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Environmental Standards Scotland

Baseline Evidence Review – Air

(Strategy and Analysis)

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Executive summary

This baseline evidence review provides a high-level summary of key published information about the current position, recent trends and performance and progress towards relevant targets and standards in air quality and emissions in Scotland.

Background

A series of rapid reviews of key evidence sources were undertaken to support the identification of environmental issues of most concern, where Environmental Standards Scotland's (ESS) proposes to focus its initial analytical work.

Eight reviews were produced, covering the environmental categories of air; biodiversity, and ecosystem resilience; climate change; cross-cutting environmental governance; land and soil; population, human health and cultural heritage; resource use and waste; and water. These categories are primarily intended to help Environmental Standards Scotland organise, manage and prioritise its work and are based on those used in the Strategic Environmental Assessment and the Environmental Impact Assessment processes. Considering the evidence within each category provides a structure for assessment.

There will be overlaps amongst these categories and to minimise duplication, topics have been covered under what was considered to be the most relevant category. For example, the issue of the health impacts of air quality has been considered under the 'population, human health and cultural heritage' review.

Rapid reviews were undertaken in each topic area, with a narrow scope of identifying key data sources and summarising what they tell us about how the environment is changing in Scotland. The focus was on National or Official Statistics and Annual Reports and their related data, mainly from Government and other national organisations, to obtain a high-level summary of current environmental conditions and to ensure confidence in the quality of the information.

The approach started with the data, considering whether Scotland is on track to achieve its current environmental targets and objectives. They are not intended to be detailed explorations of individual issues e.g. indoor air quality. Similarly, they are not intended to provide exhaustive lists of relevant legislation. If a topic is not included, it is because it is covered in another review or or relevant published data was not

found within the scope of the review at this point. However, the topic will still form part of ongoing horizon scanning activity and could be explored in the future with relevant organisations.

Future stages of analysis will consider whether performance trends relate to any issues of compliance with or effectiveness of environmental legislation and scrutinise the detail underpinning trends identified.

ESS' monitoring and analysis work will progress through a series of stages. These stages range from horizon scanning to identify high-level areas of concern, through to a deepening analysis and understanding of how things are changing, the causes of this, and how policy and regulatory decisions affect this. All of the monitoring and analysis work will be focused on identifying areas where further investigation or use of ESS' powers may be necessary. It will also support active investigations and assess whether the changes that have been made in response to ESS' recommendations or use of powers are having the desired impact.

As the analytical priorities are taken forward, it is likely that some will quickly be identified as not having any compliance or effectiveness issues that merit further analysis or investigation at this stage. These can then be returned to horizon scanning in case an issue arises in the future, and a new issue can be added to the list of those subject to more detailed analysis. The list of analysis priorities is expected to be dynamic and regularly updated. The evidence reviews, however, are a snapshot in time as of August 2022 and there is no plan for these to be updated on a regular basis.

Summary of key baseline evidence review findings

Air quality

There is evidence that air pollution concentrations are generally lower in Scotland than other parts of the UK and internationally. Scotland appears to be meeting almost all of its air quality limits and targets. However, there remain nitrogen dioxide (NO_2) exceedances at a small number of sites. COVID-19 lockdowns are likely to have contributed to reduced average NO_2 concentrations in 2020, however evidence suggests that Scotland is returning to pre-COVID levels and that NO_2 concentrations may not be decreasing at all urban background sites. It will be important to continue to check progress in the published 2021 and 2022 data to determine whether the

move out of COVID lockdowns does reverse improvements seen in 2020 as the currently available evidence indicates.

Although ozone (0_3) targets are being met, the EU Directive long-term objective for health is not and there are indications that overall concentrations may be increasing.

Despite the majority of limits and targets being met for most pollutants, the most recent WHO guidelines are more stringent and wouldn't be met if currently in place. Concerns also remain about whether any level of particulate matter is safe for human health.

Emission trends and sources

Compliance with emissions ceilings is determined at the UK level and the latest data shows that the UK has not exceeded the 2020 emissions ceilings set out in legislation for sulphur dioxide (SO_2), nitrogen oxides (NO_x), non-methane volatile organic compounds (NMVOC) or Particulate Matter 2.5 ($PM_{2.5}$). The 2020 data suggests there was an exceedance of the ceiling for ammonia (NH_3) although this is under review and may be adjusted to below the ceiling following review by UNECE. The Scottish Government's Cleaner Air for Scotland 2 (CAFS2) strategy[1] acknowledges that new policies will be required to ensure compliance with 2030 emissions ceilings.

Data is also available on the amount of each pollutant released into the air by individual UK nations. This shows that most pollutants were lower in average concentration in 2019 than they were in 2005 in Scotland. However, this masks increasing trends for carbon monoxide (CO) and $PM_{2.5}$ emissions in the residential sector (corresponding with an increase in the use of wood fuel in the domestic sector), commercial and public sector combustion sectors. Similarly, there have been increases in NMVOCs due to the increasing production and storage of whisky. In addition, since 2008, there has been no significant change in NH_3 emissions from the agriculture sector.

The biggest contributing sectors vary by pollutant. In 2019:

- Agriculture was the biggest sector contributing to ammonia release (NH_3);

- Residential, commercial and public sector combustion were the biggest contributors of benzo(a)pyrene (B[a]p) (90%), dioxins (43%), $PM_{2.5}$ (43%), CO (41%) and SO_2 (31.5%);
- Industrial processes were the biggest contributors of NMVOCs (54%); and
- Transport was the biggest contributor of lead (Pb) (52%) and nitrogen oxides (NO_x) (48%).
- Unlike most other pollutants, the emissions profile of PM_{10} is diverse: transport, residential and industrial processes each accounted for over 16% of total emissions.

Environmental Standards Scotland air quality investigation

In March 2021, The European Court of Justice delivered a judgement that, across the UK, exceedances of statutory air quality limit levels in respect of (NO_2) had remained 'systematic and persistent' for at least seven years (2010-2017).

In view of the serious, longstanding and intractable nature of the failure to meet limit levels, and ongoing concerns about whether air quality limit values for NO2 would be met going into the future, ESS decided to launch an investigation into the arrangements put in place by the Scottish Government to deliver compliance with statutory air quality limit levels in respect of (NO_2).

Information was sought from a number of local authorities and the Scottish Government to inform the investigation. The investigation found a number of areas where the system of local management of air quality could be improved. It also found that governance and oversight arrangements are overly complex and opaque. In view of this, ESS issued an improvement report to Scottish Ministers recommending measures that should be taken to strengthen the effectiveness of the law underpinning the systems in place to improve air quality. The Scottish Government must now prepare and seek Parliamentary approval for an improvement plan – setting out how they intend to respond to our recommendations.

While the focus of the investigation is NO_2, ESS' remit covers issues relating to all matters of air quality. As a result, this report covers baseline evidence in relation to a wide range of pollutant concentrations and emissions.

Conclusions for initial ESS analytical priorities

This baseline review identified a wide range of possible issues for further analysis. For example, domestic wood fuel use and its contribution to emissions of carbon dioxide and $PM_{2.5}$ and associated impact on air quality (as being considered by Scottish Government's Rural and Environment Science and Analytical Services Division – RESAS)[2]. Other examples included particulate matter concentration, emissions trends and emerging evidence on sources or emissions from the agriculture and residential sectors.

However, for the purposes of setting out initial analytical priorities, ESS will focus on:

- Progress against air quality targets/standards, with an initial focus on particulate matter.

ESS' proposed Strategic Plan describes how issues will be prioritised for further analysis according to a range of criteria, including:

- Importance – the size and risk of the potential effect on the environment and/or public health; the urgency with which improvement is required;
- Nature and Scope – recent trends in environmental performance; whether the issue of concern appears to be systematic and/or longstanding;
- Neglect – whether there has been action taken on the issue of concern, or further action is planned in the near future; and
- Added-value – the contribution we could make, considering whether other monitoring, oversight or scrutiny bodies are planning to take, or could take, action to address the issue of concern.

The analytical priority for air takes account of that scheme. It recognises the potential impact that air quality can have on human health and the fact that Scotland is currently not achieving more stringent WHO guidelines. In keeping with the prioritisation process, the contributions of other actors and the added value that ESS can bring to an area will also be considered, in deciding where to focus future work.

Although ESS intends to focus on one issue in the first instance, other issues will be retained on a list for potential future analysis and horizon scanning in line with the stages of monitoring and analysis work set out in the strategic plan.

Air Baseline Evidence Review

This baseline evidence review provides a high-level summary of key published information about the current position, recent trends and performance and progress towards relevant targets and standards in air quality and emissions in Scotland.

1. Introduction

Air quality describes the concentration of pollutants in the atmosphere and concerns the level of pollution in the air at ground level. Pollutants can exist in a gas, liquid or particulate phase and be emitted, produced in the atmosphere or transported from long or short distances. Pollution can come from a wide range of sources (e.g. traffic, industry, energy for heating) and cover a wide range of substances (e.g. nitrogen dioxide and particular matter). Removal pathways also vary and can be affected by climate, meteorology and land use/type. Poor air quality can cause harm to both the environment and human health and is widely recognised as being the largest environmental risk to public health in the UK[3].

