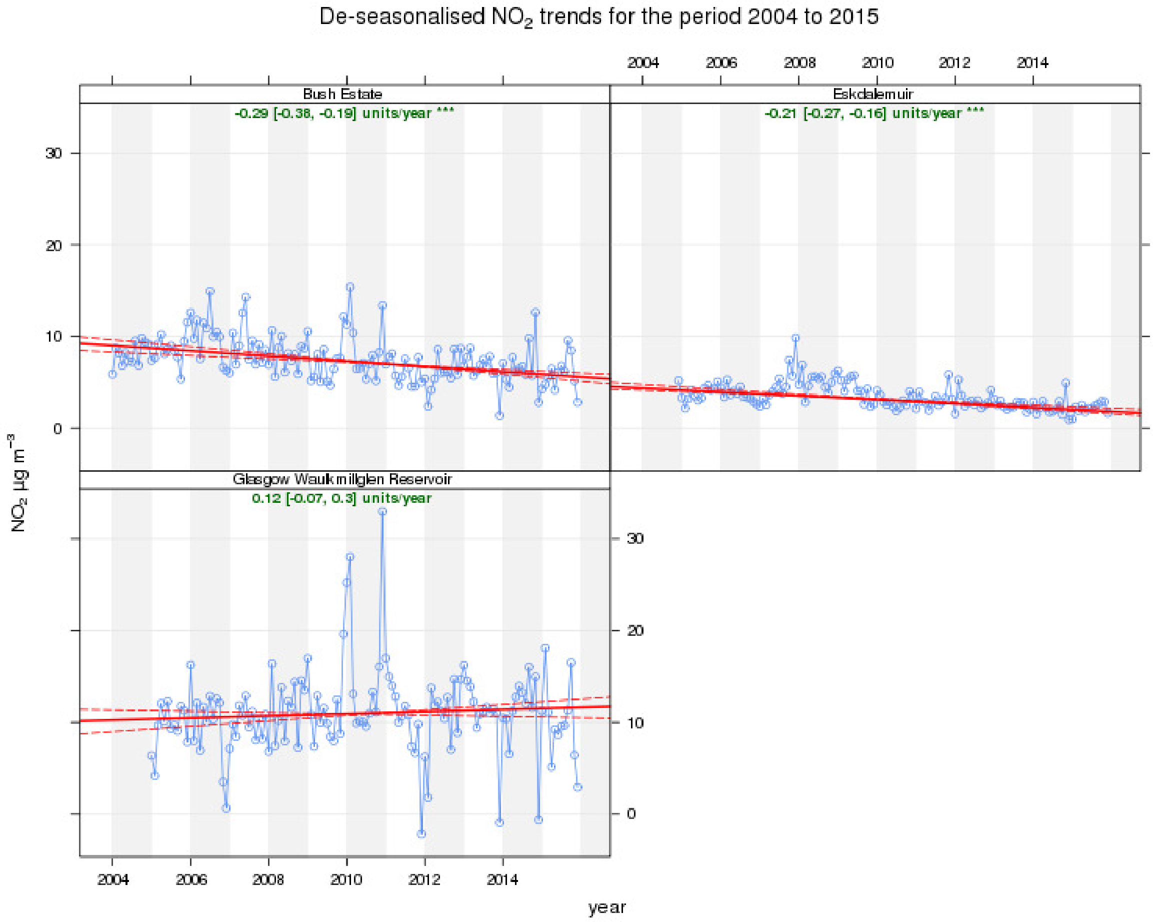
Figure 8-4 Trends in NO_2 Concentration at Three Long-running Urban Non-Roadside Sites, 2004-2015



8.1.2 NO_2 at Rural Sites

Three long-running rural sites have monitored oxides of nitrogen since 2005 or earlier: Bush Estate (to the south of Edinburgh close to the Pentland Hills Regional Park), Eskdalemuir and Glasgow Waulkmillglen Reservoir. Figure 8-5 shows trends in NO_2 concentration at these sites. (We have not plotted NO_x in this case as these rural sites are well away from sources of NOx – therefore most of the NO_x measured at these sites is likely to be NO_2). While the sites at Bush Estate and Eskdalemuir show small but highly significant downward trends, this is not the case for Glasgow Waulkmillglen Reservoir, where – by contrast - concentrations are increasing though the trend is not significant.

Figure 8-5 Trends in NO_2 Concentration at Three Rural Sites, 2005 – 2015



8.1.3 NO_x and NO_2 at Traffic-related Urban Sites

Figure 8-6 and Figure 8-7 show smoothed trend plots of NO_x and NO_2 concentration respectively, at Scotland's longest running traffic-related urban site, Glasgow Kerbside. This site began monitoring NO_x in 1997 and is still doing so. There is considerable fluctuation in NO_x at this site, but some indication of an overall downward trend. By contrast, in the case of NO_2, there is no apparent downward trend over this period. A downward trend is however evident from 2010 (when concentrations peaked since 1997) onwards.

Figure 8-6 Smoothed Trend Plot of NOx Concentration at Glasgow Kerbside: 1997 – 2015

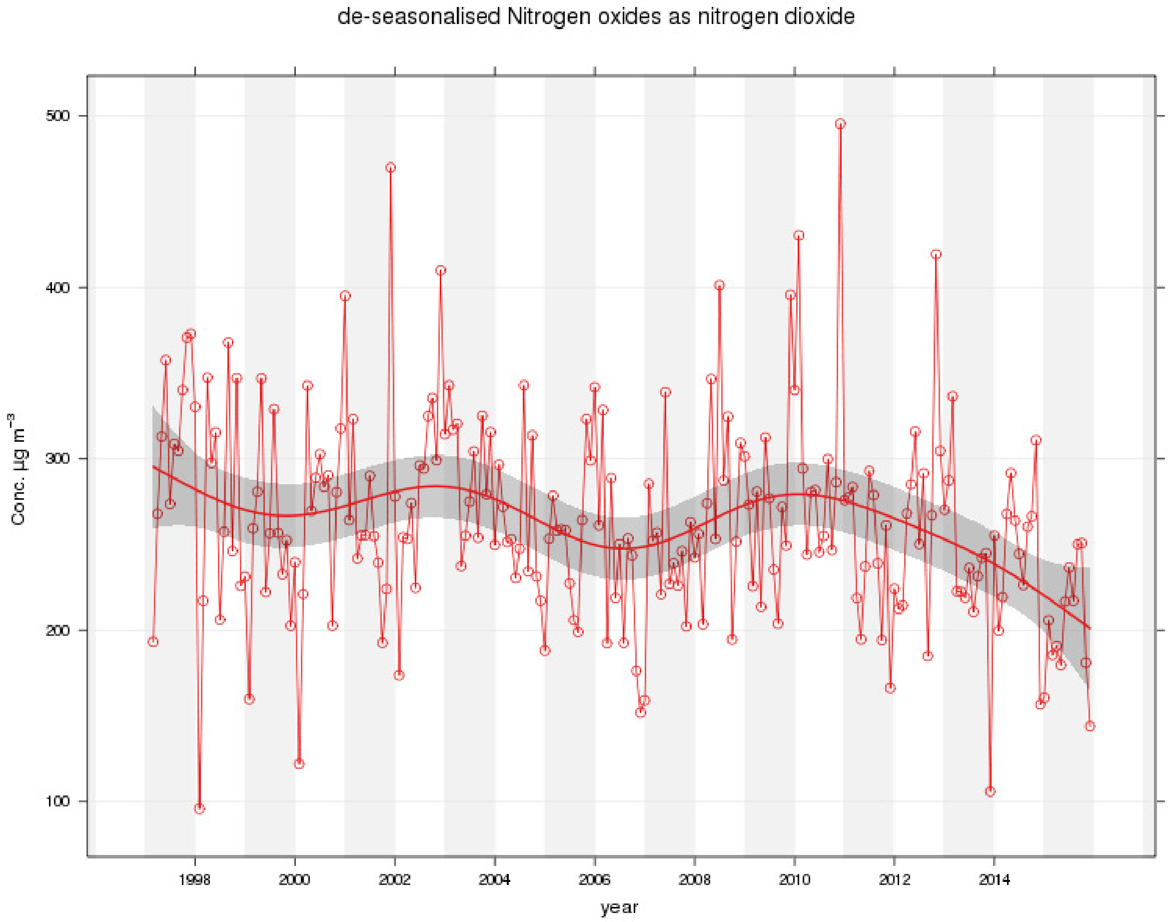
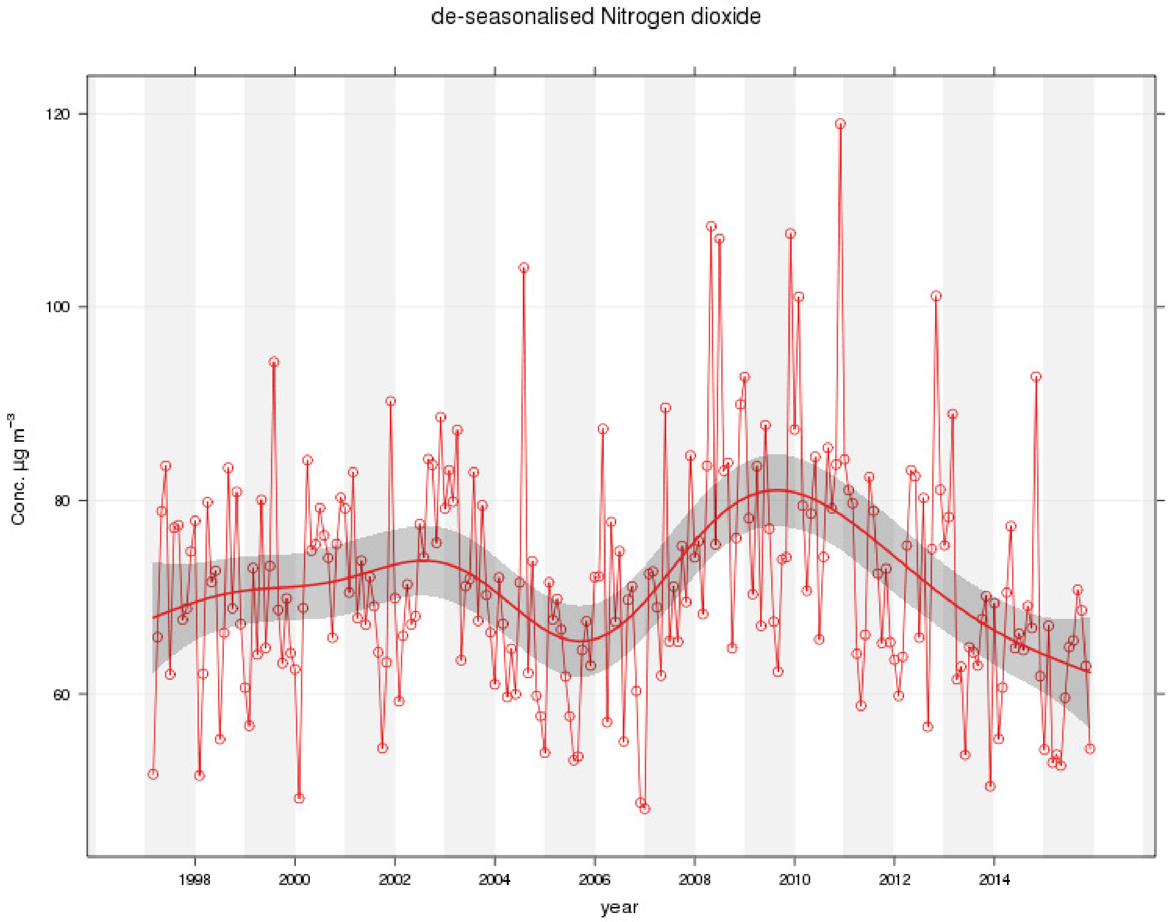


Figure 8-7 Smoothed Trend Plot of NO_2 Concentration at Glasgow Kerbside: 1997 – 2015

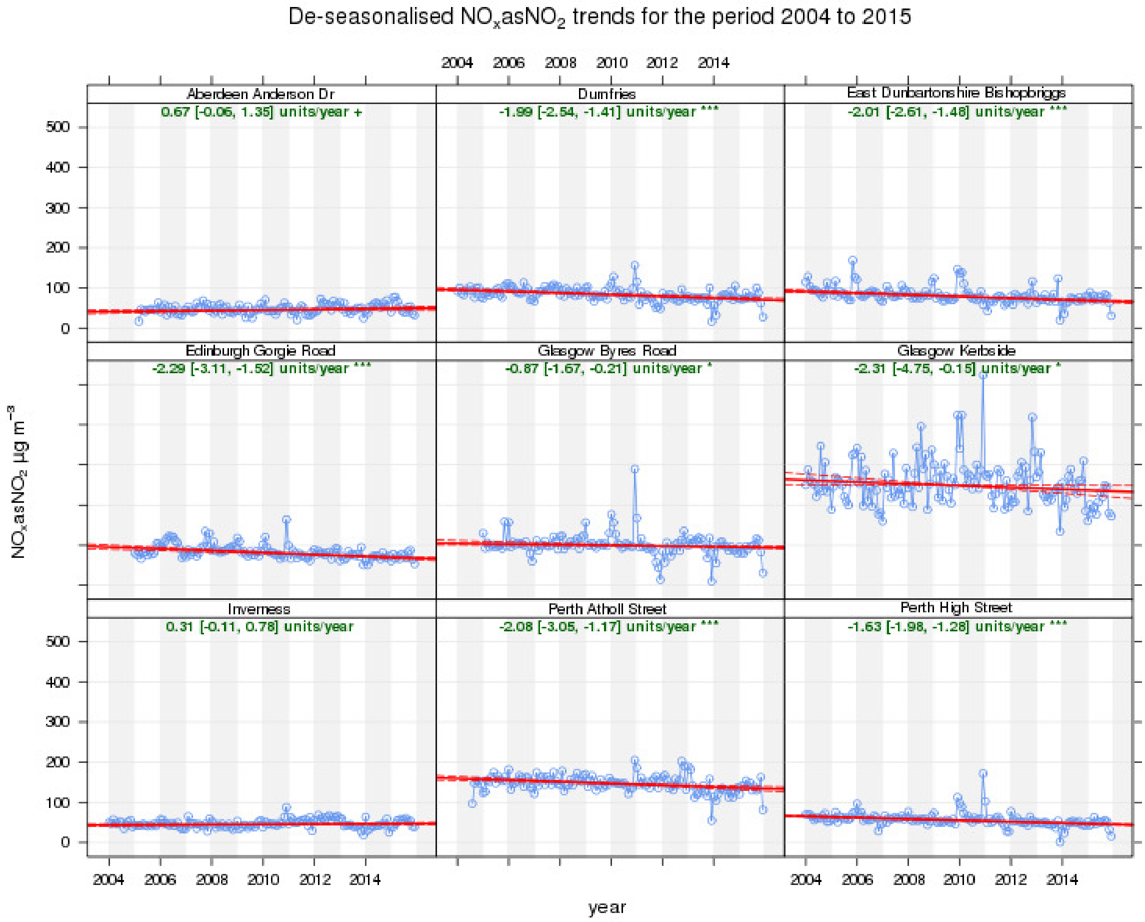


As in the case of the urban non-roadside sites, the Openair Theil-Sen function has been used quantify trends in NO_x and NO_2 in more recent years, when more sites were operating.

Figure 8-8 and

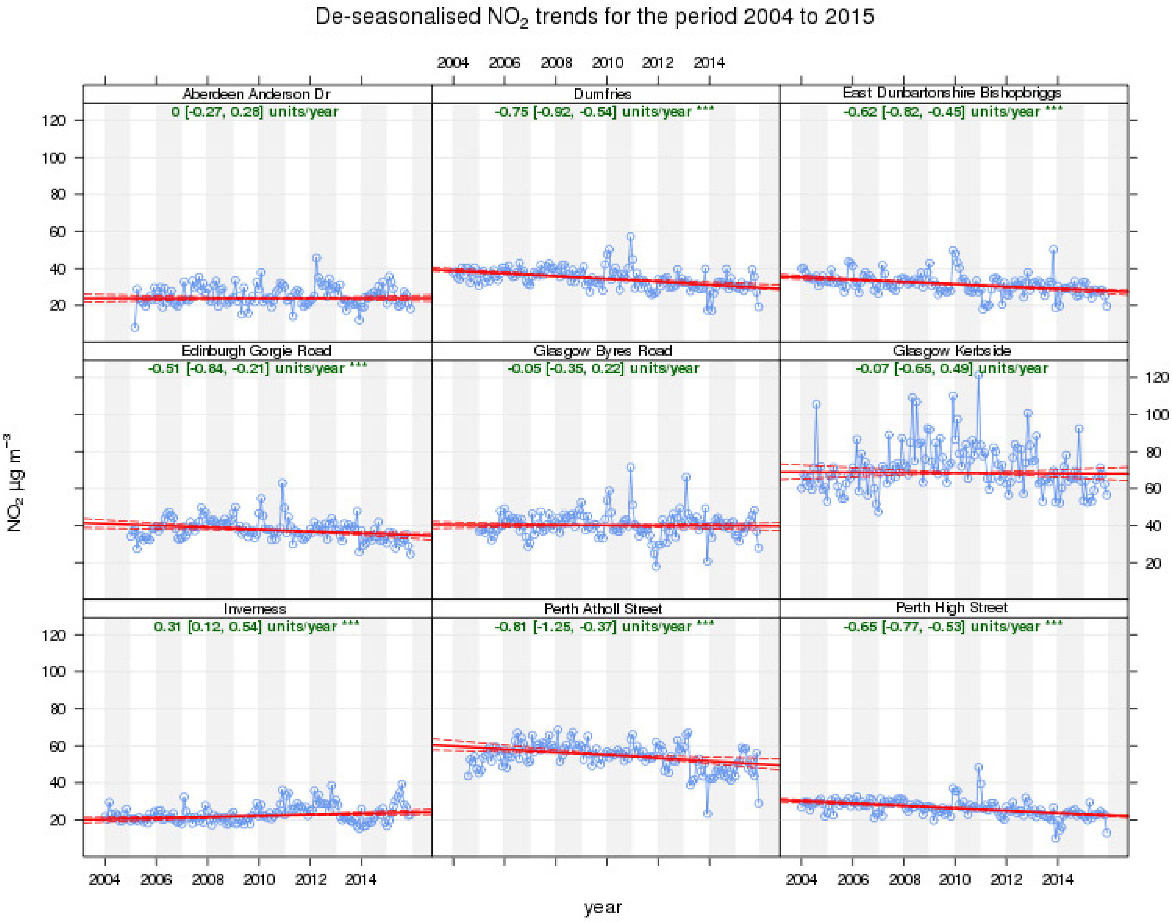
Figure 8-9 show trends in NO_x and NO_2 respectively for a subset of nine long-running sites at urban traffic locations. These sites are: Aberdeen Anderson Drive, Dumfries, East Dunbartonshire Bishopbriggs, Edinburgh Gorgie Road, Glasgow Byres Road, Glasgow Kerbside, Inverness, Perth Atholl Street and Perth High Street), all of which have been in operation since 2004 or earlier. Seven of the sites show a downward trend in NO_x (highly statistically significant at Dumfries, East Dunbartonshire Bishopbriggs, Edinburgh Gorgie Road and both the Perth sites; less significant for the two Glasgow sites but this is the first year in which they have shown any significant decrease). However, both Aberdeen Anderson Drive and Inverness show slight upward trends (statistically significant in the case of Aberdeen Anderson Drive).

Figure 8-8 Trends in NOx Concentration at Nine Long-Running Urban Traffic sites: 2004 – 2015



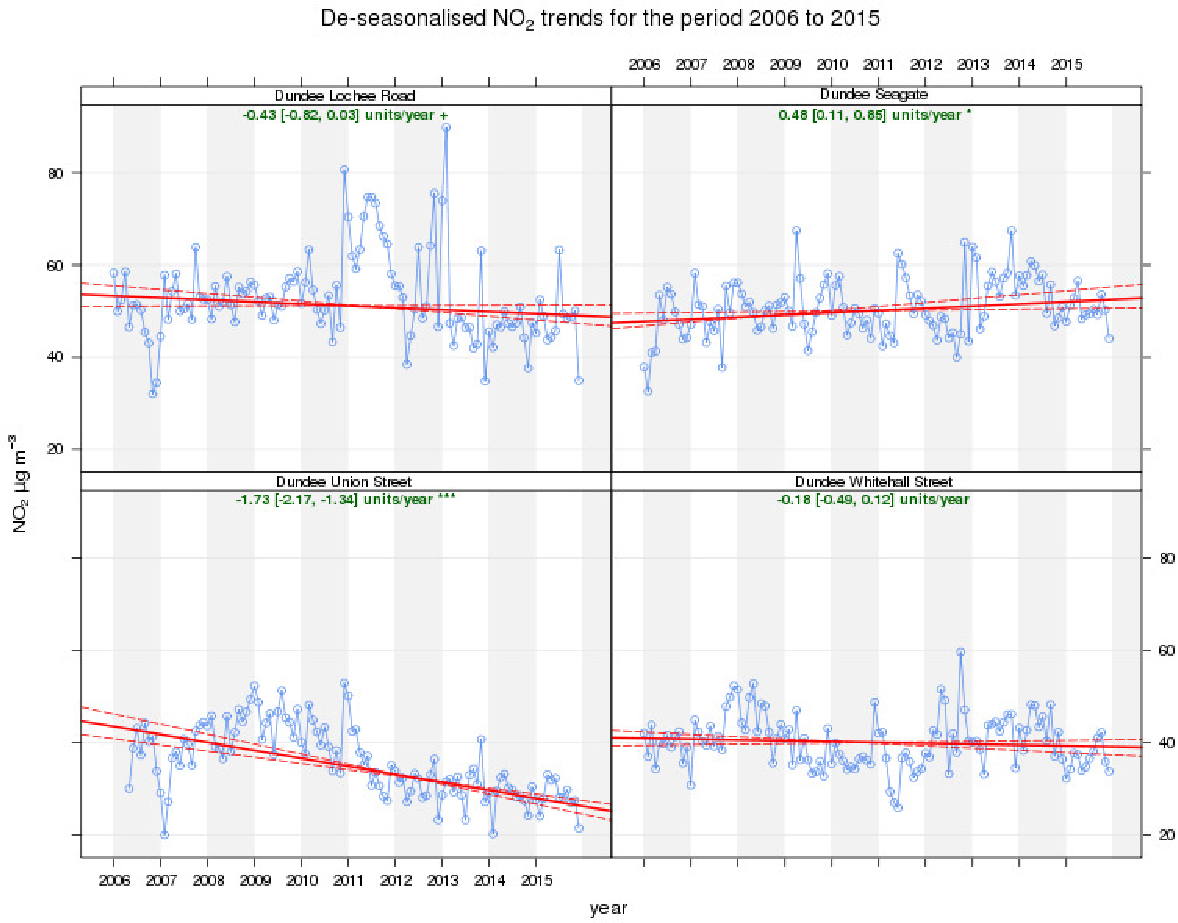
In the case of NO2, five of the sites (Dumfries, East Dunbartonshire Bishopbriggs, Edinburgh Gorgie Road, Perth Atholl Street and Perth High Street) show statistically significant downward trends. Inverness shows a small but statistically significant upward trend and the remaining three show no significant trend at all. This is similar to observations in the previous two years' reports: it may indicate that trends in concentrations of this pollutant depend greatly on conditions at the various sites.

Figure 8-9 Trends in NO_2 Concentration at Nine Long-Running Urban Traffic sites: 2004 – 2015



This may be illustrated by data from Dundee. Four urban traffic monitoring sites in Dundee have been measuring NO_2 since 2006. These are Dundee Lochee Road, Dundee Seagate, Dundee Union Street and Dundee Whitehall Street, all shown in Figure 8-10. Even though all these sites are at roadside locations, and in the same city, they show different trends in NO_2 concentration over the period 2006 to 2015. There is a statistically significant upward trend at Dundee Seagate, a highly significant downward trend at Dundee Union Street, a less significant downward trend at Dundee Lochee Road and end at Dundee Union Street, and no significant trend at Dundee Whitehall Road.

Figure 8-10 Example: Trends in NO_2 Concentration at Four Urban Traffic sites in Dundee, 2006 – 2015



8.2 Particulate Matter

This pollutant is of particular interest because:

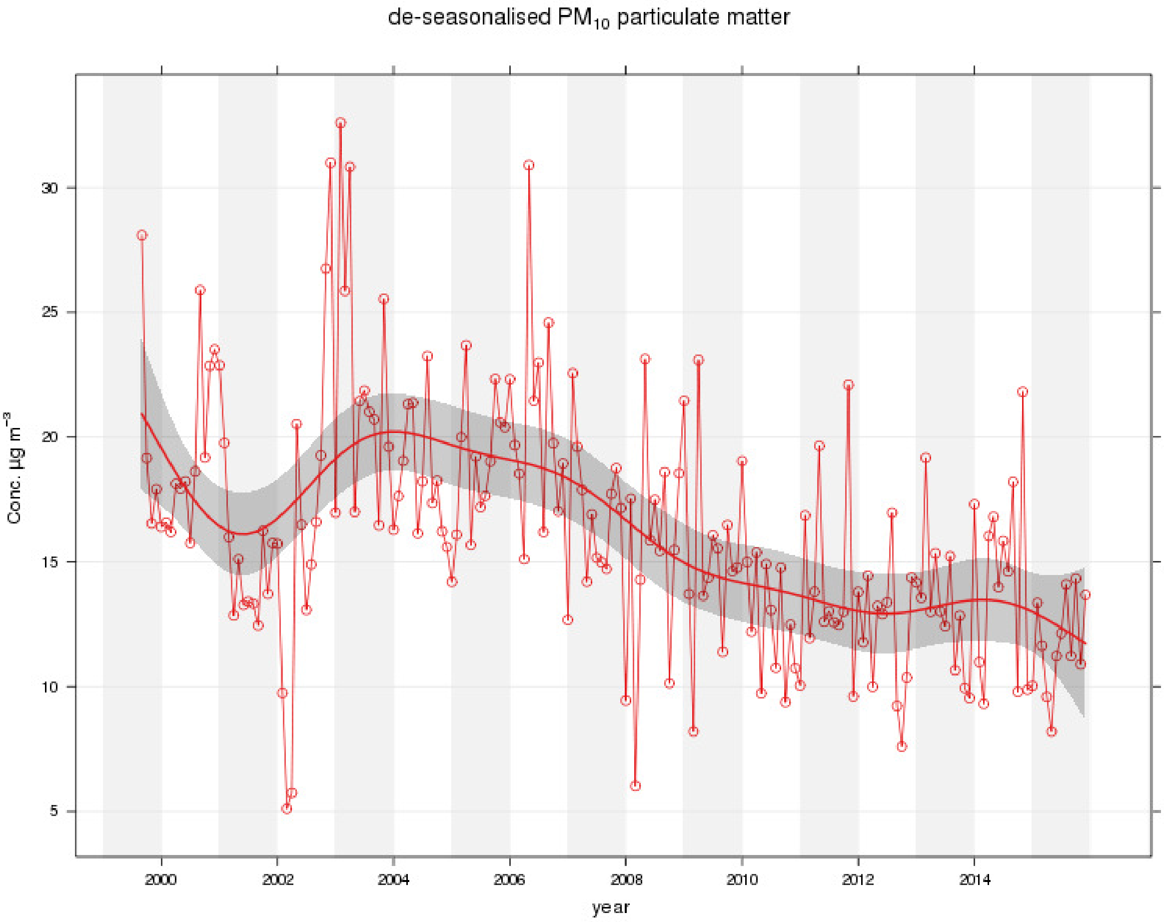
- Scientists do not believe that there is actually a safe level of this pollutant in terms of human health effects.
- Scotland's current annual mean PM_{10} objective is 18 µg m^{-3}, which is more stringent than the objective of 40 µg m^{-3} adopted in the rest of the UK.
- Scotland has recently opted 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.

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 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

The longest-running Scottish urban background PM_{10} monitoring site is Aberdeen Errol Place, which has been measuring this parameter since late 1999. A smoothed trend plot of de-seasonalised monthly mean PM_{10} concentrations at this site is shown in Figure 8-11. This shows no clear trend in the early years, followed by a general decrease from around 2004 until 2013. There is some indication of a recent small up-turn around 2014 but the decrease appears to have resumed in 2015.

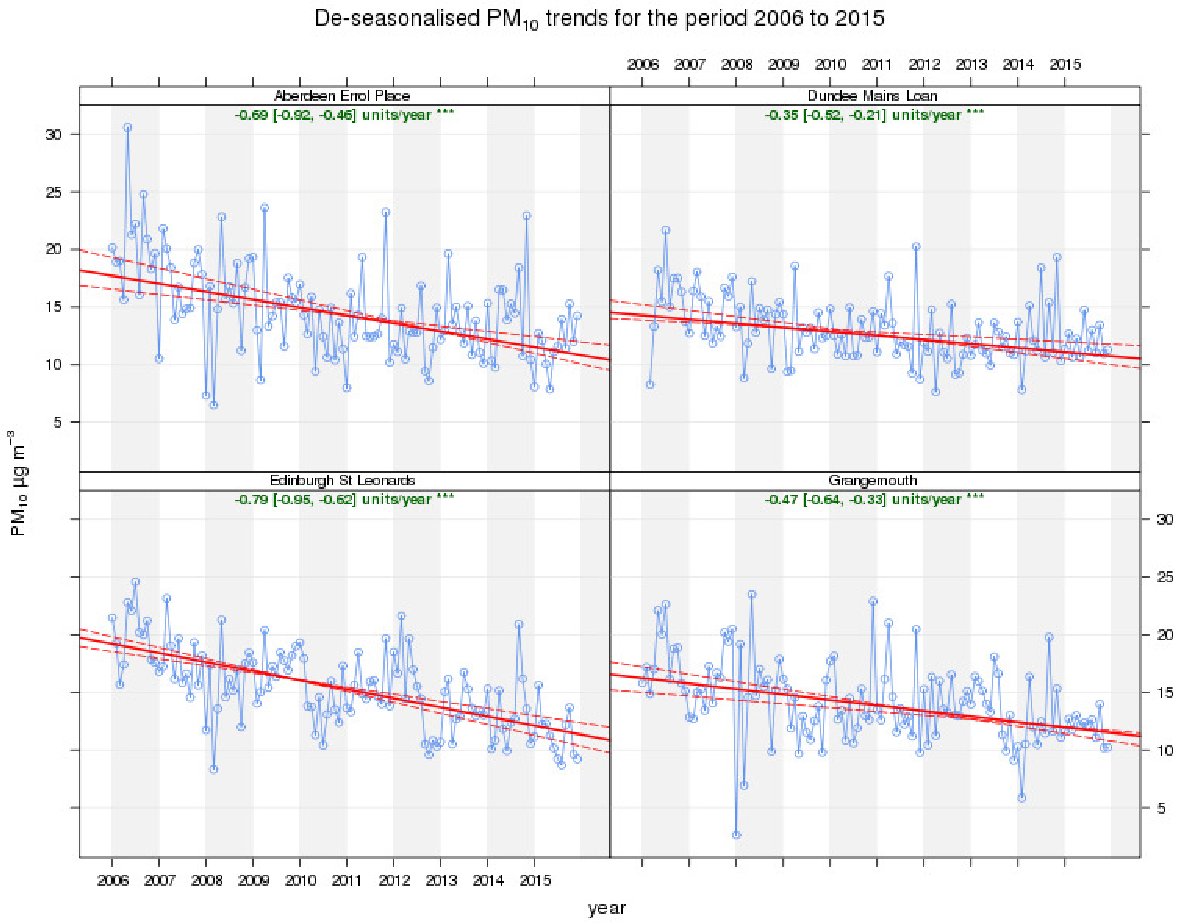
Figure 8-11 Smoothed Trend Plot of PM_{10} Concentration at Aberdeen Errol Place: 1999 - 2015.