This baseline evidence review covers the ESS environmental sub-categories of air quality and emissions sources. It will also have links to other reviews, particularly those on climate change and human health.

2. Methodology

A rapid review of key evidence sources has informed this report. This has focussed on scanning across the topic area, identifying key data sources and summarising what they tell us about how the environment is changing in Scotland and whether environmental targets and objectives are on track to be achieved.

The scope of the work was deliberately narrow and was intended to provide a snapshot of the evidence rather than a fully comprehensive picture. Where ESS' initial assessment of the evidence has identified potential concerns or issues that warrant further scrutiny, more detailed monitoring and analysis will be considered.

The work focussed on published analytical reports and datasets, searching for relevant evidence by using the terms 'air quality', 'emissions' and 'emission sources'. Where necessary these terms were combined with 'Scotland', 'UK' or 'International' to search for comparisons with other countries.

These terms were derived from ESS' environmental categories and sub-categories. Specific searches of key organisations' websites were also undertaken, based on knowledge and understanding of those active in the area. For air quality this included Scottish Government, DEFRA, Air Quality Scotland and Climate Change Committee. There is some subjectivity in the choice of terms and organisations and this was somewhat mitigated by consulting with key stakeholders on sources.

The focus of the reviews was on National or Official Statistics and Annual Reports and their related data, mainly from Government and other national organisations, to obtain a high-level summary of current environmental conditions with a tight scope which allowed the reviews to be completed in time to inform strategic plan development. Only publicly available information was considered. Individual research reports or grey literature on specific, detailed areas of the topic were not within scope. Evidence of issues relating to compliance with or effectiveness of environmental legislation was not the focus at this stage. It is envisaged that this will form part of future analysis activity on priority analytical areas.

The approach started with the data, considering whether Scotland is on track to achieve its current environmental targets and objectives in this area. The reviews are not intended to be detailed explorations of individual issues or to provide exhaustive lists of relevant legislation.

Baseline evidence reviews have been undertaken in each of the ESS Environmental Categories and there are naturally some topics which could fall across a number of reviews. For example, the issue of the health impacts of air quality is considered under the 'population, human health and cultural heritage' review.

If a topic is not included, either no relevant published data was found within scope or it is covered in another review. However the topic is likely to still form part of ongoing horizon scanning and could be explored with relevant organisations in future.

Initial drafts of the evidence reviews were shared with the ESS Board and with key identified analytical stakeholders to provide proportionate checks that no key sources had been missed and no information had been misinterpreted. Going forward into more detailed analytical projects and undertaking further horizon scanning, ESS expects to engage a wide range of experts, including academics and specialist organisations.

3. Baseline evidence for environmental sub-categories

Air quality

Overall trends

In 2021, Environmental Standards Scotland commissioned a SEFARI fellowship report[4] to identify environmental priorities. The report found that air pollution has some of the best established and accessible environmental data. The report stated that long-term trend analysis indicated that levels of nitrogen dioxide (NO_2), particulate matter 10 and 2.5 (PM_{10} and $PM_{2.5}$) have all tended to decrease over the past ~10 – 15 years and these trends tend to be statistically significant. Despite this, the report finds that exceedances still occur regularly at many urban sites. However, levels of ozone (O_3) have tended to increase slightly over the same period although these increases are only statistically significant at the longest running monitoring sites (~30 years continuous data) where the sheer number of data points provides more statistical power.

Standards, objectives and targets

The Environment Act 1995 requires the UK Government and the devolved administrations for Scotland and Wales to produce a national air quality strategy containing standards, objectives and measures for improving ambient air quality and to keep these policies under review. There is equivalent legislation in Northern Ireland. The most recent UK wide strategy was published in 2007[5]. Further details of relevant Strategies are provided in section 7.

It is helpful to start by setting out the commonly accepted definitions of standards, exceedances and objectives in relation to air quality in environmental law[6,7]:

- Standards – average concentrations recorded over a given time period, which are considered to be acceptable in terms of what is known about the effects of each pollutant on health and on the environment.
- Exceedance – a period of time (defined for each standard) where the concentration is higher than that set out in the Standard.
- Objective – a policy target defined as average concentrations over a given time period and derived from the standards. There is a compromise between what is desirable purely on health grounds and what is practical in terms of

feasibility and costs. Generally expressed in terms of a target date on which exceedances of a Standard must not exceed a specified number.

There is no legal requirement to meet the objectives set out in the UK Air Quality Strategy (AQS).

The Environment Act 1995 also requires local authorities in the UK to review and make assessments of air quality in their area and designate air quality management areas (AQMA) if improvements are necessary to achieve AQS objectives. Where areas are designated, local authorities must work towards the AQS objectives and an air quality action plan describing the pollution reduction measures must be put in place.

In Scotland, to facilitate this, AQS objectives are set out in the Air Quality (Scotland) Regulations 2000[8], the Air Quality (Scotland) Amendment Regulations 2002[9] and the Air Quality (Scotland) Amendment Regulations 2016[10]. These, combined, provide the statutory basis for Local Air Quality Management (LAQM). Local authorities are not legally obliged to achieve the objectives by the required dates but they must demonstrate that they are doing all that is reasonably possible to work towards them[1,11].

At an EU level (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)[12], the Scottish Government, other UK administrations and EU Member States are responsible for securing compliance with legally binding limit values for pollutants. Work undertaken by local authorities through the LAQM contributes towards the compliance actions implemented by central government. This legislation describes limit or target values which are similar to the objectives described above although have different legal status:

- Limit values – legally binding parameters that must not be exceeded. These are set for individual pollutants and are made up of a concentration value, an averaging time over which it is to be measured, the number of exceedances

[1] Some pollution sources are outwith direct local authority control, for example Transport Scotland controlled trunk roads and SEPA regulated processes. However, authorities are expected to liaise with these and other relevant organisations when developing action plan measures.

allowed per year, if any, and a date by which it must be achieved. A pollutant can have more than one limit value covering different end points or averaging times.

- Target values – set out in the same way as limit values, they are to be attained where possible by taking all necessary measures not entailing disproportionate costs.[6]

The legislation also describes long-term objectives, information and alert thresholds for O_3 as well as alert thresholds for sulphur dioxide (SO_2) and NO_2 which have particular requirements. For example, if there is a risk of alert thresholds being exceeded then short-term action plans must be drawn up and if an alert threshold is breached then the public must be informed by means of radio, television, newspapers or the internet.

In September 2021, WHO published updated air quality guidelines for the protection of health which are generally stricter than those set out in the EU Directive[13].

Table 1 below sets out LAQM and UK AQS objectives, and Directive limits and targets as well as the most recent assessment of progress against the Directive. Footnotes are provided to illustrate where these differ from the most recent WHO guidelines.

In order to achieve the limits (SO_2, NO_2, benzene (C_6H_6), carbon monoxide (CO), lead (Pb), PM_{10} and $PM_{2.5}$) and targets (O_3, arsenic (As), cadmium (Cd), nickel (Ni) and benzo(a)pyrene (BaP)) set out in the Air Quality Standards (Scotland) Regulations 2010[12] (AQS), these values must not be exceeded in the six Scottish 'zones and agglomerations' (referred to hereafter as zones):

- Glasgow Urban Area;
- Edinburgh Urban Area;
- Central Scotland;
- North East Scotland;
- Highlands; and
- Scottish Borders.

Overall, the UK has 43 zones – 28 agglomerations (large urban areas) and 15 non-agglomeration zones.

Assessment of compliance is based on measurements from the UK national monitoring networks[2] and national modelling assessments (pollutant concentrations at background locations, on a 1X1 km grid square basis and roadside pollutant concentrations at 4m from the kerb of urban major road links)[14]. Modelled data is validated against the monitored measurements.

The compliance status of a zone is determined by the maximum concentration from all valid measurements and model results[15]. Measurements are regarded as the primary basis for the compliance status if both measurements and modelling show that a threshold has been exceeded. Where locations have been identified as exceeding by modelling, this indicates that modelled concentrations were higher than measured concentrations or that measurements were not available or not required for that zone. Modelling was not possible for CO and therefore, where there is no measurement in a zone, compliance is determined through objective estimation.[14]

[2] Monitoring Networks - Defra, UK. The Automatic Urban and Rural Network is the UK's largest automatic monitoring network and is the main network used for compliance reporting against the Ambient Air Quality Directives. It includes automatic air quality monitoring stations measuring oxides of nitrogen (NO_x), SO_2, O_3, CO and particles (PM_{10}, $PM_{2.5}$). These sites provide high resolution hourly information which is communicated rapidly to the public, using a wide range of electronic, media and web platforms. In 2020, there were 172 AURN monitoring sites, of which 22 were in Scotland. Other networks with smaller numbers of monitoring sites are used to assess the other pollutants e.g. C_6H_6. This includes 24 rural diffusion tube sites and 177 urban traffic diffusion tube sites passively monitoring NO_2. Of the 172 AURN sites, 22 were in Scotland.