Four urban non-roadside sites in Scotland have been monitoring PM_{10} since 2006 or earlier. These are Aberdeen Errol Place (TEOM, converted to FDMS in 2009), Dundee Mains Loan (TEOM, data VCM corrected) Edinburgh St Leonards (FDMS since 2007), and the urban industrial site Grangemouth (FDMS since 2009).

Figure **8-12** shows trends in de-seasonalised monthly mean PM_{10} at this subset of long-running sites. All four sites show a negative trend, significant at the 0.001 level (and strongest for Edinburgh St Leonard).

Figure 8-12 Trends in PM_{10} Concentration at Four Long-Running Urban Non-Roadside sites, 2006 – 2015

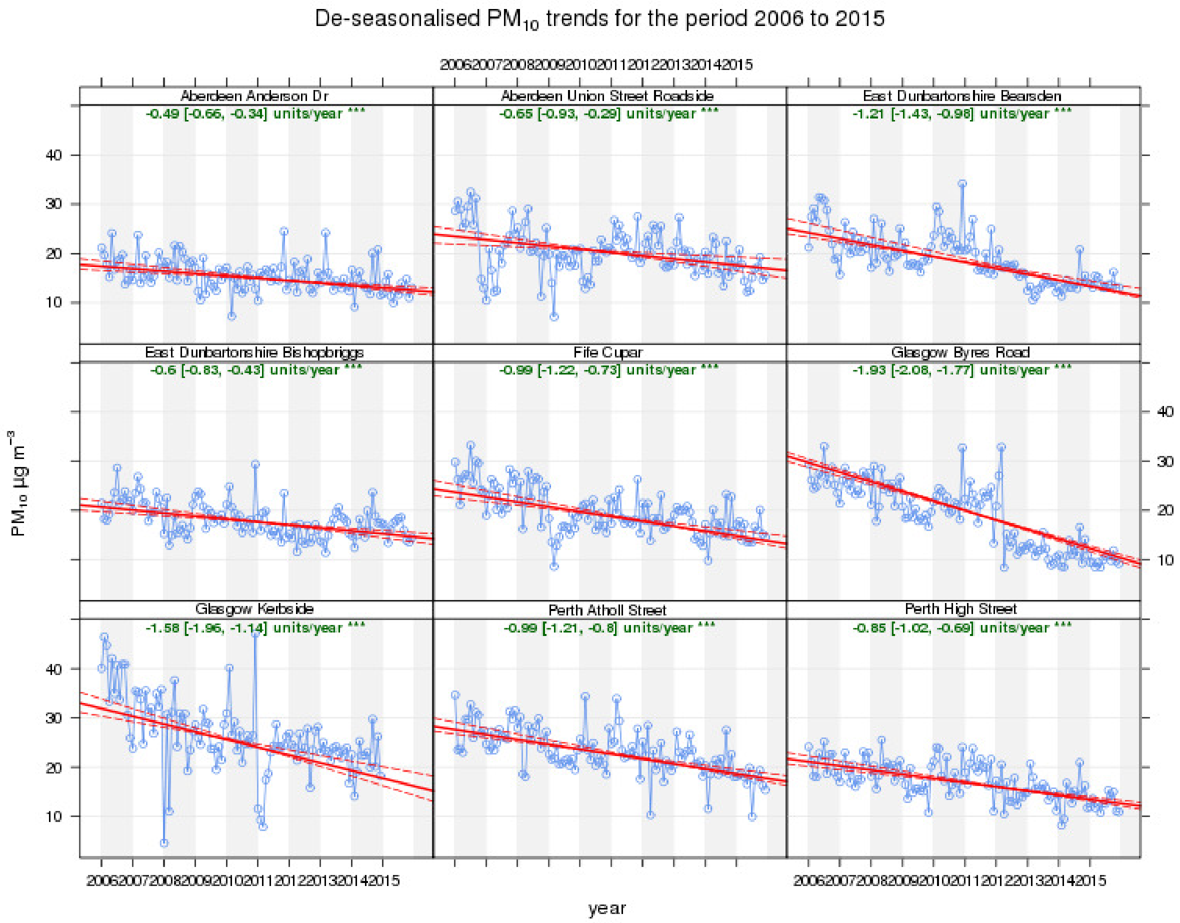


8.2.2 PM_{10} at Urban Traffic Sites

Historically, the longest-running traffic-related PM_{10} monitoring site in Scotland has been Glasgow Kerbside, which monitored PM_{10} from early 1997 to 2014. However, although it is still in operation it no longer monitors PM_{10}. For more details of trends at this site, please see earlier reports in this series.

Trends in de-seasonalised monthly mean PM_{10} concentrations for nine traffic-related sites in operation since 2005 or earlier are shown in Figure 8-13. These are the long-running Aberdeen Anderson Drive, Aberdeen Union Street, East Dunbartonshire Bearsden, East Dunbartonshire Bishopbriggs, Fife Cupar, Glasgow Byres Road, Glasgow Kerbside (shown although it closed at the end of 2014), Perth Atholl Street and Perth High Street. All nine sites show statistically significant downward trends, significant at the 0.001 level. The trends indicate that PM_{10} is decreasing year on year at these roadside sites.

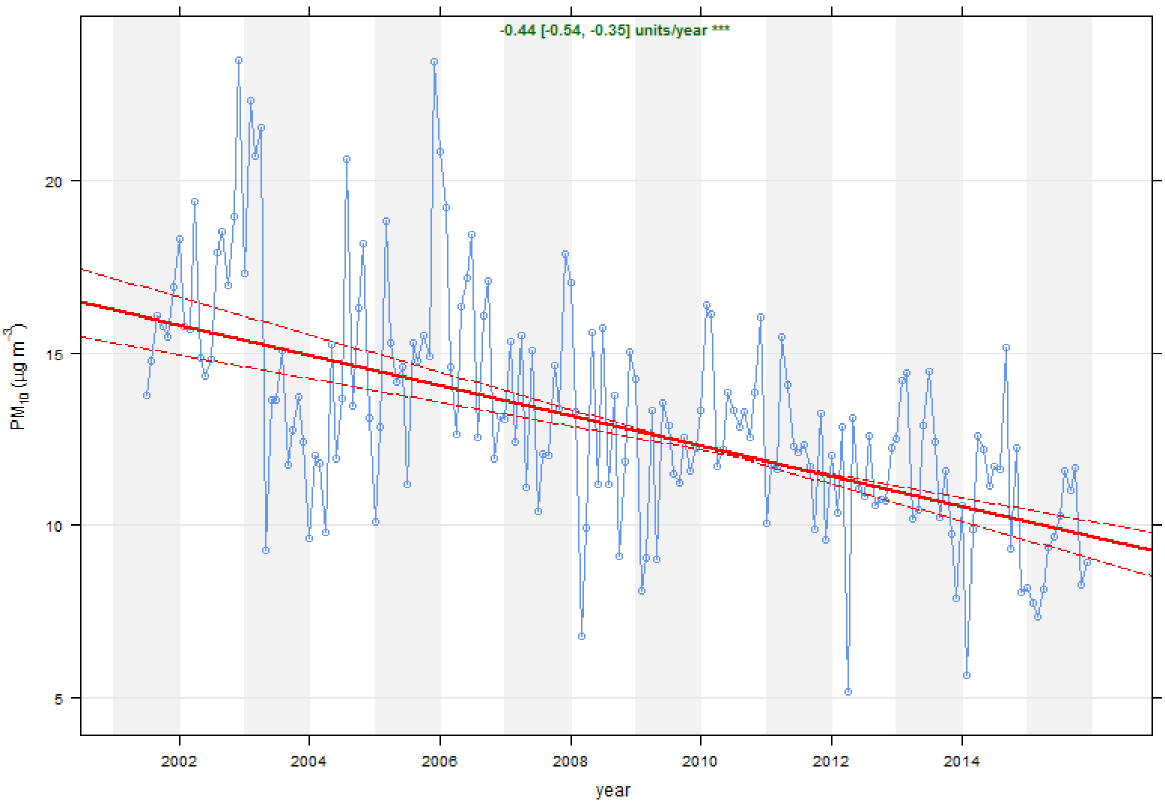
Figure 8-13 Trends in PM_{10} Concentration at Nine Long-Running Urban Traffic Sites, 2006 – 2015



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

Figure 8-14. This site too shows a highly significant downward trend, significant at the 0.001 level.

Figure 8-14 Trends in PM_{10} Concentration at Inverness (Partisol site), 2001 – 2015



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 2015 there were six sites with at least five consecutive years of $PM_{2.5}$ data (the minimum considered necessary for assessment of long-term trends). These sites are as follows: Aberdeen Errol Place (urban background), Auchencorth Moss (rural), Edinburgh St Leonards (urban background), Glasgow Kerbside until 2014 (urban traffic) and Grangemouth (urban industrial), as well as Inverness which uses the Partisol gravimetric sampler and therefore only takes daily measurements. The trend plots are shown in

Figure 8-15, with the Inverness Partisol data plotted separately in Figure 8-16 (please note, the scale is different).

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

Figure 8-15 Trends in $PM_{2.5}$ Concentration at Five Long-Running Monitoring Sites, 2009 – 2015

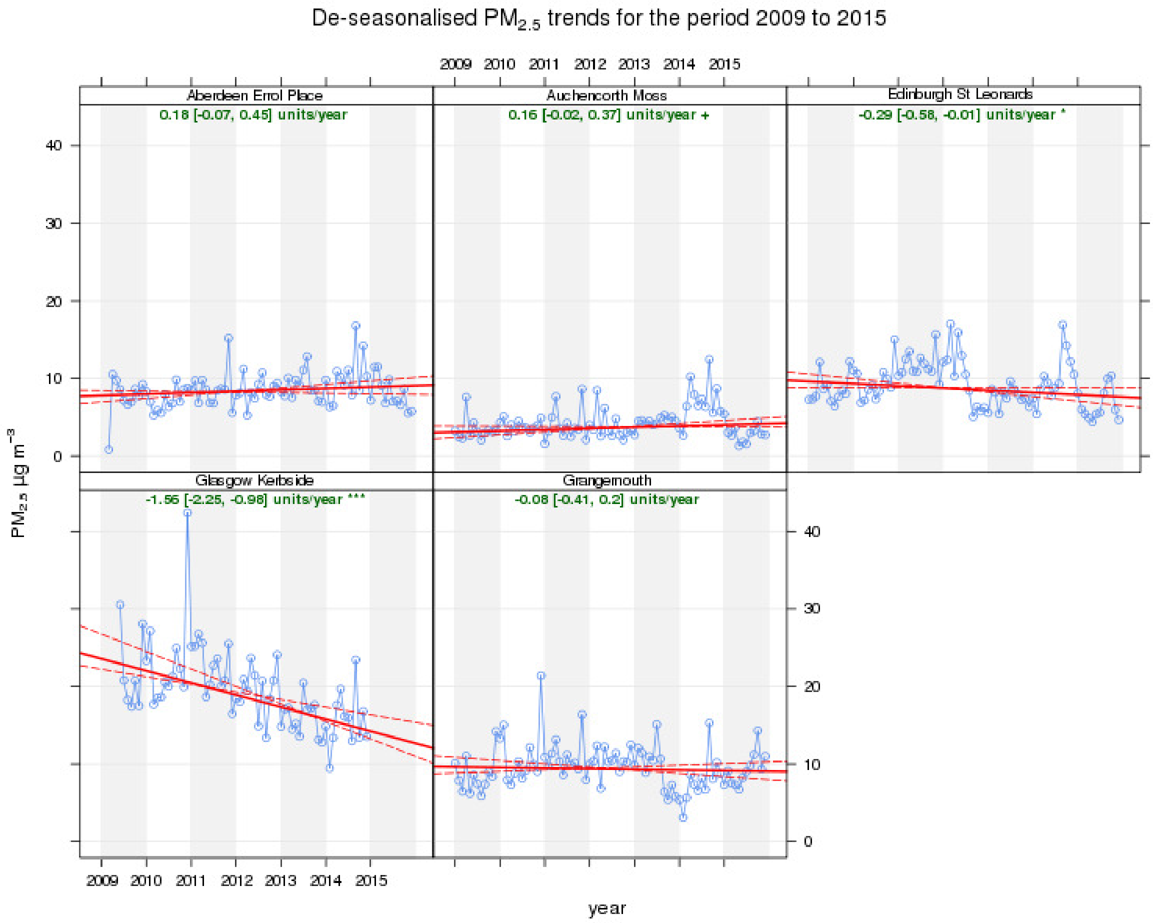
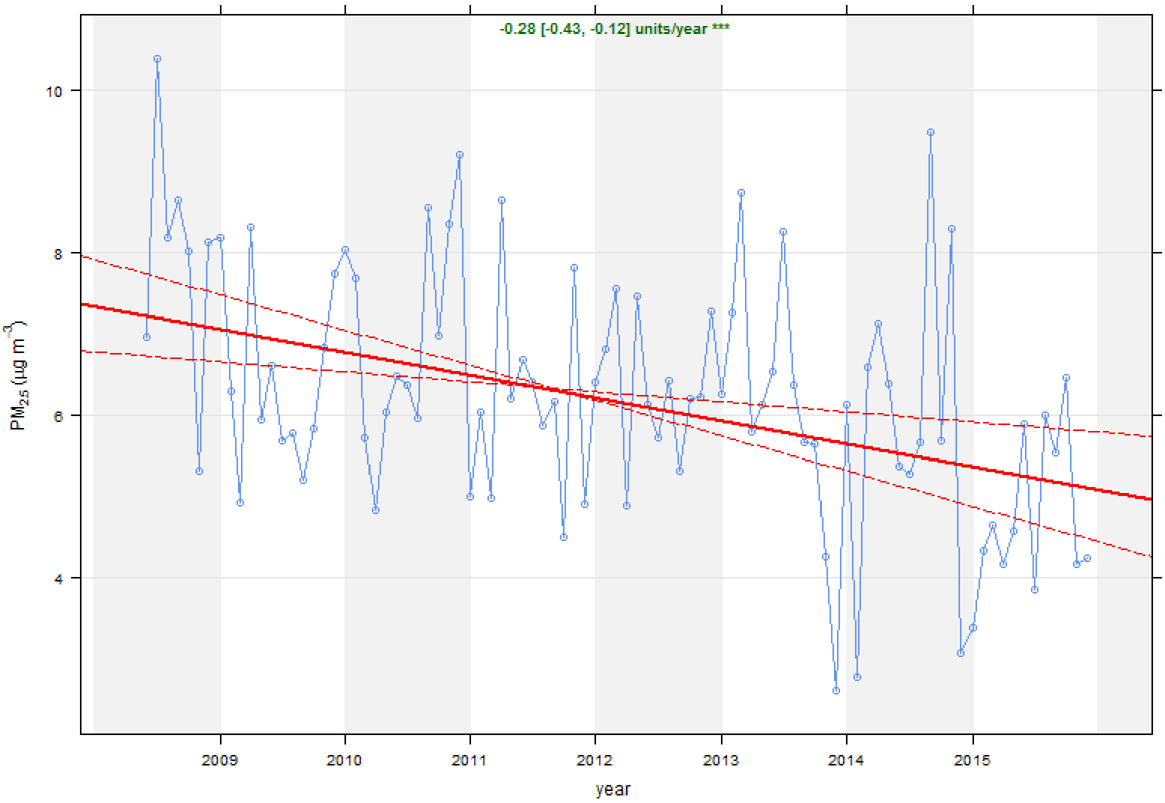


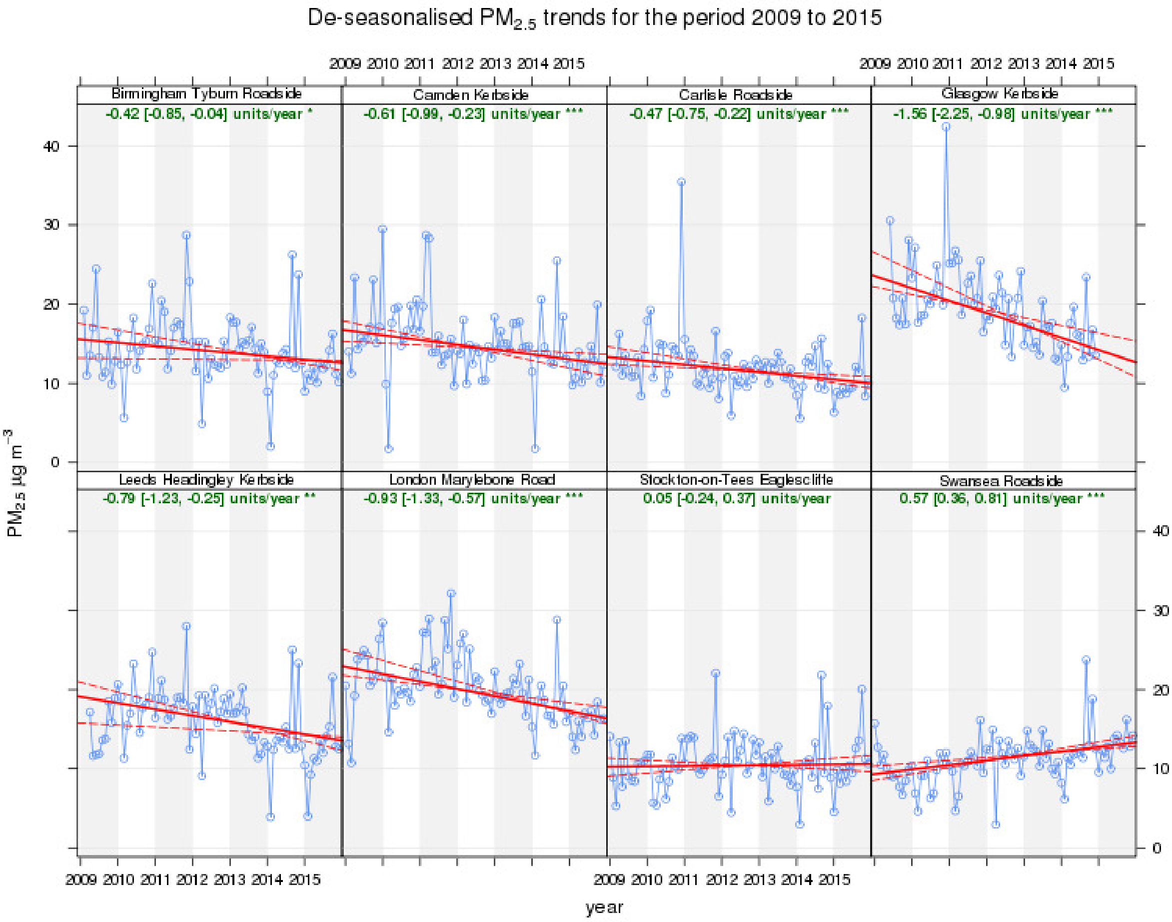
Figure 8-16 Trends in $PM_{2.5}$ Concentration at Inverness (Partisol site), 2008 – 2015



By comparing the trend at Glasgow Kerbside with that at other similar monitoring sites, it may be possible to tell if the downward trend is typical. Since Glasgow Kerbside and Inverness are the only urban traffic sites in Scotland to have monitored $PM_{2.5}$ over this period, it is necessary to look elsewhere in the UK to find sites for comparison.

Figure 8-17 compares the $PM_{2.5}$ trend at Glasgow Kerbside with those observed at seven other "urban traffic" air quality monitoring sites in cities in England and Wales. Five of these other sites (Birmingham Tyburn Roadside, Camden Kerbside, Carlisle Roadside, Leeds Headingley Kerbside and London Marylebone Road) also show statistically significant downward trends in $PM_{2.5}$ concentration: one (Swansea Roadside) shows a highly significant upward trend, and one (Stockton on Tees Eaglescliffe) shows no trend. On this basis, it appears that downward trends in $PM_{2.5}$ concentrations are now being observed at roadside locations around the UK. However, the downward trend at Glasgow Kerbside is steeper than is typical. There is also considerable variation from site to site, possibly reflecting differing trends in relevant factors influencing localised $PM_{2.5}$ concentrations, such as traffic flow.

Figure 8-17 Comparison of Trends in $PM_{2.5}$ at Urban Traffic sites in Selected UK Cities, 2009-2015



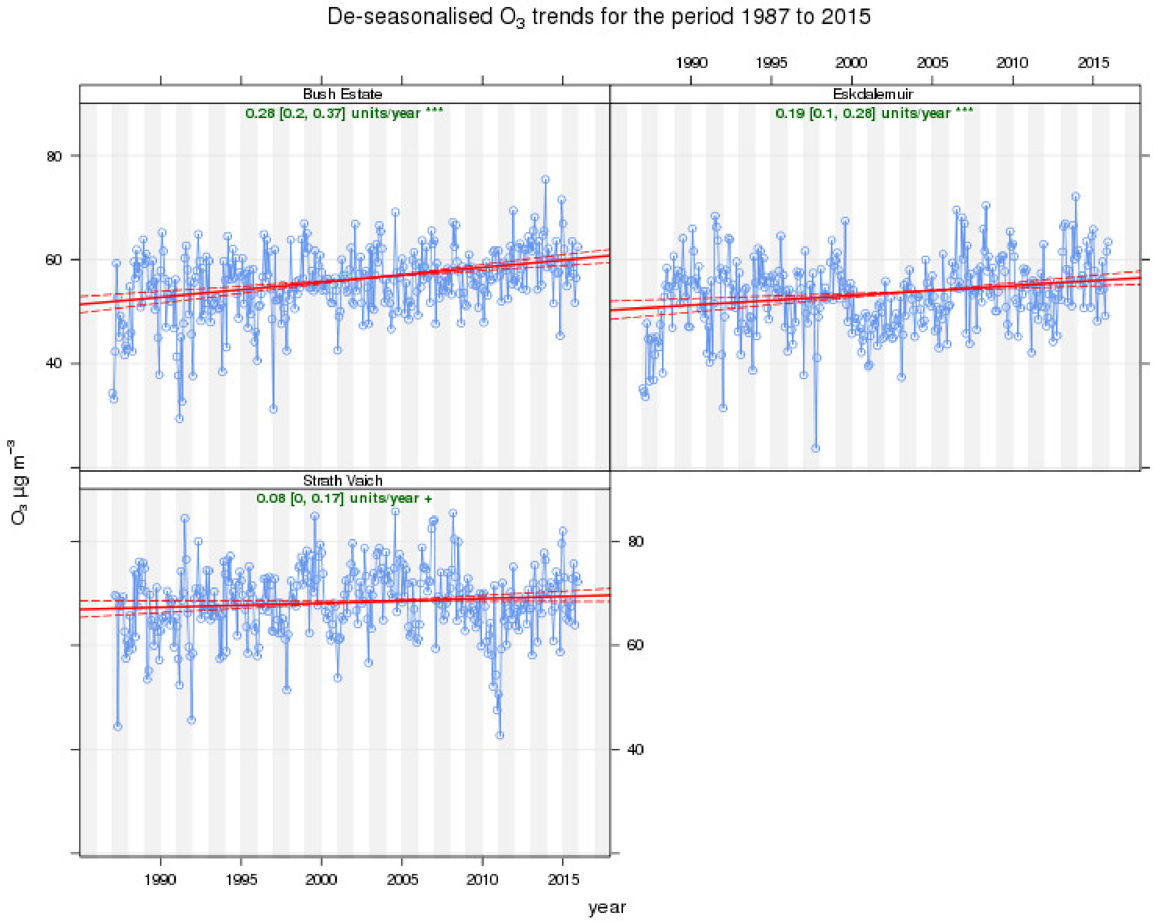
8.3 Ozone

8.3.1 Rural Ozone

Figure 8-18 shows trends in de-seasonalised monthly mean ozone (O_3) concentrations at the three long-running rural monitoring sites in Scotland. These sites have all been in operation since 1987: they are Bush Estate, Eskdalemuir and Strath Vaich. All three sites show a small but statistically significant upward trend in monthly mean rural ozone concentrations over this period. For Bush Estate and Eskdalemuir this trend is statistically significant at the 0.001 level. 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.[9]

Figure 8-18 Trends in O_3 Concentrations at Long-Running Rural Sites, 1987 – 2015

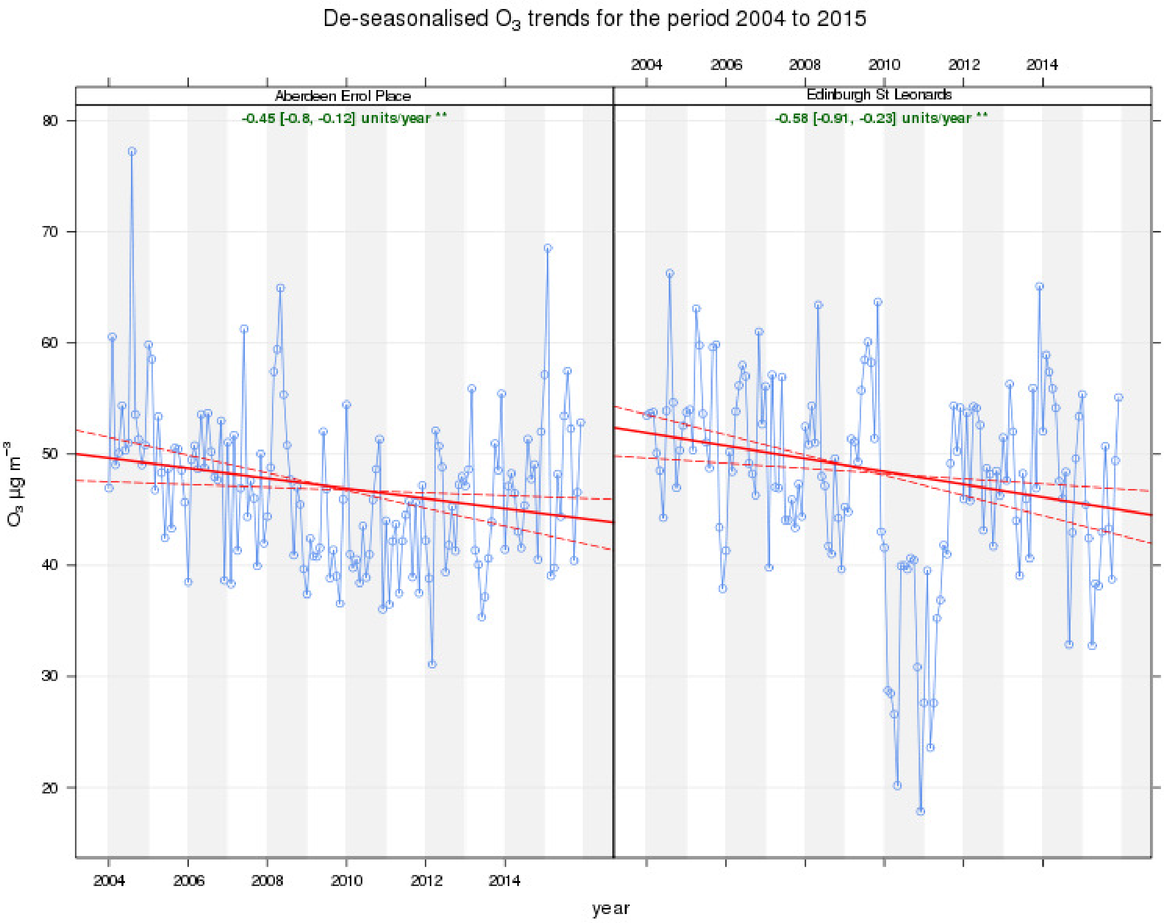


8.3.2 Urban Background Ozone

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

Figure 8-19 shows trends in de-seasonalised monthly mean ozone concentrations at the two Scottish urban background monitoring sites which currently monitor ozone, and have done so since 2004 or earlier: Edinburgh St Leonards and Aberdeen Errol Place. In contrast to the pattern observed at rural sites, both these urban background sites show *decreasing* trends in ozone concentration in the years since 2004. The trends are statistically significant at both sites. At Edinburgh St Leonards there is 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 8-19 Trends in O_3 Concentration at Two Long-Running Urban Background Sites, 2004 – 2015



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[10]. The inventory covers a wide range of pollutants, but in this report we provide information on NO_2 and PM_{10} only. Information on other pollutants can be found at www.naei.org.uk .

Within Scotland, SEPA collate 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 www.scottishairquality.co.uk . 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 9.2 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.

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).

9.1.1 Scotland NO_x Inventory by NFR Sector, 1990 – 2013

Table 9-1 and Figure 9.1 provide a summary of the NO_X emissions in Scotland by broad NFR sector categories. The detailed data are available in the report and website cited in the introduction to this Chapter.