Table 1: Air Quality Objectives, Limits and Targets (limit values unless otherwise stated) with 2019 and 2020[iii] Assessment of Progress

Pollutant	Country	LAQM and AQS Objectives	EU Directive limits and targets	2019 and 2020 Progress on EU Directive
For the Protection of Human Health				
Benzene (C_6H_6)	UK	Running annual mean - 16.25 µg m^{-3} by 31 December 2003	Annual Average - 5 µg m^{-3} by 1 January 2010	No breaches of benzene limit values in local authorities / zones / agglomerations across the UK. The UK has been compliant with the limit value since 2007.
	Scotland and Northern Ireland	Running annual mean - 3.25 µg m^{-3} by 31 December 2010		
	England and Wales	Annual average – 5 µg m^{-3} by 31 December 2010		
1,3-Butadiene	UK	Running annual mean - 2.25 µg m^{-3} by 31 December 2003	N/A	N/A
Carbon Monoxide (CO)[5]	UK	Running 8-hour mean (Scotland) / Maximum daily running 8-hour mean (rest of UK) - 10 mg m^{-3} by 31 December 2003	Maximum daily running 8 hour mean - 10 mg m^{-3} by 1 January 2005	The UK has been compliant with carbon monoxide limit value since 2003.
Lead (Pb)	UK	Annual mean - 0.5 µg m^{-3} by 31 December 2004	Annual mean - 0.5 µg m^{-3} by 1 January 2005	The UK has been compliant with lead limit value since 2003.
		Annual mean - 0.25 µg m^{-3} by 31 December 2008		

[iii] Air Pollution in the UK report - Defra, UK. 2019 data is also provided as 2020 may be affected by changes in behaviour due to COVID lock downs.

Nitrogen Dioxide (NO_2)[3]	UK	1-hour mean - 200 µg m^{-3} not to be exceeded more than 18 times a year by 31 December 2005	1-hour mean - 200 µg m^{-3} not to be exceeded more than 18 times a year by 1 January 2010	No breaches of limit in either 2019 or 2020 in Scotland. In 2019, one Welsh zone breached the 1-hour limit (South Wales)
		Annual mean - 40 µg m^{-3} by 31 December 2005	Annual mean - 40 µg m^{-3} by 1 January 2010	In 2020, there were no breaches of limit in Scotland. 13 local authorities (5 zones / agglomerations) in England and Wales had exceedances. In 2019, 4 of 6 Scottish zones / agglomerations exceeded the limit, 1 of 2 Northern Irish, 3 of 4 Welsh and 25 of 31 English. The large increase in compliance in 2020 is expected to be due to COVID-19 lockdown restrictions.
Particles (PM_{10}) (gravimetric)[2]	UK	24-hour mean - 50 µg m^{-3} not to be exceeded more than 35 times a year by 31 December 2004	24-hour mean - 50 µg m^{-3} not to be exceeded more than 35 times a year by 1 January 2005	No breaches of daily or annual limits applicable at UK level. The UK has been compliant with Air Quality Standards limit values in all years since 2010.
	Scotland	24-hour mean - 50 µg m^{-3} not to be exceeded more than 7 times a year by 31 December 2010		
	UK	Annual mean - 40 µg m^{-3} by 31 December 2004	Annual mean - 40 µg m^{-3} by 1 January 2005	
	Scotland	Annual mean - 18 µg m^{-3} by 31 December 2010		
Particles ($PM_{2.5}$) (gravimetric)*[,1]	All UK Urban Areas	N/A	15% cut in urban background exposure between 2010 and 2020**	Exposure reduction target for the UK was achieved in 2020.

	UK (except Scotland)	Annual mean - 20 µg m^{-3} by 1st January 2020	Annual mean - 25 µg m^{-3} target by 2010 and as limit by 2015, indicative 20 µg m^{-3} limit value by 1 January 2020.	The UK has been compliant limit values (except stage 2 for 2020) in all years since 2008.
	Scotland	Annual mean - 10 µg m^{-3} by 31st December 2020		
Sulphur dioxide (SO^2)[4]	UK	1-hour mean - 350 µg m^{-3} not to be exceeded more than 24 times a year by 31 December 2004	1-hour mean - 350 µg m^{-3} not to be exceeded more than 24 times a year by 1 January 2005	No breaches of limits. The UK has been compliant with limit values in all years since 2008.
		24-hour mean - 125 µg m^{-3} not to be exceeded more than 3 times a year by 31 December 2004	24-hour mean - 125 µg m^{-3} not to be exceeded more than 3 times a year by 1 January 2005	
		15-min mean - 266 µg m^{-3} not to be exceeded more than 35 times a year by 31 December 2005	N/A	
Polcyclic Aromatic Hydrocarbons (PAH)*	UK	Annual mean - 0.25 ng m^{-3} B[a]p by 31 December 2010 (AQS only)	Annual mean - 1 ng m^{-3} B[a]p by 31 Dec 2012 (target)	In 2020, there were no breaches of target in Scotland while 2 authorities (3 zones / agglomerations) in England and Wales had exceedances, the same as in 2019.
Ozone (O_3)*,[6]	UK	8 hour mean - 100 µg m^{-3} not to be exceeded more than 10 times a year by 31 December 2005 (AQS only)	8 hour mean - 120 µg m^{-3} not to be exceeded on more than 25 days per year averaged over three years (target)	No exceedances of targets since 2008.
		N/A	Maximum daily 8-hour mean within a calendar year - 120 µg m^{-3} (long-term objective)	10 of 32 local authorities (3 of 6 zones / agglomerations) with exceedances in 2020 in Scotland of LTO. All Welsh, Northern Irish and 316 of 317 English authorities exceeded the LTO (all zones /

				agglomerations). All zones and agglomerations in UK exceeded in 2019.
Arsenic (As)	UK	N/A	Annual mean - 6 ng m^{-3} (target) by 31 December 2012	No breaches of target. The UK has been compliant in all years since 2008.
Cadmium (Cd)	UK	N/A	Annual mean - 5 ng m^{-3} (target) by 31 December 2012	No breaches of target. The UK has been compliant in all years since 2008.
Nickel (Ni)	UK	N/A	Annual mean - 20 ng m^{-3} (target) by 31 December 2012	All Scottish zones met target values for nickel while a small number of English and Welsh did not (2 English authorities and 1 Welsh in 2020) as has been the case since 2008.
For the Protection of Vegetation and Ecosystems				
Oxides of Nitrogen (NO_x)	UK	Annual mean - 30 µg m^{-3} (critical level) by 31 December 2000 (AQS only)	Annual mean - 30 µg m^{-3} (critical level) by 19 July 2001	All non-agglomeration zones (to which critical level applies) have been compliant since 2008.
Sulphur dioxide (SO_2)	UK	Annual mean - 20 µg m^{-3} (critical level) by 31 December 2000 (AQS only)	Annual mean - 20 µg m^{-3} (critical level) by 19 July 2001	No breaches of critical level.
		Winter average (Oct to Mar) - 20 µg m^{-3} (critical level) by 31 December 2000 (AQS only)	Winter average (Oct to Mar) - 20 µg m^{-3} (critical level) by 19 July 2001	No breaches of critical level.

Ozone (O_3)*	UK	AOT 40[iv] (calculated from 1 hour values May to July) 18,000 µg m^{-3} per hour averaged over 5 years (starting 2010) by 1 January 2010 (AQS only)	AOT 40 (calculated from 1 hour values May to July) 18,000 µg m^{-3} per hour averaged over 5 years (starting 2010) by 1 January 2010 (target)	No exceedances of targets in 2019 or 2020.
		AOT 40 (calculated from 1 hour values May to July) 6,000 µg m^{-3} per hour (AQS only)	AOT 40 (calculated from 1 hour values May to July) 6,000 µg m^{-3} per hour (long-term objective)	No exceedances in Scotland in 2020 of LTO for vegetation and ecosystems but 183 local authorities (14 zones / agglomerations) in England and 9 (2 zones / agglomerations) in Wales had exceedances. In 2019, 6 zones (none in Scotland) exceeded the long-term objective. The increase to 16 exceedances in 2020 is thought to have been affected by COVID-19 restrictions.