Table 9-1 Scotland emissions of NO_X by NFR source sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005
1A1 - Energy Industries	98	66	53	50	57	52	51	48	47	47
1A2 - Industrial Combustion	13	11	8	9	9	9	8	8	8	8
1A3 - Transport Sources	117	96	81	76	70	66	64	61	59	57
1A4 -Commercial, Domestic and Agricultural Combustion	29	27	26	25	24	23	21	20	19	18
1A5,1B,2,4,5,6 - Other	27	22	22	21	20	20	17	16	17	17
Total:	283	222	190	182	180	171	161	154	149	147

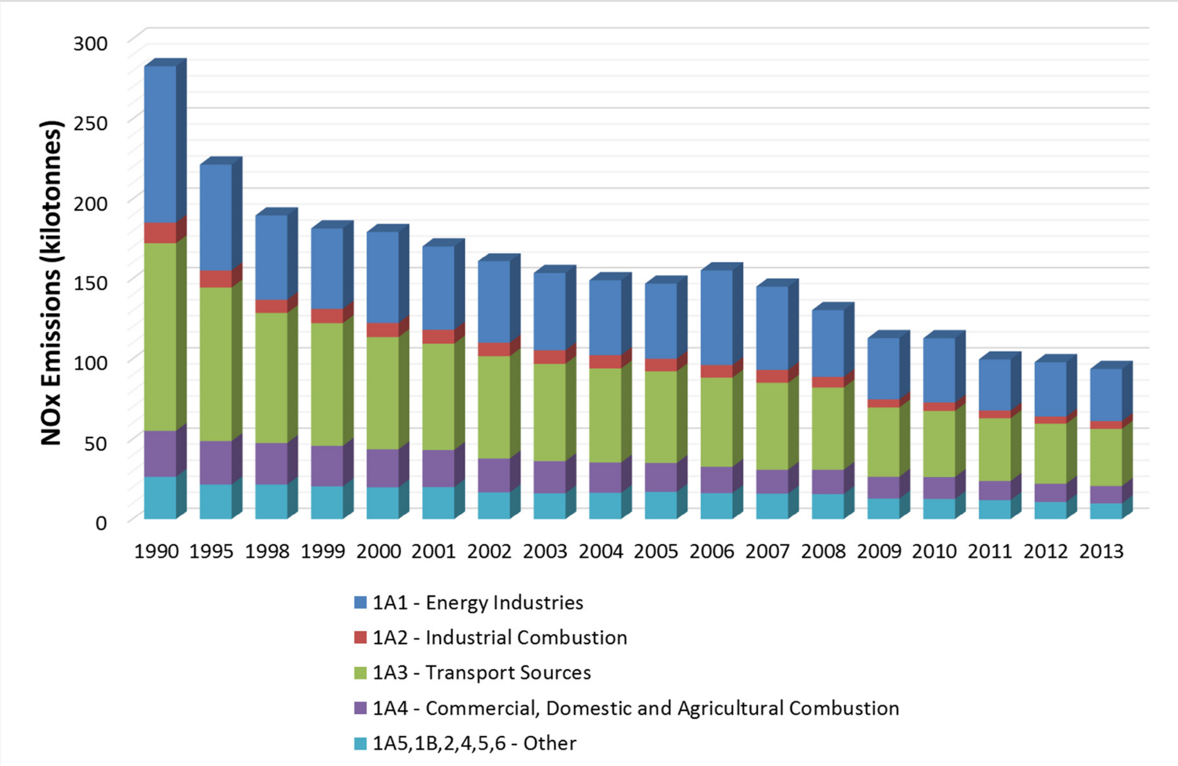
NFR Code	2006	2007	2008	2009	2010	2011	2012	2013	2013 (%)
1A1 - Energy Industries	59	52	42	38	40	32	34	32	35%

[10] Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 1990 – 2013 http://naei.defra.gov.uk/reports/reports?report_id=829

1A2 - Industrial Combustion	8	8	7	5	5	5	4	5	5%
1A3 - Transport Sources	56	54	51	43	41	39	37	36	38%
1A4 - Commercial, Domestic and Agricultural Combustion	16	15	15	14	14	12	11	11	12%
1A5,1B,2,4,5,6 - Other	17	16	16	13	13	12	11	10	11%
Total:	155	145	131	113	113	100	98	94	100%

Units: kilotonnes
Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 1990 – 2013

Figure 9.1 Time series of Scotland NO_x emissions 1990-2013



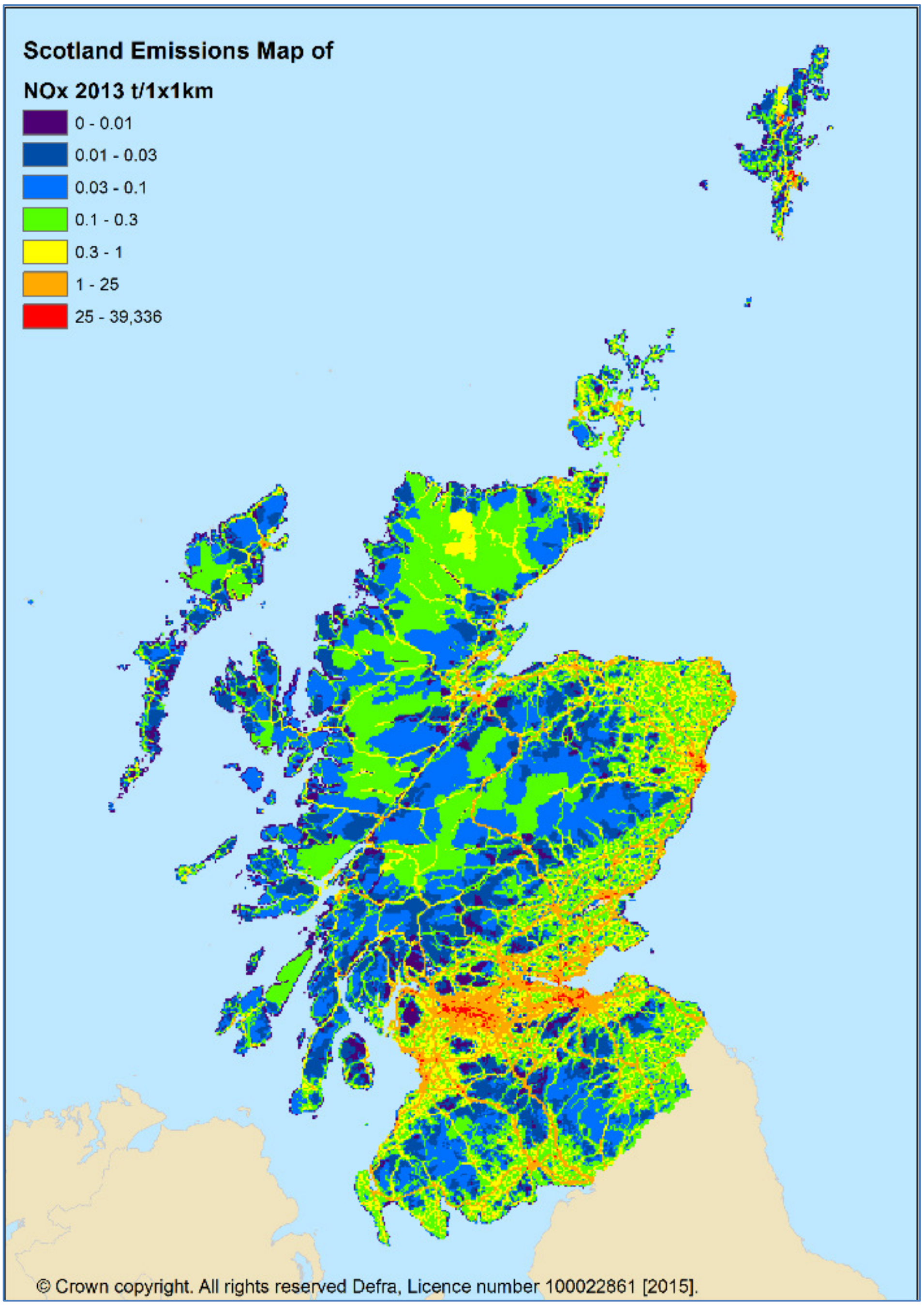
Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 1990 – 2013

Scotland's NO_x emissions have declined by 67% since 1990 and in 2013 accounted for 9% (94kt) of the UK total. 38% of these emissions stemmed from road transport combustion sources and 35% from power generation. These two sectors also represent the main sources of decline in NO_x emissions. The decline has mainly resulted from improvements in catalysts and the introduction of Euro Standards in vehicles, and the improvement in abatement technology and increase in renewables in power generation. *(Note that in the table and figure above, the sector 1A1 includes power generation, petroleum refining and other energy industries such as collieries and gas processing).*

Since 2009 the decreasing trend in NO_x emissions appears to have slowed in all sectors with the exception of transport sources. The peak in NO_x 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 9.1 energy sources is shown to have increased in 2012 from 2011 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 NO_x 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 NO_X emissions from coal-fired generation by up to 25%. BOFA systems were also fitted at Cockenzie power station which then closed in 2013.

Figure 9.2 shows a map of Scotland's NO_X emissions in 2013.

Figure 9.2 Map of NO_X Emissions in Scotland, 2013



Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 1990 – 2013

9.1.2 Scotland PM10 Inventory by NFR Sector 1990 – 2013

The table and graph below give a summary of the PM_{10} emissions in Scotland by broad NFR sector categories. The detailed data are available in report and website cited in the introduction to this Chapter.

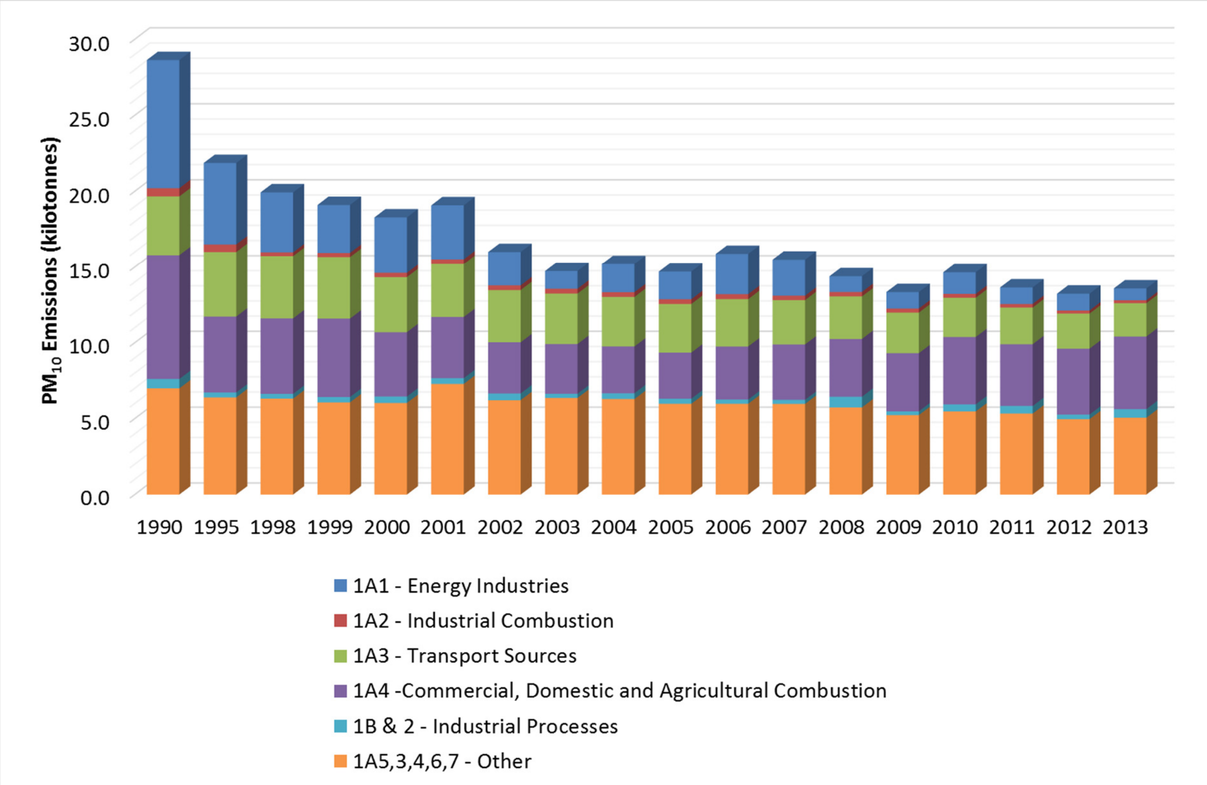
Table 9-2 Scotland's emissions of PM_{10}- by NFR source sector.

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005
1A1 - Energy Industries	8.4	5.4	3.9	3.2	3.7	3.6	2.2	1.2	1.9	1.8
1A2 - Industrial Combustion	0.5	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
1A3 - Transport Sources	3.9	4.3	4.1	4.1	3.6	3.5	3.4	3.3	3.3	3.2
1A4 -Commercial, Domestic and Agricultural Combustion	8.2	5.0	5.0	5.2	4.2	4.0	3.4	3.3	3.1	3.0
1B & 2 - Industrial Processes	0.6	0.3	0.3	0.4	0.4	0.4	0.4	0.3	0.4	0.3
1A5,3,4,6,7 - Other	7.0	6.4	6.3	6.1	6.0	7.3	6.2	6.4	6.3	6.0
Total:	28.6	21.9	19.9	19.1	18.3	19.1	16.0	14.7	15.2	14.7

NFR Code	2006	2007	2008	2009	2010	2011	2012	2013	2013 (%)
1A1 - Energy Industries	2.7	2.4	1.0	1.1	1.4	1.1	1.1	0.8	6%
1A2 - Industrial Combustion	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	1%
1A3 - Transport Sources	3.1	2.9	2.8	2.7	2.6	2.4	2.3	2.2	16%
1A4 -Commercial, Domestic and Agricultural Combustion	3.5	3.7	3.8	3.8	4.4	4.1	4.3	4.8	35%
1B & 2 - Industrial Processes	0.3	0.3	0.7	0.2	0.5	0.5	0.3	0.6	4%
1A5,3,4,6,7 - Other	6.0	6.0	5.7	5.2	5.5	5.3	5.0	5.1	37%
Total:	15.9	15.5	14.4	13.3	14.7	13.7	13.2	13.6	100%

Units: kilotonnes
Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 1990 – 2013

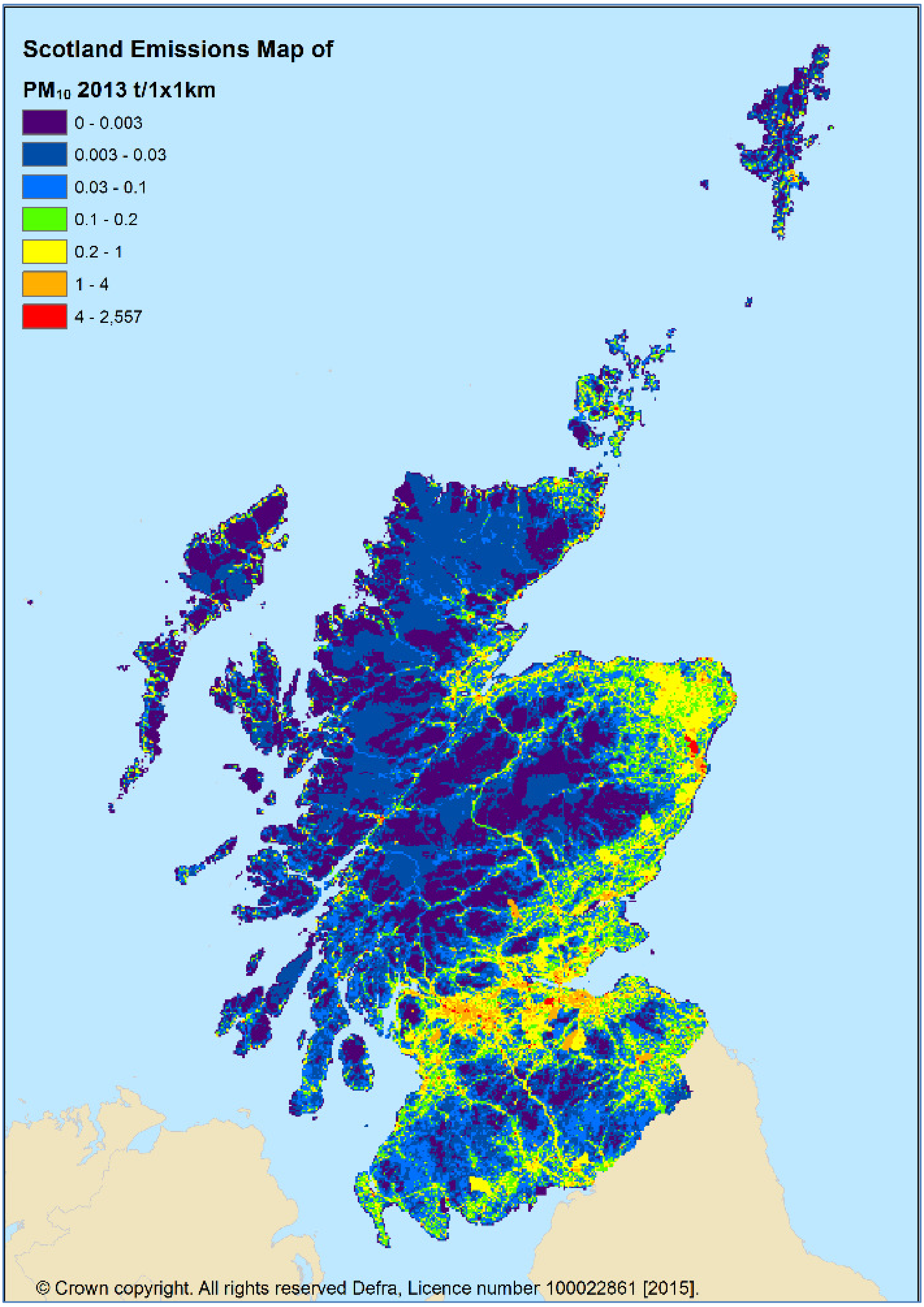
Figure 9.3 Time series of Scotland's PM_{10} emissions 1990-2013



Emissions of PM_{10} have declined by 53% since 1990 and in 2013 accounted for 11% (14kt) of the UK total. At 35%, emissions from commercial, domestic and agricultural combustion were the main source of PM_{10} in 2013. The percentage emissions from this source appear to have increased since 2000. Emissions from energy industries have had the most significant impact on the trend since 1990. Emissions from energy Industries which accounted for 25% of total emissions in 1990 have significantly reduced to 6% in 2013. This reduction is primarily due to abatement at coal fired stations, and the reduction in coal fired energy generation in place of natural gas (which has negligible PM_{10} emissions), nuclear and renewable sources.

Figure 9.4 shows a map of PM10 emission in Scotland for 2013.

Figure 9.4 Map of PM_{10} Emissions in Scotland, 2013



Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 1990 – 2013

10 Developments and Projects during 2015

10.1 Particulate Matter Monitoring Studies

In 2015, the Scottish Government commissioned two reports to help inform the planned changes to the Particulate Matter (PM) objectives to align them with the World Health Organisation (WHO) Guideline Values. These were;

- $PM_{2.5}$ and PM_{10} in Scotland: Investigation of concentrations and ratios of $PM_{2.5}$ and PM_{10} across Scotland to help inform potential changes to Air Quality Strategy Objectives and Local Air Quality Management [11]
- $PM_{2.5}$ Network in Scotland: Investigation of current PM_{10} and $PM_{2.5}$ monitoring network within Scotland to help inform the expansion of the network[12]

In November 2015 the 'Cleaner Air for Scotland – The Road to a Healthier Future' (CAFS) document stated the intentions to include in legislation as Scottish objectives the World Health Organization (WHO) guideline values for PM_{10} and $PM_{2.5}$. The Scottish Government also identified the need to establish a $PM_{2.5}$ monitoring network, these reports helped inform these actions.

The adoption of more stringent $PM_{2.5}$ and alignment with the WHO guidelines is principally based on addressing health concerns of finer fraction of Particulate Matter: The Scottish Government document CAFS states:

"…that there may be value in aligning the Scottish objectives with the WHO guidelines, both for consistency and because an increasing body of evidence suggests that $PM_{2.5}$ is the more significant particulate fraction in terms of health impacts".

It was estimated that in 2012 nearly 7 million people died worldwide prematurely due to air pollution[13]. The WHO stated that:

"…high concentrations of small and fine particulate pollution are particularly associated with high numbers of deaths from heart disease and stroke, as well as respiratory illnesses and cancers. Measurement of fine particulate matter of 2.5 micrometres or less in diameter ($PM_{2.5}$) is considered to be the best indicator of the level of health risks from air pollution"[14]. "*Diseases caused by $PM_{2.5}$ exposure include stroke, ischaemic heart disease, acute lower respiratory disease, chronic obstructive pulmonary disease, and lung cancer"*[15].

10.1.1 $PM_{2.5}$ and PM_{10} in Scotland

This report looked at particle concentration using current and historical data from Scottish Air Quality Database (SAQD) network, Pollution Concentration Mapping (PCM) and mobile monitoring, to establish how these proposed changes would affect the current Air Quality Management Areas (AQMAs) and Air Quality Action Plans (AQAPs).

The report also investigated the relationship between $PM_{2.5}$ to PM_{10}, to understand whether measured PM_{10} concentration could be used to estimate $PM_{2.5}$ concentrations. If so, this could help understand the impact of the proposed changes, and in the development of AQMAs and AQAPs

Finding, conclusions and recommendations from this report were as follows;

[11] http://www.scottishairquality.co.uk/news/reports?view=technical&id=528
[12] http://www.scottishairquality.co.uk/news/reports?view=technical&id=527
[13] WHO (2014a) *7 million premature deaths annually linked to air pollution.* WHO: World Health Organization. Available at: http://www.who.int/mediacentre/news/releases/2014/air-pollution/en/.
[14] WHO (2014b) *WHO | Air quality deteriorating in many of the world's cities.* WHO: World Health Organization. Available at: http://www.who.int/mediacentre/news/releases/2014/air-quality/en/ (Accessed: 09/11/15.
[15] Scovronick, N. (2015) *Reducing Global Health Risks: Through mitigation of short-lived climate pollutants - Scoping report for policymakers*, World Health Organization. Available at: http://apps.who.int/iris/bitstream/10665/189524/1/9789241565080_eng.pdf?ua=1.

- Exceedances of the current annual objectives (of 18 and 12 µg m^{-3} for PM_{10} and $PM_{2.5}$ respectively) have reduced from 2014 to 2015 at SAQD sites, from 19 to 11 exceedances for PM_{10} and from three to zero for $PM_{2.5}$. Increasing the PM_{10} objective from 18 to 20 µg m^{-3} would result in fewer exceedances: six in 2014 and three exceedances in 2015. By lowering the $PM_{2.5}$ Objective from 12 µg m^{-3} to 10 µg m^{-3} the number of exceedances in 2015 would increase very slightly.

- PCM data indicated that the number of exceedances would increase from zero to 22 as a result of the proposed decrease in the $PM_{2.5}$ objective of 12 to 10 µg m^{-3}. Mobile monitoring results were also compared with the objectives but since the mobile monitoring was only carried out on a short-term basis the results were not comparable with the annual mean objective. The mobile monitoring data could only provide a "snap shot" representative of local conditions and weather at a specific location and time

- Changing the PM_{10} objective to 20 µg m^{-3} would impact on the Air Quality Management Areas across Scotland, with many current PM_{10} AQMAs becoming unnecessary. This would have effects on the Air Quality Action Plans that have been developed by local authorities to improve local concentrations of PM_{10}, perhaps leading the abandoning of such plans. This could be counter-productive to efforts to reduce PM_{10} and $PM_{2.5}$: by tackling PM_{10} (or more specifically primary PM), $PM_{2.5}$ is also targeted indirectly. Thus by maintaining the PM_{10} objective at 18 µg m^{-3} the AQMAs and Action Plans will stay as they are and $PM_{2.5}$ may reduce proportionally (albeit to a limited extent, because reduction of primary PM does not address the problem of transboundary particulate pollution which is believed to make a large contribution to $PM_{2.5}$.). This proportional reduction for annual mean $PM_{2.5}$ is estimated to be in the order of 0.8 µg m^{-3} for a 30% reduction in primary PM, thus there is limit to what can be achieved. The modelled background concentration of $PM_{2.5}$ for Scotland is 6.6 µg m^{-3}, whereas within the Scotland's cities this is around 8 µg m^{-3}, thus an annual mean objective of less than 10 µg m^{-3} might be difficult to achieve in some areas.

- Changes in the $PM_{2.5}$ objectives may also require further planning to develop AQMAs specifically for $PM_{2.5}$, and thus there is a need to increase the current $PM_{2.5}$ network. The study investigated the feasibility of using data from the PM_{10} network to estimate $PM_{2.5}$ concentrations. The SAQD network operates over 70 PM_{10} monitors measuring particulates, and although the number of $PM_{2.5}$ monitors is rising (from nine to fourteen between 2014 and 2015), there are still many more monitoring sites for PM_{10} than for $PM_{2.5}$. If it is possible to estimate $PM_{2.5}$ from PM_{10} data on the basis of typical relationships between the two metrics – specifically, the ratio of annual mean $PM_{2.5}$ to annual mean PM_{10} - this could increase the number of $PM_{2.5}$ data points by fivefold throughout Scotland.

- The data from the SAQD from recent years indicates that the ratio of annual mean $PM_{2.5}$ / annual mean PM_{10} are changeable, but largely similar to those seen across Northern Europe. As an approximate indication, based on the sites and years included in this study, it was concluded that equation; **annual mean [$PM_{2.5}$] ≈ 0.63 x annual mean [PM_{10}**] would provide the best estimate concentration of $PM_{2.5}$. This however, should only be used to provide indicative estimates of annual concentrations. When applied to 2015 PM_{10} data is was estimated that five SAQD PM_{10} sites would have exceeded the $PM_{2.5}$ Objective for of 12 µg m^{-3}. Twenty-seven SAQD PM_{10} sites were likely to have exceeded the proposed new Objective (10 µg m^{-3}).

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

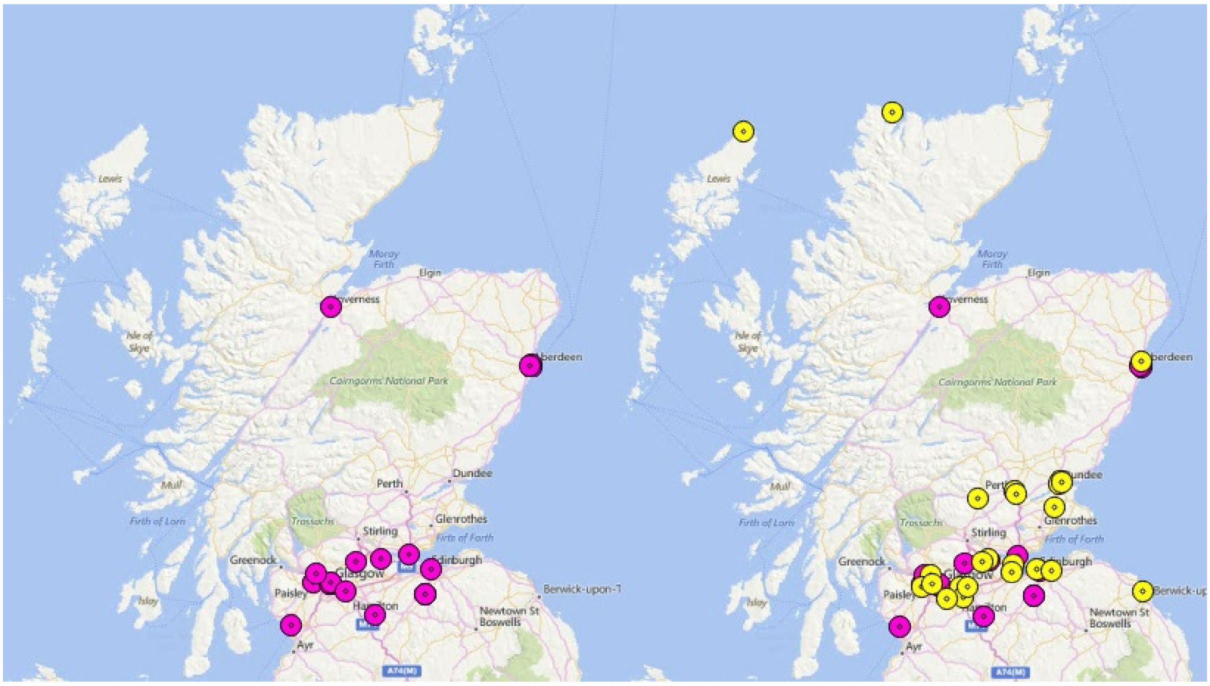
- It was recommended within the report to maintain the current PM_{10} objective and to change the $PM_{2.5}$ Objective to align with the WHO guidance.

Since this work was commissioned, the Scottish Government brought into force the Scottish objective for $PM_{2.5}$ of 10 µg m^{-3} on the 1st April 2016.

10.1.2 $PM_{2.5}$ Network in Scotland

This report looked at the current $PM_{2.5}$ network in Scotland, it investigated the current $PM_{2.5}$ and PM_{10} monitoring network and aimed to help inform the future expansion of the network. The report looked at the existing $PM_{2.5}$ network, shown in Figure 7.2 (in purple), the type of analysers available to measure $PM_{2.5}$ fraction and monitoring site locations. It also took into consideration the current PM_{10} network, the potential to include $PM_{2.5}$ monitoring through supplementary sites or upgrades, the potential costs and how the network could be implemented.

Figure 7.2 Current $PM_{2.5}$ monitoring sites (in purple) in Scotland as of January 2016 (each site also measures PM_{10}), and proposed $PM_{2.5}$ sites (in yellow) overlaid over current sites.



Finding, conclusions and recommendations from this report were as follows;

- There are currently significantly fewer $PM_{2.5}$ monitoring sites in the SAQD Network than there are PM_{10} monitoring sites: at the time of writing, 16 $PM_{2.5}$ instruments compared to 76 PM_{10} throughout the SAQD.
- Geographical coverage of $PM_{2.5}$ monitoring is uneven, with sites concentrated around the major cities particularly in the Central Belt of Scotland. There are only four $PM_{2.5}$ instruments within the 21 PM_{10} Air Quality Management Areas within Scotland,
- Based upon modelling data from Scottish and UK pollution climate mapping programmes, and on estimates of $PM_{2.5}$ concentration using typical annual mean $PM_{2.5}/PM_{10}$ ratios from sites in Scotland where both metrics are measured, it has been estimated that numerous PM_{10} AQMAs might also have exceedances of the 10 µg m^{-3} $PM_{2.5}$ Objective.
- The recent increase in the number of $PM_{2.5}$ monitoring sites within Scotland has been partly brought about by the replacement of aging instruments, but also increased take-up of a new analyser which has been shown to reduce costs.
- The financial pressure on local authorities is likely to significantly influence the acquisition of new instruments, thus this expansion of the $PM_{2.5}$ network is unlikely to continue due to market forces alone, and will probably require some influence from the local and national Government.
- The majority (66% for $PM_{2.5}$ and 87% for PM_{10} respectively) of SAQD sites are roadside or kerbside.

- Instrument types also varied across the network, as did their age, TEOM FDMS and the newer FIDAS instruments dominated $PM_{2.5}$ analysers, whereas for PM_{10} monitoring, older instruments such as the TEOM and BAM were numerous. The age of instruments ranged from a few months to 15 years.