* Not currently assessed by Scottish local authorities.
**The national exposure reduction target varies according to the 2010 starting threshold. In the UK, the 2010 value was 13 µg m^{-3} which requires a 15% reduction.
*** Note that there are 317 local authorities in England, 11 in Northern Ireland, 32 in Scotland, 22 in Wales.
[1] New WHO AQG level of 5 for the annual mean and 15 for a 24-hour mean (with 3-4 exceedance days per year).
[2] New WHO AQG level of 15 for the annual mean and 45 for a 24-hour mean (with 3-4 exceedance days per year).
[3] New WHO AQG level of 10 for the annual mean and 25 for a 24-hour mean (with 3-4 exceedance days per year).
[4] New WHO AQG level of 40 for a 24-hour mean (with 3-4 exceedance days per year).
[5] New WHO AQG level of 4 for a 24-hour mean (with 3-4 exceedance days per year).
[6] New WHO AQG level of 100 for the maximum 8-hour mean and 60 for the average of daily maximum 8-hour mean concentration in the six consecutive months with the highest six month running average.

[iv] Measured accumulated exposure to ozone. The sum of the differences between hourly O_3 concentrations greater than 80 µg m^{-3} (=40 parts per billion) and 80 µg m^{-3} during the growing season from May to July, using only the one-hour values measured between 8am and 8pm Central European Time (CET) each day. The indicator is designed for the protection of crops and (semi) natural vegetation.

Compliance with limits and targets

Data presented in the Annual Report on Air Pollution in the UK[16] provides an assessment of compliance with the EU Directive and, as can be seen in Table 1, indicates that Scotland is achieving all of the limit or target values with the exception (until 2020) of those for NO_2.

- In 2020, there were no breaches of SO_2, CO, C_6H_6, Pb, As, Cd, PM_{10}, and $PM_{2.5}$ limit values across the UK. In all of these cases, the UK has been compliant with limit or target values which applied in all years since at least 2008 (Pb and CO since 2003 and C_6H_6 since 2007).
- All Scottish zones met target values for Ni and BaP while a small number of English and Welsh zones did not. This has been the case since 2008.
- All Scottish zones were within NO_2 limits in 2020 but four English and one Welsh zone exceeded the annual mean limit value. However, this data is affected by the COVID lockdowns and represents a large reduction in zones breaching limits from previous years. In 2019, 4 of the 6 Scottish zones and 29 of the 37 in England, Wales and Northern Ireland[17] breached limits.
- All areas met target values for health and vegetation relating to O_3 in 2020 and have done for many years. However, there are also long-term objectives for protection of human health and for vegetation. For O_3, only 3 (all in Scotland) of the 43 zones in the UK met the long-term objective for protection of human health (none met this in 2019). All Scottish areas met the long-term objective for vegetation while 16 areas in England and Wales did not. However, this is a higher number of exceedances than normal and is also likely to have been affected by COVID lockdowns since O_3 is removed from the air by reaction with nitric oxide, a component of vehicle emissions which reduced during 2020, likely due to lockdown restrictions[17].

Reporting at the level of zones can mask the extent of the problem. Where a zone is reported as having an exceedance, this tells us that at least one monitored or modelled exceedance has been identified but not whether this is many sites or just one. This compliance reporting also does not consider instances of LAQM / AQS objectives which are more stringent than EU requirements. More detailed information is available at individual site level and is discussed in the next section.

Trends from UK monitoring sites

DEFRA produces national statistics on trends in the concentrations of key pollutants at a UK level[18]. These produce an index for each pollutant, taking account of all sites in the AURN[e] which had annual data capture of at least 75%. The individual sites which feed into calculations can change from year to year as a result of sites shutting, opening or having operational issues leading to less than 75% data capture. However, DEFRA advise that the impact of changes in siting should be minimal when comparing different years.

Their most recent analysis indicates that:

- For NO_2
    - The annual mean NO_2 concentration at urban background sites reduced rapidly between 1992 (59.75 µg m^{-3}) and 2002 (32.71 µg m^{-3}), followed by a period to 2006 of no clear trend and then a slower reduction to 2019 (19.56 µg m^{-3}). It is likely that COVID-19 restrictions contributed to the decrease to 15.06 µg m^{-3} in 2020 before rising again to 15.84 µg m^{-3} in 2021.
    - At roadside locations, there have also been reductions, from 59.72 µg m^{-3} in 1997 to 24.79 µg m^{-3} in 2021 although there was a period of stability in the 2000s. The annual mean concentration at roadside locations is greater than at urban background locations.
    - At rural background locations, concentrations of NO_2 are at low levels and have reduced gradually over time from 17.69 µg m^{-3} in 1997 to 5.74 µg m^{-3} in 2021.

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[e] Monitoring Networks - Defra, UK. The Automatic Urban and Rural Network is the UK's largest automatic monitoring network and is the main network used for compliance reporting against the Ambient Air Quality Directives. It includes automatic air quality monitoring stations measuring oxides of nitrogen (NOx), SO_2, O_3, CO and particles (PM_{10}, $PM_{2.5}$). These sites provide high resolution hourly information which is communicated rapidly to the public, using a wide range of electronic, media and web platforms. In 2020, there were 172 AURN monitoring sites, of which 22 were in Scotland. Other networks with smaller numbers of monitoring sites are used to assess the other pollutants e.g. C_6H_6. This includes 24 rural diffusion tube sites and 177 urban traffic diffusion tube sites passively monitoring NO_2. Of the 172 AURN sites, 22 were in Scotland.

- For PM_{10}
    - PM_{10} pollution at urban background sites and roadside sites decreased in the long-term though was relatively stable between 2015 and 2019.
    - For urban background sites, there were rapid reductions in the annual mean between 1992 (36.1 µg m^{-3}) and 2000 (22.9 µg m^{-3}), followed by a period of no clear trend to 2006 and then a slower reduction to 2015 (15.2 µg m^{-3}) from which the mean was stable to 2019 (15.0 µg m^{-3}). There was then a reduction to 12.97 µg m^{-3} in 2021.
    - At roadside locations, there was a steady decline of the annual mean from 36.7 µg m^{-3} in 1997 to 17.3 µg m^{-3} in 2015, followed by a period of stability to 17.99 µg m^{-3} in 2019 and then to 15.93 µg m^{-3} in 2021. The annual mean concentration at roadside locations is greater than at urban background locations in 2021 though there has not always been a statistically significant difference in the past[19].
- For $PM_{2.5}$
    - There has been a reduction in urban background $PM_{2.5}$ annual mean concentrations from 12.4 µg m^{-3} in 1999 to 8.3 µg m^{-3} in 2021 and has followed a similar trend to PM_{10}, though this masks a period of increase between 2009 and 2011 and stability between 2015 and 2019.[19]
    - At roadside locations, there has been a reduction in $PM_{2.5}$ annual mean concentrations from 12.8 µg m^{-3} in 1999 to 7.9 µg m^{-3} in 2021 though this masks a period of increase between 2009 and 2011 and stability between 2015 and 2019. The difference between urban background and roadside locations is not statistically significant.[19]
- For O_3
    - Unlike NO_2, PM_{10} and $PM_{2.5}$, the long-term trend for O_3 is increasing. From 1992 (39.9 µg m^{-3}), the annual average daily maximum eight hour mean concentration at urban background sites increased to the mid-2000s (60.7 µg m^{-3} in 2006). The report suggests this may have been due to the reduction in nitrogen oxide emissions in the UK and Europe[20] due to the complex interactions involving volatile organic compounds and their

interplay with nitrogen oxides in forming O_3. There was then no obvious trend to 2017 (58.06 µg m^{-3}) followed by an increase to 64.42 µg m^{-3} in 2020 and a decrease to 62.49 µg m^{-3} in 2021. O_3 concentrations can vary with the weather – hot summer conditions are associated with high O_3 concentrations.

- In rural background locations, O_3 has fluctuated throughout the time series, from 65.6 µg m^{-3} in 1988 to 70.6 µg m^{-3} in 2021 with a peak of 73.9 µg m^{-3} in 2006 and a low of 65.2 µg m^{-3} in 1993.

Reporting from Scottish monitoring sites

Scotland produces reporting at site level based on data from a greater number of individual monitoring sites than the above UK-wide compliance monitoring[21,f]. Assessment is made of compliance with the AQS objectives (more stringent for some pollutants than the EU Directive limits and targets). The latest published data available is for 2020[22,23] and indicates that of those sites (automatic[g],[24] and non-automatic monitoring[h],[25]) with more than 75% data capture, there were no instances of exceedances above the relevant AQS concentration objectives for most pollutants with the exception of passive (non-automatic) monitoring of NO_2 where 7 of 1,050 sites exceeded AQS objectives.

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[f] The monitoring of compliance for the EU Directive is more precisely defined in the legislation. Local authorities add their own monitoring sites in locations necessary for LAQM and there is no standard protocol for the siting of local authority automatic monitoring stations.

[g] The Automatic Urban and Rural Network is the UK's largest automatic monitoring network and is the main network used for compliance reporting against the Ambient Air Quality Directives. It includes automatic air quality monitoring stations measuring oxides of nitrogen (NOx), SO_2, O_3, CO and particles (PM_{10}, $PM_{2.5}$). These sites provide high resolution hourly information which is communicated rapidly to the public, using a wide range of electronic, media and web platforms. In 2020, there were 172 AURN sites, of which 22 were in Scotland. In addition to the AURN sites, local authorities have their own automatic monitoring sites, taking the total in Scotland in 2019 and 2020 to 100. For AURN sites, data can be available from as far back as 1986 whereas for local authority sites, data is available from when the site joined the Scottish Air Quality Database Project.