- Of these instruments all but one type demonstrate equivalence, though some require corrections for equivalence according to Defra and EU standard. Although it is possible to simply and inexpensively retrofit most PM_{10} analysers to measure $PM_{2.5}$, there is likely to be a requirement to measure PM_{10} at the same location.

- Installing an additional PM analyser might not always be cost effective if a larger enclosure is required.

- If the $PM_{2.5}$ Objective is reduced to 10 µg m^{-3} and Scottish Government wish to expand the $PM_{2.5}$ network to capture compliance (especially considering the current geographical limitation of the network), then it is recommended that a strategy to increase the number of sites with $PM_{2.5}$ analysers needs to be considered.

- The initial focus should be to cover areas with currently no $PM_{2.5}$ monitoring, especially those with current AQMAs for PM_{10}. Additionally, a further expansion of the $PM_{2.5}$ network should look to mirror, to some extent, the current PM_{10} network within Scotland, with consideration to an area having both roadside, urban background and rural sites.

As stated previously, since this work was commissioned, the Scottish Government brought into force the Scottish objective for $PM_{2.5}$ of 10 µg m^{-3} on the 1st April 2016.

10.2 Open Data Web Services for the SAQD

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

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

In response to the INSPIRE directive; the European Air Quality e-Reporting rules and standards for open data sharing; the need for automated machine readable access to the SAQD; and wider Scottish Government policy drivers on open data and transparency, the Scottish Air Quality Website was updated with a new data sharing mechanism called Open Data Services.

The implementation of Open Data Web services to the SAQD was broken down into 5 thematic service types;

1. Metadata for discovery for the SAQD observational datasets
2. INSPIRE conformant viewing services for the SAQD monitoring locations and related spatial datasets
3. Services for the download of SAQD monitoring station configurations in human and machine readable format
4. Services for the download of historical ratified and provisional up-to-date observational data in machine readable format
5. Services for the download of aggregated observational data in machine readable format

At the time of writing this report the Open Data Web services were under review by Scottish Government. Once approved the Air Quality in Scotland website data page (http://www.scottishairquality.co.uk/data/) will be updated with the following sub-sections:

- **Air Quality Spatial Object Register** - a resource for viewing and retrieving information on the air quality objects / features from the Scottish Government's Air Quality e-Reporting data holdings. It acts as a directory of all air quality related spatial and data objects managed by the Scottish Government.
- **Atom Download Services** - providing users with a resource to download measurement data and metadata on assessment methods in open formats. The Atom feeds are aimed at users wishing to download larger volumes of data in a consistent format.
- **Sensor Observation Services** - providing a machine readable access point for air pollution measurements hosted on Air Quality in Scotland. The service provides an API type interface to Scottish Air Quality for developers and machine to machine data transfer in open, machine readable data formats.

10.3 Education

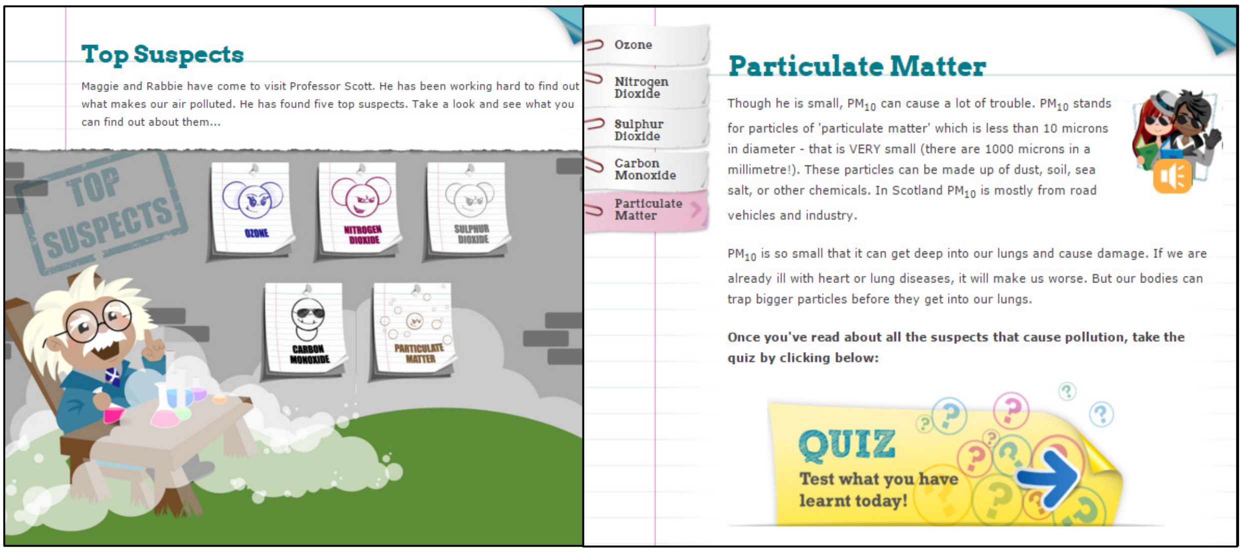
Education has been a relatively recent development for Air Quality in Scotland. Interactive education packages have been developed through the creation of two sections which form part of Air Quality in Scotland website. The first education website 'Air Pollution Detectives' was created for primary school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

Figure 10.2 Air pollution Detectives and Clear the Air

10.3.1 Air Pollution Detectives

Initially launched in 2011, the Air Pollution Detectives has been revised and updated. The webpage was designed to introduce air quality issues to primary school pupils between the ages of 8-11 years old. The animated, interactive webpages provide an introduction to air pollution sources and how pupil's actions can impact the air quality around them. Pupils can select individual pollutants to learn more and can take the quiz after each section to see what they have learned. The website is accompanied by a set of teacher's 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/

Figure 10.3: Interactive sections on the Air Pollution Detectives webpages



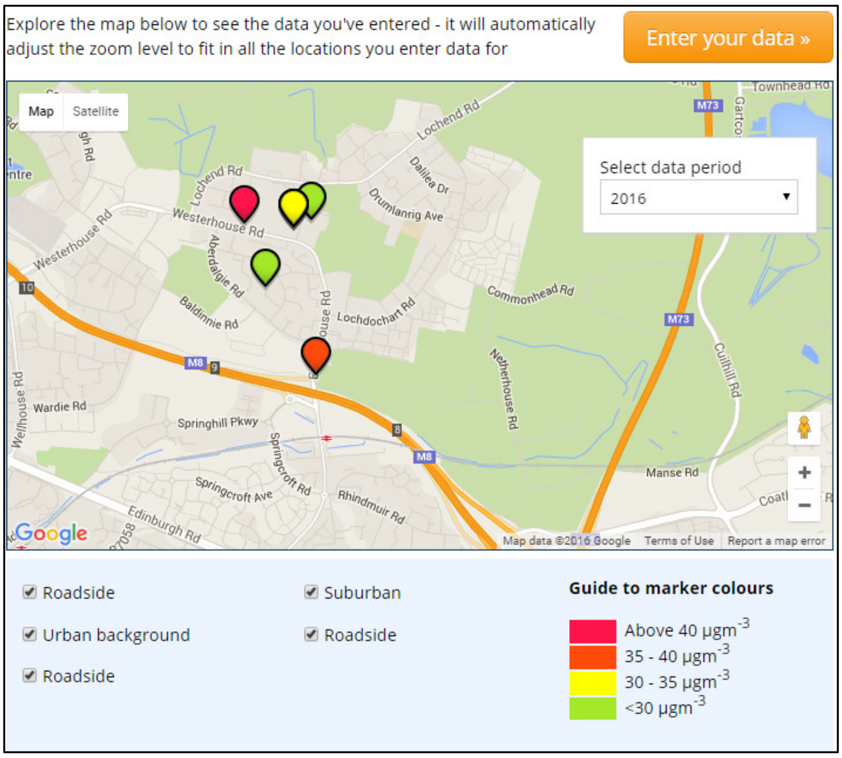
10.3.2 Clear the Air

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 webpage is aimed at secondary school pupils between the ages of 12-15 years old. The Clear the Air package includes a series of interactive webinars and exercises designed to be undertaken by pupils. These interactive exercises include 'What air pollution is like near me', 'Calculating your emissions to school' and lastly a class citizen science project which allows air quality to be monitored around the school by using NO_2 diffusion tubes. Pupils will also be given an NO_2 diffusion tube to take home so they may also monitor outside their house.

10.3.3 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 at or near their homes. Once the results have been analysed the website enables the monitoring data to be input in terms of location and measured concentration via the school's private user portal so that the results can be displayed on a map, as shown in Figure 10.4. The package encourages pupils to discuss the results and the factors influencing the air quality measured within the area. The Clear the Air package is supported by a teacher's pack including notes to supplement the monitoring equipment and webinars to help introduce the concept of local air quality and conduct the monitoring. Further information regarding the programme can be obtained at: http://cleartheair.scottishairquality.co.uk

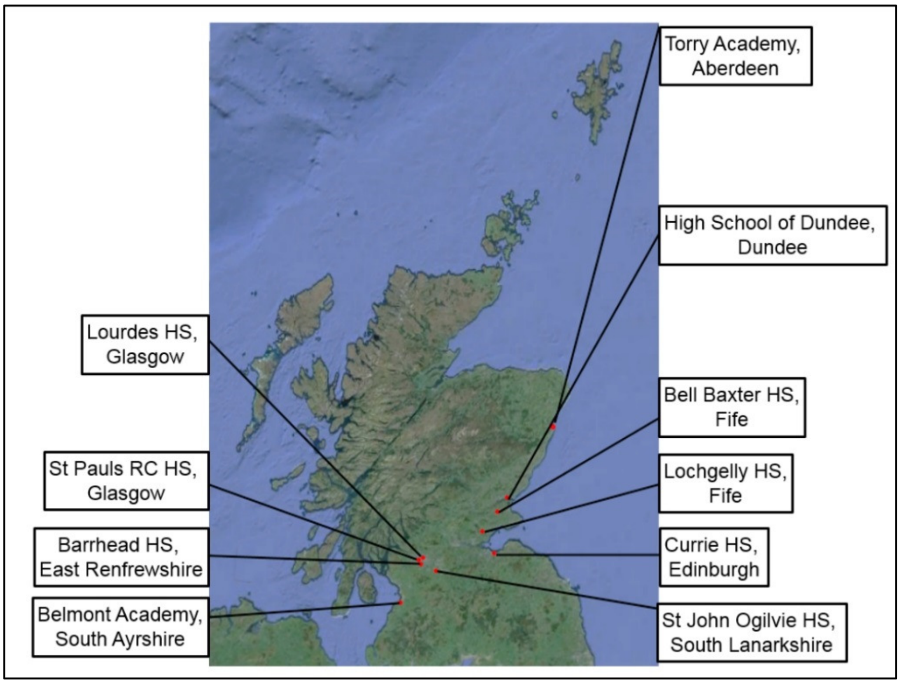
Figure 10.4: Data entry available on each school profile



10.3.4 Clear the Air – Funded Schools

In 2015, the Scottish Government allocated funds to provide the Clear the Air packs to a number of Scottish secondary schools. The ten schools selected to receive funded packs are shown in figure 10.5. Each school is in the process of going through the Clear the Air programme.

Figure 10.5: Schools allocated Scottish Government funded packs



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

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

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

10.4 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 . Additionally, to awstats, Google Analytics is also used to track and evaluate website usage.

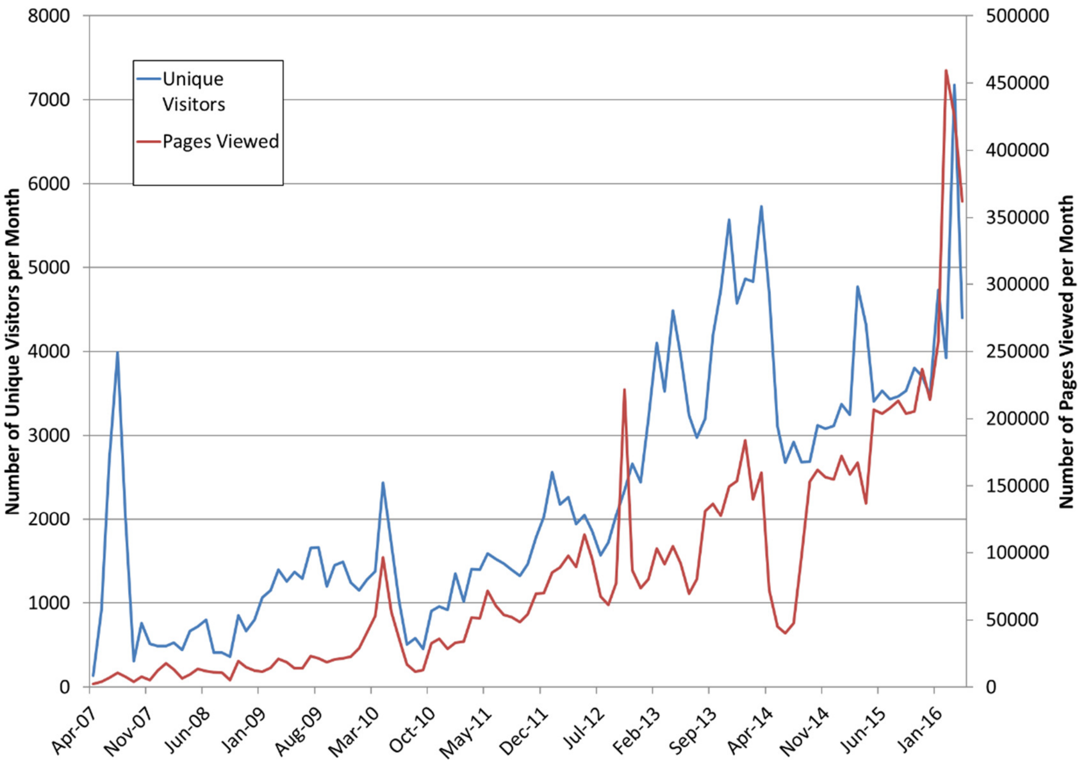
These software tool provides in-depth analysis of the time, date, location and access route of every visit to the website (It does not store any personal information which would require declaring under the Data Protection Act). Figure 10.6 below illustrates how the number of hits has varied during the period April 2007 to April 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 10.6 clearly indicates an upward trend in the number of unique visitors and pages viewed since the site was launched in 2007. The plot also shows that the largest number of unique visitors were recorded during March 2016. This is in addition to the annual cycle of review and assessment activity which sees local authorities use the site (usually between April and May) to compile data and statistics for their annual reports.

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 10.6 Air Quality Scotland Website Hits April 2007 - April 2016



10.5 Website Maintenance

On a daily basis the web pages are fully checked by the Ricardo Energy and Environment web 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 national AURN sites are made as required (e.g. If new particulate monitoring instruments come on-line or other sites/instruments are changed)
- New local authority monitoring sites are added to the database once agreement is reached with the operators.
- Site photos are added as soon as Ricardo Energy and Environment carry out our QA/QC visits, or they are provided by the local authority.
- 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 LAQM pages are 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.

- The news section is updated with any relevant information provided by the Scottish Government or other website stakeholders.
- Requests to subscribe to the discussion forum are reviewed on a daily basis.

We are pleased to report that thanks to the on-going checks and maintenance the web pages were available for over 99% of the time during 2015 with no extended breakdowns or downtime reported.

11 Summary and Conclusions

Legislation and Policy

The "Cleaner Air for Scotland – The Road to a Healthier Future" (CAFS) strategy was published by 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 our 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 $PM_{2.5}$ objectives with the WHO guideline value of 10 ug m^{-3}. This was introduced on the 1st April 2016.