[h] Non-automatic Networks measure less frequently compared to automatic networks - either daily, weekly or monthly - and samples are collected by some physical means (such as diffusion tube or filter). These samples are then subjected to chemical analysis, and final pollutant concentrations calculated from these results.

Passive monitoring of NO_2 showed a significant reduction in exceedances compared to previous years (59 in 2019) and this is attributed to COVID restrictions. O_3 exceedances also saw a significant change from 2019, with none of the 11 sites registering exceedances of the AQS objectives, compared to 7 the previous year.

For automatic monitoring sites, the 2020 data represents small improvements from 2019 when there were 5 automatic monitoring sites exceeding the annual mean objective for NO_2 and one site exceeding the daily mean objective for PM_{10}[22].

Data for 2021 is not yet published but individual site information available on the Air Quality in Scotland website suggests that one site (Glasgow Kerbside) exceeded the annual mean NO_2 limit in 2021.[26]

There are challenges in exploring trends over time given changes in the number of monitoring sites over time and the length of time each site has been active. As such, analysis tends to focus on sites which have at least 5-, 10- or 15-years' worth of data. Where there are higher numbers of such sites, a smaller subset, usually 8, are selected for trends analysis generally on the basis of length of time they have been monitoring, historical exceedances of limit values and geographical coverage. This data (same sources as above) shows that for:

- NO_2 monitored via urban background sites[i]: the five sites with 15 years or more of data showed significant decreasing trends from 2006 to 2020. However, there was less consistency when looking at the seven sites with data for at least five years. For example, one site (Glasgow Anderston) showed a not statistically significant increasing trend over this shorter-term period compared to its decreasing trend over the long-term. The data suggests that caution is needed in assuming that NO_2 concentrations are decreasing at all urban background sites. Trends indicate that background levels dipped in the first half of 2020 and then returned to what could be considered pre-lockdown levels.

[i] Sites in an urban area away from major roads that are representative of exposure of the general population. Urban background sites should not be dominated by single sources and should be representative of a wide area.

- NO_2 monitored at urban roadside / kerbside sites[j]: analysis of 8 sites indicates downward trends overall in the past 5 and 10 years.
- Passive monitoring of NO_2: less than 1% of sites had an exceedance in 2020 (due to COVID lockdowns) compared to 5% in 2019, and down from 16% in 2013 (although the number of monitoring sites varied over this period).
- PM_{10} emissions: for the eight urban background sites selected, all show highly statistically significant decreases over ten years and a decreasing trend (though not all highlight significant) over the most recent five years. Analysis of eight urban traffic sites also show highly significant decreases over ten years and over the most recent five years. This is with the exception of Edinburgh Queensferry Street and Glasgow Byers Road where the five-year trend is decreasing but no longer statistically significant suggesting they are showing signs of levelling off.
- $PM_{2.5}$ emissions: for the four sites with over 10 years' worth of data, the three urban sites showed slight but highly significant decreases while there was no real change for the one rural site. Considering the 9 sites with five years' worth of data, four have decreasing trends with varying significance while the other five have no real identifiable statistically significant trend.
- CO: rates have been well within the AQS objective for many years.
- O_3: this was monitored at 11 sites during 2020 and showed no instances of the AQS being exceeded which was a significant improvement from 2019 when 7 exceeded the objective[k]. However, longer term trends are less clear

[j] Sites in an urban area at least 25 metres from the edge of major junctions and no more than 10 metres from the kerbside.

[k] O_3 is a secondary pollutant which can be transported over long distances. The AQS objective is not set out in LAQM regulation in recognition of this transboundary nature which means that individual authorities may have little control over concentrations. Although there were exceedances of the AQS objective in 2019, there have been no exceedances of the EU Directive targets in recent years – this reflects the differences in the targets with the AQS objective allowing not more than 10 days where there is a maximum 8-hour running mean over 100 micrograms per metre cubed whereas the EU Directive target is for no more than 25 days with an 8-hour mean over 120 micrograms per metre cubed, averaged over 3 years.

and there appears to be an (though not always statistically significant) increasing trend in O_3 concentrations.

- BaP: of four sites measuring BaP, none exceeded the AQS in 2020 but Kinlochleven did in 2019[l].

Modelled air quality concentrations

As highlighted above, national modelling assessments feed into compliance monitoring for the EU Directive. These are based on Pollution Climate Mapping (PCM) models which are designed to assess compliance with the limit and target values and long-term objectives in zones and agglomerations.

The UK modelled data for 2020 is presented in the annual Air Pollution in the UK report[16]. This indicates that no road links or background locations except in London had modelled exceedances of the annual mean objective limit for NO_2. There were no modelled exceedances of the PM_{10} objective for Scotland at either background or roadside locations. Similarly there were no modelled exceedances of the UK PM_{10} objective but there would have been a small number, particularly in London, had the UK objective been as low as the Scottish objective. The UK modelling includes $PM_{2.5}$, and shows that in 2020 no roadside or background sites were above the Directive limit value and none in Scotland were above the Scottish air quality objective value which is lower. Scotland had the lowest background concentrations while some urban locations in England had values which would have exceeded the Scottish air quality objective value. The modelling also shows that Scotland tends to have lower O_3 concentrations and AOT 40^m averages than other parts of the UK with the highest tending to be in the south and south west of England.

The UK PCM methodology has also been applied (by Ricardo Energy for the Scottish Government) to provide Scotland-specific air pollutant maps of annual mean background and roadside nitrogen oxide, NO_2 and PM_{10} concentrations. This tailors

[l] Although Kinlochleven exceeded the AQS objective in 2019, the objective itself is lower than the EU Directive target and no Scottish zones / agglomerations exceeded that in 2019.

[m] The sum of the differences between hourly O_3 concentration and 40 ppb for each hour when the concentration exceeds 40 ppb during the growing season from May to July.

the UK methodology to represent air pollutant concentrations in Scotland, calibrated and verified by Scottish meteorology and air quality monitoring site data.

Their modelled analysis maps NO_2 and PM_{10} concentrations on a 1 km X 1 km basis (background) and for road links (roadside) as discussed above. The latest data, for 2019[27], suggests that there were no modelled exceedances of the Scottish annual mean NO_2 objective of 40 µg m-3 at background locations. However, there were modelled exceedances at roadside locations in four of six Scottish zones, including 52 road links (102.5 km of road) in the Glasgow Urban Area, 20 road links (45.0 km of road) in Central Scotland, 9 road links (11.0 km of road) in the Edinburgh Urban Area and 4 road links (8.5 km of road) in the North East Scotland zone. The more rural zones of Highlands and Scottish Borers had no modelled roadside exceedances. There were no modelled exceedances of the PM_{10} objective for 2019 at either background or roadside locations.

Modelling has also been used to help understanding of the impact of COVID on pollutants, comparing measured values to a counterfactual 'business as usual' model which also takes account of the weather[16].

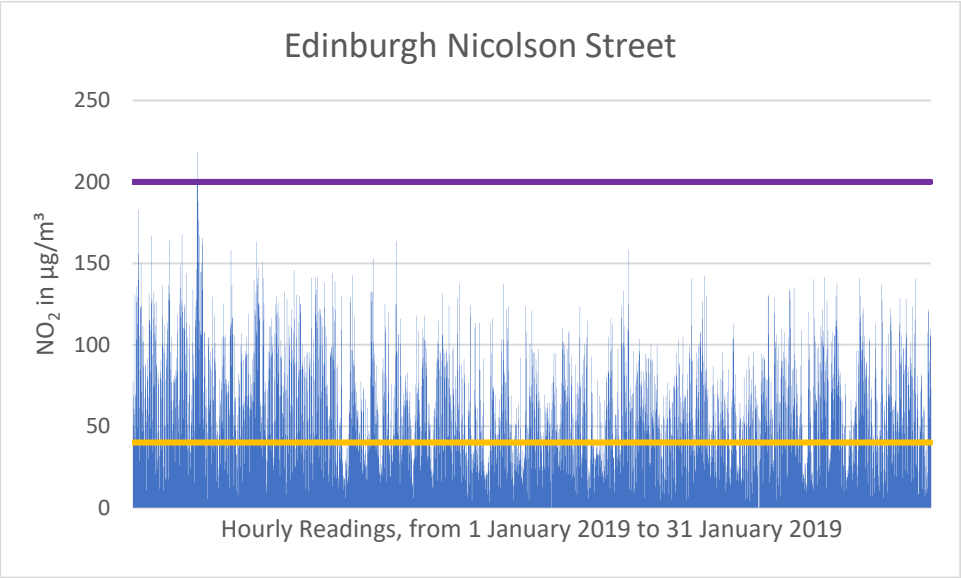
Separate modelling is carried out for LAQM and is different from the national methodology. This usually outputs contour plots showing dispersion away from the source, on a fine resolution grid, and has a greater level of detail and resolution to allow focus on local hotspots. LAQM modelling, with its different scope and purpose, may not meet the requirements for air quality assessment under the Air Quality Standards Regulations[12].