The Scottish Government Policy Guidance and the Defra and Devolved Administrations Technical Guidance on LAQM were updated in April 2016. The newly published UK 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.

Automatic Monitoring Data 2014

Air pollution data for 92 automatic monitoring sites throughout Scotland are available in the database for all or part of 2015. All automatic data 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.

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 present, 15 local authorities in Scotland have declared a total of 37 AQMAs.

Nitrogen Dioxide

Nitrogen dioxide data was collected for 78 sites utilising automatic monitoring during 2015. Although, data for eight of these are only available for part of the year with the overall data capture less than 75%. These include sites which opened or closed during the year, sites which were closed for part of the year due to instrument problems.

Of the remaining 70 sites with more than 75% data capture, eight of these (kerbside or roadside sites) exceeded the AQS Objective for the NO_2 annual mean (40 µg m^{-3}). The AQS Objective of not more than 18 exceedances of 200 µg m^{-3} for the hourly mean was also exceeded at Edinburgh St John's Road; a Kerbside site.

The highest annual average concentrations were measured at Edinburgh St John's Road, with a measured annual mean concentration of 65 µg m^{-3}. The greatest number of exceedances of the hourly mean objective was measured at Edinburgh St John's Road with 42 exceedances.

Particulate Matter (PM_{10})

Gravimetric equivalent particulate matter PM_{10} data from 76 sites utilising automatic monitoring and the Partisol daily sampler was collected during 2015. Of these sites, 17 have less than 75% data capture.

Of the 59 sites with 75% or greater data capture, 4 sites exceeded the annual average PM_{10} Objective of 18 µg m^{-3} and a further 3 equaled this Objective. Of these sites, Aberdeen Market St 2, Aberdeen Wellington Rd and Edinburgh Salamander St also exceeded the daily mean objective of 50 µg m^{-3} not to be exceeded more than 7 times in a year. The daily mean object was also exceeded at Aberdeen King St, unusually without exceeding the annual mean objective.

The maximum PM_{10} annual mean concentration was measured at Aberdeen Wellington Rd, Dundee Lochee Rd and Edinburgh Salamander St with a measured annual mean concentration of 20 µg m^{-3} and 16, 5 and 8 exceedances of the daily mean objective, respectively.

Of the 17 sites with less than 75% data capture East Ayrshire Kilmarnock John Finnie St measured average PM_{10} concentrations equaling than the annual average PM_{10} Objective of 18 µg m^{-3}.

No site exceeded the UK AQS Objective of 40 µg m^{-3} for the annual mean PM_{10} and the daily mean objective of no more than 35 exceedances of 50 µg m^{-3}.

Note that at the rural Auchencorth Moss site south of Edinburgh, both FDMS and Partisol analysers are operated for PM_{10} (and $PM_{2.5}$). Both methods measured similar annual average PM_{10} concentrations of 6 µg m^{-3} and 7 µg m^{-3}, respectively. No exceedances of the daily objective were measured at the two sites.

Particulate Matter ($PM_{2.5}$)

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 kerbside site in Glasgow and 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} being introduced in April 2015, local authorities introduced $PM_{2.5}$ monitoring. During 2015 $PM_{2.5}$ monitoring started at Fife Rosyth, North Ayrshire Irvine High St, South Lanarkshire Lanark and Uddingston, and West Dunbartonshire Clydebank resulting in a total of 15 $PM_{2.5}$ monitoring sites.

Data capture rates of less than 75% were measured at Aberdeen Market St 2, Fife Rosyth, North Ayrshire Irvine High St and South Lanarkshire Lanark. $PM_{2.5}$ concentrations in excess of the Scottish AQS Objective of 10 µg m^{-3} as an annual mean was measured at Aberdeen Union St with a data capture rate of 83%. .

At the rural Auchencorth Moss site south of Edinburgh, both FDMS and Partisol analysers are operated for $PM_{2.5}$. Annual mean $PM_{2.5}$ concentrations were measured by the Partisol sampler and FDMS analyser during 2015, 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 2015. The highest $PM_{2.5}/PM_{10}$ ratios during 2015 for sites with greater than 75% data capture was calculated at Aberdeen Errol Place and Glasgow Kerbside with calculated ratios of 0.69 and 0.70, respectively.

Carbon Monoxide

Carbon monoxide was monitored using automatic techniques at 2 sites (Edinburgh St Leonard's and N Lanarkshire Croy) during 2015. All monitoring sites achieved the Air Quality Strategy Objective for this pollutant.

Sulphur Dioxide

Sulphur dioxide (SO_2) was monitored using automatic techniques at 9 sites during 2015. Dundee Broughty Ferry Rd, N Lanarkshire Kirkshaws and Shetland Lerwick were de commissioned on 16/01/15, 25/03/15 and 10/11/15 respectively so data are only available for part of the year. All sites in Scotland met the 15 minute, 1-hour and 24-hour mean Objectives for SO_2 in 2015.

Ozone

Ozone was monitored at 11 sites utilising automatic monitoring for 2015. Ozone 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 2015, the air quality objective of not more than 10 days with a maximum 8 hr running mean greater than 100 µg m^{-3} was not exceeded at any sites.

Air Quality Mapping

NO_2 Maps for 2014

Maps shows that there were three modelled exceedances of the Scottish annual mean NO_2 objective of 40 µg m^{-3} at background locations. These three exceedances are located close to Aberdeen Harbour and are linked to emissions from shipping.

The Scotland-specific model predicted that the Scottish annual mean NO_2 air quality objective was exceeded along 54 road links (63 km of road). The majority of exceedances were predicted to occur in the Glasgow Urban Area where exceedances were modelled for 34 road links (41 km of road). Overall exceedances of the Scottish annual mean NO_2 air quality objective were modelled in four of the six zones and agglomerations in Scotland. In each of the other three Scottish zones and agglomerations there were fewer than 10 road links where exceedances of the Scottish annual mean NO_2 air quality objective were modelled, effecting 5-9 km of roads. No roadside exceedances of the Scottish annual mean NO_2 air quality objective were modelled in the more rural zones and agglomerations of Scotland.

PM_{10} Maps for 2014

Exceedances of the Scottish annual mean PM_{10} objective of 18 µg m^{-3} were modelled at seventy-one 1 km^2 grid squares in Scotland, as shown in Table 7.3. Twenty-nine exceedances in background concentrations of PM_{10} occur in the vicinity of Edinburgh. The majority of these are located on the western outskirts of Edinburgh close to Edinburgh airport and the M8 corridor. Additional isolated exceedances on the outskirts of Edinburgh and are related to industry and agriculture. Forty-one exceedances are located close to Aberdeen. The causes of exceedances modelled in these areas are varied and relate to a combination of quarrying and industry, the contribution of road transport emissions to background, or shipping close to Aberdeen Harbour.

72 road links (84 km of road) were identified as exceeding the Scottish annual mean PM_{10} air quality objective. Exceedances of the Scottish annual mean PM_{10} objective were modelled on 15 road links (24.7 km of road) in North East Scotland, 12 road links (9.5 km of road) in Central Scotland and 9 road links in the Edinburgh Urban Area (12.8 km of road). No roadside exceedances of the Scottish PM_{10} objective were modelled in the Highlands or Scottish Borders.

Air Quality Trends

NO_2

In terms of concentrations of NOx the longest-running urban background monitoring site in Scotland is Aberdeen, Errol Place (in operation from late 1999 onwards). NOx concentrations at this site increased slightly in its earlier years of operation but have shown a general decrease since 2002. The pattern for NO_2 is in some respects similar to that observed for NOx, in that it peaks around 2002 with a subsequent decrease: however, NO_2 appears to show more variation.

Three urban non-roadside sites have been monitoring NOx since 2004 or earlier; Aberdeen Errol Place, Edinburgh St Leonards, and Grangemouth. All three sites show a negative trend (i.e. decreasing NOx). The actual decrease year-on-year is small; however, the trend is statistically highly significant at Aberdeen Errol Place, and significant at Edinburgh St Leonards. In the case of NO_2 all sites again show a slight negative trend, though the year-on-year decrease is even smaller than for total NOx.

Three long-running rural sites have monitored oxides of nitrogen since 2005 or earlier: Bush Estate, Eskdalemuir and Glasgow Waulkmillglen Reservoir. While the sites at Bush Estate and Eskdalemuir show small but highly significant downward trends, this is not the case for Glasgow Waulkmillglen Reservoir, where – by contrast - concentrations are increasing (though the trend is not significant).

At Scotland's longest running traffic-related urban site, Glasgow Kerbside, there is considerable fluctuation in NOx at this site, but some indication of an overall downward trend. By contrast, in the case of NO_2, there is no apparent downward trend over this period. A downward trend is however evident from 2010 (when concentrations peaked since 1997) onwards.

Looking at a subset of nine long-running sites at urban traffic locations (Aberdeen Anderson Drive, Dumfries, East Dunbartonshire Bishopbriggs, Edinburgh Gorgie Road, Glasgow Byres Road, Glasgow Kerbside, Inverness, Perth Atholl Street and Perth High Street). Seven of the sites show a downward trend in NOx, however, both Aberdeen Anderson Drive and Inverness show slight upward trends (statistically significant in the case of Aberdeen Anderson Drive).

In the case of NO_2, five of the sites (Dumfries, East Dunbartonshire Bishopbriggs, Edinburgh Gorgie Road, Perth Atholl Street and Perth High Street) show statistically significant downward trends. Inverness shows a small but statistically significant upward trend and the remaining three show no significant trend at all. This is similar to the previous two years reports and indicating that trends depend greatly on local conditions. This may be illustrated by data from Dundee, where four urban traffic monitoring sites have been measuring NO_2 since 2006. Even though all these sites are at roadside locations, and in the same city, they show different trends in NO_2 concentration.

PM_{10}

The longest-running Scottish urban background PM_{10} monitoring site is Aberdeen Errol Place (since 1999). This shows no clear trend in the early years, followed by a significant decrease from around 2004 until 2013. There is some indication of a recent small up-turn around 2014 but the decrease appears to have resumed in 2015.

Looking at a subset of longest running urban non roadside sites (Aberdeen Errol Place, Dundee Mains Loan, Edinburgh St Leonards and Grangemouth), all sites show a negative trend significant at 0.001.

In terms of long term traffic related sites. A subset of the longest running sites all show a statistically significant downward trend, indicating a year on year decrease.

Since Glasgow Kerbside ceased monitoring PM10 in 2014, the longest-running urban traffic PM_{10} monitoring site is now Inverness (which began monitoring this pollutant in 2001). This site too shows a highly significant downward trend, significant at the 0.001 level.

$PM_{2.5}$

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

When Glasgow Kerbside is compared to other similar sites in the UK, it appears that downward trends in $PM_{2.5}$ concentrations are now being observed at roadside locations around the UK. However, this is not consistent at all sites and there is still a considerable variation. It is possible that this variation reflects differing trends in relevant factors influencing localised $PM_{2.5}$ concentrations (such as traffic flow)

Ozone

For all long running rural ozone sites (Bush estate, Eskdalemuir and Strath Vaich), though fluctuating considerably, plots show a small but statistically significant upward trend. In contrast to the pattern observed at rural sites, both these urban background sites show decreasing trends in ozone concentration in the years since 2004. The trends are statistically significant at both sites.

Emissions of Pollutants

Scotland's NO_x emissions have declined by 67% since 1990 and in 2013 accounted for 9% (94kt) of the UK total. Road transport combustion and power generation represent the main sources of decline in NO_x emissions.

Since 2009 the decreasing trend in NO_x emissions appears to have slowed in all sectors with the exception of transport sources. Energy sources is shown to have increased in 2012 from 2011 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.

Emissions of PM_{10} have declined by 53% since 1990 and in 2013 accounted for 11% (14kt) of the UK total. At 35%, emissions from commercial, domestic and agricultural combustion were the main source of PM_{10} in 2013. The Percentage emissions from this source appears to have increased since 2000. Emissions from energy Industries which accounted for 25% of total emissions in 1990 have significantly reduced to 6% in 2013. This reduction is primarily due to abatement at coal fired stations, and the reduction in coal fired energy generation in place of natural gas (which has negligible PM_{10} emissions), nuclear and renewable sources.

Developments and Projects during 2015

A number of developments and projects were undertaken during 2015. These included;

- In 2015, the Scottish Government commissioned two reports to help inform the planned changes to the Particulate Matter (PM) objectives to align them with the World Health Organisation (WHO) Guideline Values. These were;
  - $PM_{2.5}$ and PM_{10} in Scotland: Investigation of concentrations and ratios of $PM_{2.5}$ and PM_{10} across Scotland to help inform potential changes to Air Quality Strategy Objectives and Local Air Quality Management [16]
  - PM2.5 Network in Scotland: Investigation of current PM_{10} and $PM_{2.5}$ monitoring network within Scotland to help inform the expansion of the network[17]

- In response to the INSPIRE directive; the European Air Quality e-Reporting rules and standards for open data sharing; the need for automated machine readable access to the SAQD; and Wider Scottish Government policy drivers on open data and transparency, the Scottish Air Quality Website was updated with a new data sharing mechanism called Open Data Services.
- To promote the education of Air Quality issues in schools, Scottish Government allocated funds to provide the Clear the Air – Air Quality Monitoring Packs to ten secondary schools across Scotland during 2015.

[16] http://www.scottishairquality.co.uk/news/reports?view=technical&id=528
[17] http://www.scottishairquality.co.uk/news/reports?view=technical&id=527

Appendices

Appendix 1 – National Monitoring Networks in Scotland 2014

Table A1.1. AURN Measurement Sites in Scotland 2015

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
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	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
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 2015

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 2015

Site Name	Site Type	Species Measured	Grid Reference
Glasgow Kerbside$^{\alpha}$	KERBSIDE	Benzene	258708, 665200

Grangemouth	URBAN INDUSTRIAL	Benzene	293840,681032

EU requirement and part of the EMEP long-range transboundary air pollution monitoring programme.
[α]Non-Automatic Monitoring of Benzene started at this site on 01/09/10.

Table A1.3 PAH Monitoring Sites in Scotland 2015

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 2015

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 2015

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 2015

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 2015

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	✓	
Loch Awe	196673,711509	✓	

Name	Grid Ref	Ammonia	Nitric Acid
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 in a doubling of the analyser signal response. If an analyser is not linear, data cannot be reliably scaled into concentrations.
- Ozone analyser calibration against a traceable ozone photometer
- Instrument signal noise, to check for a stable analyser response to calibration gases.
- Analyser response time, to check that the analyser responds quickly to a change in gas concentrations.
- Leak and flow checks, to ensure that ambient air reaches the analysers, without being compromised in any way.
- NO_X analyser converter efficiency, via gas phase titration, to ensure reliable operation. The converter must be more than 95% efficient to ensure that the NO_2 data are of the required accuracy.
- TEOM k_0 evaluation. The factor is used to calculate particulate mass concentrations.
- Particulate analyser flowrates. Any error in the flow through these particulate analysers is directly reflected in an error in the final measure of particulate concentration.
- SO_2 analyser hydrocarbon interference, certain hydrocarbons are known to interfere with the SO_2 detector.
- Evaluation of site cylinder concentrations, with reference to the certified audit gas taken to the stations. This procedure allows for the correction of data from stations where the site calibration cylinder concentration is slowly changing and for identification of any unstable cylinders that require replacement.

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

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

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

The procedures used to determine instrument performance are documented in Ricardo-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 is produced and passed to the data checker The role of the data checker is to:

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

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

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