Daily Air Quality Index

Summary measures (e.g. an annual mean) indicating compliance can mask individual episodes of where there are high levels of pollutants. The Daily Air Quality Index is therefore intended to provide information to the public about levels of pollution alongside health advice[28]. For example, Edinburgh's Salamander Street did not exceed the measured limits for PM_{10} in 2019 but did have 4 days where the DAQI was 'moderate'[28] (which suggests adults and children with lung problems, and adults with heart problems, who experience symptoms, should consider reducing strenuous physical activity, particularly outdoors) and 1 day where it was 'high' (which suggests that adults and children with lung problems, and adults with heart

problems, should reduce strenuous physical exertion, particularly outdoors, and particularly if they experience symptoms. People with asthma may find they need to use their reliever inhaler more often and older people should also reduce physical exertion. Anyone experiencing discomfort such as sore eyes, cough or sore throat should consider reducing activity, particularly outdoors)[29].

Figure 1: Edinburgh Nicolson Street site representative measurement of hourly average NO_2 concentrations from 1 January 2019 to 31 January 2019.



Note: Limit values are given by the orange (Annual mean) and purple (hourly) lines.

Source: Air Quality in Scotland Database[26]

This is also illustrated by looking at the full set of monitoring data for a site. For example, Figure 1 shows Edinburgh Nicholson Street's annual monitoring data for 2019. In that year, the site exceeded the annual average with a value of 50 µg m-3 (above the 40 µg m-3 limit value) but did not exceed the hourly mean limit more than 18 times. As illustrated in the chart, this summary information doesn't convey the range of hourly variation[26]. Horizontal lines in the chart show the annual mean (orange) and hourly mean (purple) limit values for comparison.

Local Air Quality Management

As at August 2021, 253 local authority areas (67.5%) in the UK had designated air quality management areas (AQMAs)[16]. In Scotland, 14 of the 32 local authorities have at least one AQMA[30,31] and NO_2 is a factor in all but one of the authorities. A

list of the AQMAs currently listed on the Scottish Air Quality website are provided in the Annex: Current Air Quality Management Areas in Scotland.

Each authority can have more than one AQMA and an AQMA can cover more than one pollutant. The Scottish Air Quality website currently lists 39 AQMA's in Scotland in total although 3 of these appear to have been revoked according to the authority's own website. Of the remaining 36, 25 are reported to cover NO_2 (almost all for annual mean, small number for daily mean) although the ESS air quality investigation found that one of these has recently been revoked while another 3 include NO_2 although this isn't listed on the Scottish Air Quality website. 23 are reported to cover PM_{10} (all for annual mean, small number also for 1-hour mean) and 1 to cover SO_2 (Falkirk – 15-min mean).[31] Scotland has a disproportionately high number of AQMAs for PM_{10} compared to other parts of the UK due to its lower AQS objective for that pollutant.

Annual statistical reports for each local authority can be found on the Air Quality Scotland website[32]. As part of ESS' air quality investigation, it was found that a number of AQMAs had been consistently compliant with NO_2 objective levels for the recommended three-year period and thus these are under review by the Local Authorities for revocation later this year (or about to commence this process).

Comparison with new WHO guidelines

In September 2021, WHO updated its air quality guidelines[13]. The EU expect to revise their standards to be the same as or close to the new WHO guidelines. Since Scotland has made a commitment to keep up with EU standards, it is possible that these will eventually become the standard here.

Table 1 included footnotes to show how these differ from the EU limits and targets already discussed. The WHO guidelines also include interim targets but it is the final AQG target which is considered in this analysis. Using the EU Directive compliance data[33], the available data for 2020 suggests that Scotland is further away from these guidelines for some pollutants than others:

- NO_2 – 14 of 19 (74%) automatic monitoring sites had annual mean greater than or equal to 10 µg m^{-3}.[34] 817 of 981 (83%) of roadside locations[35,n] and 274 of 85,142 (0.3%) background locations had modelled annual mean greater than or equal to the 10 µg m^{-3} guideline in 2020.[36],[o]
- $PM_{2.5}$ – 665 of 981 (68%) roadside locations[37,p] and 743 of 85,142 (0.02%) background locations[38,q] had modelled annual mean greater than or equal to 5 µg m^{-3}. 5 automatic monitoring sites (of 8) also had a value greater than or equal to 5 µg m^{-3} in 2020[39,r].
- PM_{10} – 8 of 981 (0.8%) roadside locations[40,s] and no background locations[41] had modelled annual mean greater than or equal to 15 µg m^{-3} and no automatic monitoring[42] sites had values greater than or equal to 15 µg m^{-3} in 2020.

However, as noted in other sections of this review, the 2020 data is likely to have been impacted by the COVID pandemic. Reporting from the Scottish monitoring sites[26] is available for 2021 and also demonstrates that Scotland is some way from the new WHO guidelines. Focusing on sites with more than 75% data capture:

- NO_2 – 64 of 73 automatic monitoring sites recorded annual mean levels exceeding 10 µg m^{-3} [t].
- $PM_{2.5}$ – 38 of 66 automatic monitoring sites (hourly measured) recorded annual mean levels exceeding 5 µg m^{-3} and 7 had annual mean level of 5 µg m^{-3} (rounded to one decimal place).
- PM_{10} – 1 of 66 automatic monitoring sites (hourly measured) recorded annual mean levels exceeding 15 µg m^{-3}.
- CO – at the 1 automatic monitoring site in 2021, there were no exceedances.

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[n] 59 of which have a value of 10 µg m^{-3} when rounded to the nearest integer.

[o] 108 of which have a value of 10 µg m^{-3} when rounded to the nearest integer.

[p] 527 of which have a value of 5 µg m^{-3} when rounded to the nearest integer.

[q] 728 of which have a value of 5 µg m^{-3} when rounded to the nearest integer.

[r] 4 of which have a value of 5 µg m^{-3} when rounded to the nearest integer.

[s] Of which all 8 had a value of 15 µg m^{-3} when rounded to the nearest integer.

[t] Including one site (North Lanarkshire Croy) recording an annual mean level of 10 µg m^{-3} when rounded to one decimal place.

Summary

There is evidence that air pollution concentrations are better in Scotland than other parts of the UK and internationally. Scotland appears to be meeting almost all of its target air quality limits and targets. However, there remain NO_2 exceedances in a small number of sites. COVID-19 lockdowns are likely to have contributed to reduced NO_2 concentrations in 2020, however evidence suggests that Scotland is returning to pre-COVID levels and that NO_2 concentrations may not be decreasing at all urban background sites.

Although O_3 targets are being met, the long-term objective for health set out in the EU Directive is not and there are indications that overall concentrations may be increasing. In addition, despite the majority of limits and targets being met, the most recent WHO guidelines presents more stringent standards. Concerns also remain about whether any level of particulate matter is safe for human health.

Finally, it will be important to continue to check progress in the published 2021 and 2022 data to determine whether the move out of COVID lockdowns does reverse improvements seen in 2020 as the currently available evidence indicates.

Emission trends and sources

Air quality concerns concentrations of pollutants in the air. However, it is also important to consider trends in the emissions of these pollutants being released into the air and the sources of these emissions. Reducing emissions can help reduce atmospheric concentrations though the level of reduction is not always proportionate as weather conditions, secondary formation[u] and the transboundary nature of some pollutants can also affect concentrations.

Emissions released into the air

The emission of air pollutants is controlled by UK legislation (National Emission Ceilings Regulations 2018[43]) which sets emissions ceilings for each pollutant to 2030. This legislation incorporates ceilings set by the EU National Ceiling Emissions Directives (2001/81/EC[44] and 2016/2284/EC[45]) and the Gothenburg Protocol under the United Nations Economic Commission for Europe (UNECE) Convention on Long-Range Transboundary Air Pollution (CLRTAP)[46].

The most recent data indicates that the UK has not exceeded the 2020 emissions ceilings set out in legislation for SOx, NO_x, NMVOCs and $PM_{2.5}$[47] but that the UK has exceeded the ceiling for ammonia (NH_3). However, the UK Informative Inventory Report notes that 'the UK has prepared an adjusted inventory for NH_3 which, at the time of writing, has been submitted to UNECE for scrutiny. If approved, this adjustment will reduce emissions to below the 2020 ceiling.'

The Scottish Government's Cleaner Air for Scotland 2 (CAFS2) strategy[1] acknowledges that although the UK has met the 2020 targets, new policies will be required to ensure compliance with 2030 emissions ceilings.

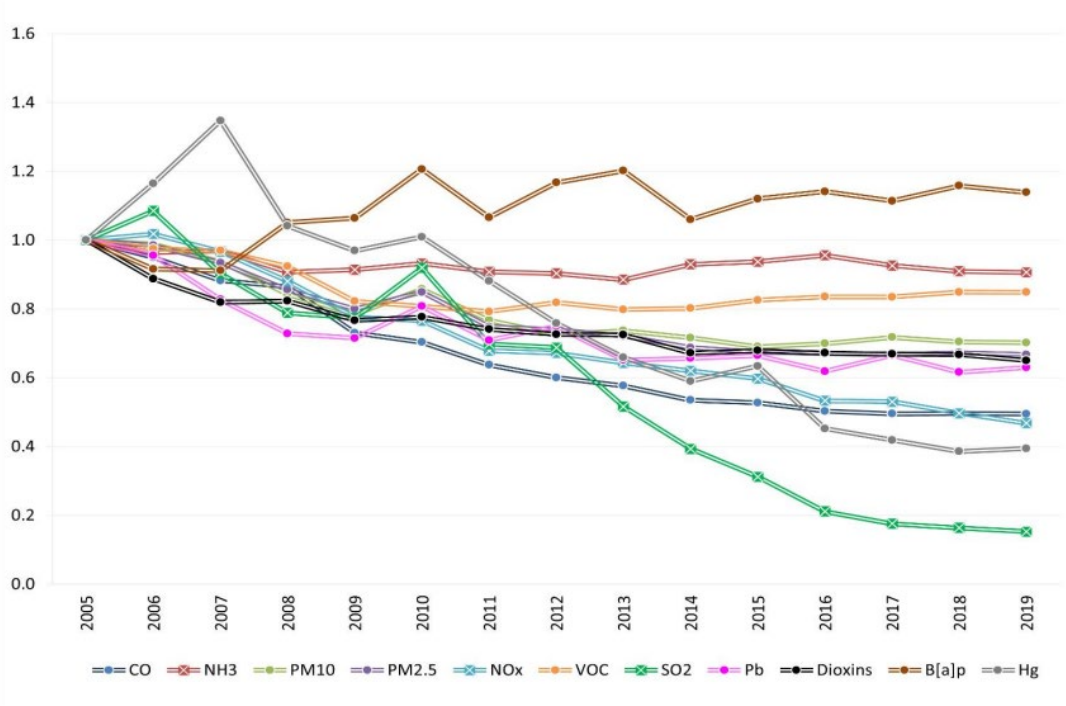
Air pollutants (NH_3, CO, NO_x, non-methane volatile organic compounds (NMVOC), PM_{10}, $PM_{2.5}$, SO_2, Pb) are reported annually in the Air Pollution Inventories for England, Scotland, Wales and Northern Ireland published by the National Atmospheric Emissions Inventory[48]. The volume of emissions of the different

[u] For example, primary emissions of NH_3 can react in the atmosphere with other substances to form secondary emissions of particulate matter.

pollutants should not be compared as their effects on the health and the environment are very different.

The latest analysis of trends for Scotland covers the period 2005 to 2019 and demonstrates that most pollutant emissions reduced over this period, particularly for SO_2 which is reported as being mainly due to reductions in coal use. This masks increasing trends for CO and $PM_{2.5}$ emissions in the residential (corresponding with an increase in the use of wood fuel in the domestic sector), commercial and public sector combustion sectors. Similarly, there have been increases in NMVOCs due to the increasing production and storage of whisky. In addition, since 2008, there has been no significant change in NH_3 emissions from the agriculture sector[48].

Figure 1: Scotland normalised trends for all pollutants



(Source: National Atmospheric Emissions Inventory[48])

Further detail on these points:

- Over this period emissions of NH_3 were 9% lower. However, most of this occurred in the early part of the period due to decreases in livestock numbers (except poultry) and declines in the use of nitrogen-based fertilisers. After 2010, there is no significant trend with this decline being offset by increasing application of urea-based and organic fertiliser.

- CO emissions down 51% mainly driven by changes in transport contributions, particularly the road sector. However, emissions from residential, commercial and public sector combustion have steadily increased, corresponding with an increase in the use of wood fuel in the domestic sector. Latest data (2016 onwards) suggests recent trend overall is more stable.
- Nitrogen Oxide emissions down 53% since 2005, also mainly due to changes in road transport.
- NMVOC have declined 15% in the period but it appears this has been mainly due to larger decreases in the early part of the period after which there have been increases, particularly from the food and drink industry. Emissions here have increased since 2009 due to the increased production and storage of whisky.
- PM_{10} emissions reduced by 30% since 2005 although the trend appears to be stable in recent years. Emissions from energy industries and transport sources have had the most notable impact on the trend.
- $PM_{2.5}$ emissions reduced by 33% although appears to be stable in recent years with the switch from coal to natural gas and improvements in transport sector being offset by increases in burning of wood in the residential sector. Emissions from the residential sector are up 50% since 2005.
- SO_2 has reduced by 35% since 2005 mainly due to changes in the power generation sector including the move away from coal.
- Pb is down 37% mainly due to changes in energy sources, industrial combustion and industrial processes. The trend appears more stable in recent years.
- Dioxins are down by 35% mainly due to reduction in emissions from the waste sector with the trend appearing stable in recent years.
- BaP emissions have increased 14% since 2005, likely due to increases in wood combustion in residential settings, which currently account for 58% of residential B[a]p emissions.

- Mercury (Hg) has reduced 61% since 2005, stemming from changes in combustion in power and heat generation and chlor-alkali process emissions. Emissions from crematoria are now the biggest source.

Emission sources

The inventory[48] report also provides more information on the sources of these emissions:

- Residential, commercial and public sector combustion is the biggest contributor of B[a]p (90%), dioxins (43%), $PM_{2.5}$ (43%), CO (41%) and SO_2 (31.5%).
- Agriculture is the biggest contributor of NH_3 (93%).
- Industrial processes are the biggest contributors of NMVOCs (54%).
- Transport is the biggest contributor of Pb (52%) and NO_x (48%).
- Unlike most other pollutants, the emissions profile of PM_{10} is diverse: transport sources, residential and industrial processes each accounted for over 16% of total emissions in 2019.

Scottish Pollutant Release Inventory

SEPA collates a Scottish Pollutants Release Inventory[49] which requires certain industrial sites to report the total amount of a substance that they emit to air or water during the period of a year. Experimental statistics from the SPRI focus on emissions and sites where emissions are 'above reporting threshold' (ART) (set at a UK level and designed to capture 95% of the UK's total emitted pollutants for the particular substance).

In 2020, the most common release above reporting thresholds (in terms of numbers of sites) was NH_3 (intensive livestock production and aquaculture) followed by methane (waste / waste-water management) and carbon dioxide (energy).

The data shows that, in 2020, ART emissions to air of carbon dioxide, methane and nitrous oxide emissions from the SEPA-regulated industrial sites which report to the SPRI continued to decrease, though less than in the period from 2007 to 2016. Carbon dioxide emissions fell by around 60% between 2007 and 2020 while methane fell by 63%. Previous reports suggest that carbon dioxide ART emissions to

air from sites in the waste and waste-water management sectors have been increasing. This is expected to be partly due to increases in the incineration of waste. This sector represents only a relatively small proportion of carbon dioxide ART emissions to air – 19% in 2020 (up from 4.5% in 2010) compared to 48% for the energy sector (down from 85.5% in 2010) – which explains why the overall trend is decreasing despite increases in this sector.

Hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride (F-gases) do not appear to be following the same clear downward trend as the other greenhouse gases. This may be partly due to the small number of reporting sites leading to potential fluctuation. However, between 2019 and 2020 there was a stark increase in hydrofluorocarbon ART emissions from 1,263 kg to 3,636 kg (188%) with the majority of this (3,241 kg) released by just five sites. SEPA is undertaking regulatory work to investigate the three sites in the chemicals sector and this is ongoing. On the other hand, SEPA notes that the two food and beverage sites had accidental releases and have since taken steps to upgrade their refrigeration[50].

Environmental impact

According to UK Government data, around 53% of Scotland's land area contains habitats sensitive to acid deposition and 54% to eutrophication and many are sensitive to both. The area of sensitive habitats in Scotland exceeding critical loads for acidification fell from 74% in 1995-97 to 24% in 2017-19, with nutrient nitrogen exceedances falling from 59% to 35% over the same period[51]. This data is helpful in understanding the effects on ecosystems of policies aimed at meeting air pollution targets.

Summary

Compliance with emissions ceilings is determined at the UK level and the latest data shows that the UK has not exceeded the 2020 emissions ceilings set out in legislation for SO_2, NO_x, NMVOC or $PM_{2.5}$. The 2020 data suggests there was an exceedance of the ceiling for NH_3 although this is under review and may be adjusted to below the ceiling following review by UNECE. The Scottish Government's Cleaner Air for Scotland 2 (CAFS2) strategy acknowledges that new policies will be required to ensure compliance with 2030 emissions ceilings.

Data is also available on the amount of each pollutant released into the air by individual UK nation. This shows that most pollutants were lower in average concentration in 2019 than they were in 2005 in Scotland. However, this masks increasing trends for CO and $PM_{2.5}$ emissions in the residential (corresponding with an increase in the use of wood fuel in the domestic sector), commercial and public sector combustion sectors. Similarly, there have been increases in NMVOCs due to the increasing production and storage of whisky. In addition, since 2008, there has been no significant change in NH_3 emissions from the agriculture sector.

Agriculture is the biggest contributor of NH_3 (93% in 2019); residential, commercial and public sector combustion is the biggest contributor of B[a]p (90%), dioxins (43%), $PM_{2.5}$ (43%), CO (41%) and SO_2 (31.5%); industrial processes are the biggest contributors of NMVOCs (54%); and transport is the biggest contributor of Pb (52%) and NO_x (48%). Unlike most other pollutants, the emissions profile of PM_{10} is diverse: transport sources, residential and industrial processes each accounted for over 16% of total emissions in 2019.

4. Comparisons to other countries

There is evidence that air pollution concentrations are better in Scotland than other parts of the UK as set out in section 2 on air quality.

The OECD also collects and presents data on exposure to $PM_{2.5}$ by country. Devolved administrations are not presented separately but 2019 data indicates that the UK was amongst the lowest 10% of 174 countries (16th lowest) ranked in order of annual average concentration with 10.02 mg per m3 on average, just above the WHO threshold of 10 mg/m3 set out in their 2005 guidelines although much higher than the new WHO guideline of 5 mg/m3 set in 2021[13].

Other OECD data presents information on mortality and welfare costs of exposure to air pollution[52]. The UK is shown to be 58th lowest of 171 countries ranked in order of annual average concentration with a mortality rate of 214 per 1 million population in 2019 due to air quality. Iceland performs best with a rate of 46 per million and North Macedonia worst with 1,321 per million. The UK is also in the best performing half of European countries, with a lower mortality rate than countries such as Germany (324 per million) and Italy (408 per million). OECD data estimates that the welfare cost of premature deaths to the UK is 2.1% of GDP.

5. Summary of next steps

This baseline review identified a wide range of possible issues for further analysis. For example, domestic wood fuel use and its contribution to emissions of carbon dioxide and $PM_{2.5}$ and associated impact on air quality (as being considered by Scottish Government's Rural and Environment Science and Analytical Services Division – RESAS)[53]. Other examples included particulate matter concentration, emissions trends and emerging evidence on sources or emissions from the agriculture and residential sectors.

However, for the purposes of setting out initial analytical priorities, ESS will focus on:

- Progress against air quality targets/standards, with an initial focus on particulate matter.

ESS' proposed Strategic Plan describes how issues will be prioritised for further analysis according to a range of criteria, including:

- Importance – the size and risk of the potential effect on the environment and/or public health; the urgency with which improvement is required;
- Nature and Scope – recent trends in environmental performance; whether the issue of concern appears to be systematic and/or longstanding;
- Neglect – whether there has been action taken on the issue of concern, or further action is planned in the near future; and
- Added-value – the contribution we could make, considering whether other monitoring, oversight or scrutiny bodies are planning to take, or could take, action to address the issue of concern.

The analytical priority for air takes account of that scheme. It recognises the potential impact that air quality can have on human health and the fact that Scotland is currently not achieving more stringent WHO guidelines. In keeping with the prioritisation process, the contributions of other actors and the added value that ESS can bring to an area will also be considered, in deciding where to focus future work.

Although ESS intends to focus on one issue in the first instance, other issues will be retained on a list for potential future analysis and horizon scanning in line with the stages of monitoring and analysis work set out in the strategic plan.

6. Summary of key sources

The end notes to this review provide details of the references and sources used throughout the document. This section is intended to provide a shorter note of those reports (in future iterations) and data sources which have been identified as likely to be important for an ongoing understanding of air quality in Scotland.

OECD Data, *Air Pollution Effects,* https://data.oecd.org/air/air-pollution-effects.htm

OECD Data, *Air Pollution Exposure,* https://data.oecd.org/air/air-pollution-exposure.htm

Ricardo Energy & Environment (Ricardo), *Air Pollution in Scotland 2020*, Report for Scottish Government, December 2021, https://www.scottishairquality.scot/sites/default/files/publications/2022-01/Air_Quality_Scotland_Brochure_2020.pdf

Department for Environment, Food and Rural Affairs, *Air Quality Compliance Data Hub,* https://compliance-data.defra.gov.uk/

National Atmospheric Emissions Inventory, Prepared by Aether Ltd for the Department for Environment, Food & Rural Affairs, The Scottish Government, The Welsh Government and The Northern Ireland Department for Agriculture, Environment and Rural Affairs, *Air Quality Pollutant Inventories for England, Scotland, Wales and Northern Ireland* https://naei.beis.gov.uk/reports/reports?report_id=1030

Scotland's Environment, Air Quality in Scotland, *Daily Air Quality Index,* https://www.scottishairquality.scot/latest/summary

Department for Environment, Food and Rural Affairs, National Statistics, *Air Quality Statistics*, https://www.gov.uk/government/statistics/air-quality-statistics

Department for Environment, Food and Rural Affairs, UK Air, *Annual and Exceedances Statistics*, https://uk-air.defra.gov.uk/data/exceedance

World Health Organisation (WHO), Global Health Observatory data repository, *Ambient Air Pollution Attributable Deaths*, https://apps.who.int/gho/data/view.main.36100

Hough, R.L. 2021, *Identifying Environmental Priorities and Analytical Requisites for Environmental Standards Scotland (ESS)*, SEFARI Fellowship Report, SEFARI Gateway, Edinburgh, https://sefari.scot/sites/default/files/documents/SEFARI%20Fellowship_Hough_Identifying%20environmental%20priorities%20%26%20analytical%20requisites.pdf

SEPA, *Pollutant Emissions and Waste Transfers from SEPA Regulated Industrial Sites,* An Experimental Official Statistics Publication for Scotland, https://www.sepa.org.uk/environment/environmental-data/spri/

Scotland's Environment, Air Quality in Scotland, *Scottish Air Quality Database*, https://www.scottishairquality.scot/data

Department for Environment, Food and Rural Affairs, *Air Pollution in the UK 2020,* September 2021, https://uk-air.defra.gov.uk/library/annualreport/viewonline?year=2020_issue_1#report_pdf

Ricardo Energy & Environment (Ricardo), *Scottish Air Quality Database, Annual Report 2020*, Report for Scottish Government – ED11194, December 2021, https://www.scottishairquality.scot/sites/default/files/publications/2021-12/SAQD_Annual_Report_2020_Issue_1.pdf

Ricardo Energy & Environment (Ricardo), *Scottish Air Quality Maps,* Report for Scottish Government, September 2021, https://www.scottishairquality.scot/sites/default/files/orig/assets/documents/Scottish_mapping_report_2019.html

Scotland's Environment, *Scottish Pollutant Release Inventory*, https://informatics.sepa.org.uk/SPRI/

Rowe EC, Sawicka K, Tomlinson S, Levy P, Banin LF, Martín Hernandez C & Fitch A (2021) *Trends Report 2021: Trends in critical load and critical level exceedances in the UK*. Report to Defra under Contract AQ0849, UKCEH project 07617. https://uk-air.defra.gov.uk/library/reports?report_id=1020

National Atmospheric Emissions Inventory, *UK Informative Inventory Reports,* https://naei.beis.gov.uk/reports/reports?report_id=1071

7. Summary of legislation

The following information on legislation and strategy was found during the review. However, this baseline work was not designed to search for legislation in particular and therefore the information below is unlikely to be comprehensive.

Legislation

Air quality and pollutant emissions were considered by Hough (2022) in their research to identify environmental priorities and analytical requisites for ESS[4]. Hough described the background to air quality legislation in Scotland as well as the current position.

Activities relating to the monitoring and management of air quality in Scotland have been primarily driven by European legislation. The Ambient Air Quality Directive 2008 (2008/50/EC) sets legally binding limits for concentrations in ambient air of most major air pollutants that are known to have a significant impact on human health (including PM_{10}, $PM_{2.5}$ and NO_x). This Directive was made law in Scotland through the Air Quality Standards (Scotland) Regulations 2010 which also incorporates the 4th Air Quality Daughter Directive (2004/107/EC) that sets targets in ambient air for specified heavy metals and PAHs.

Legislation is also in place to control emissions of air pollutants, with the main legislature under the auspices of the United Nations Economic Commission for Europe (UNECE) Gothenburg Protocol which in 2010 initiated emissions ceilings for sulphur, NO_x, VOCs and NH_4 and since incorporated into EU National Emission Ceilings Regulations (2001/81/EC). This was made into UK law (including Scotland) as the National Emissions Ceilings Regulations 2002 and was amended in 2012 to include national emission reduction commitments to be achieved by 2020 and beyond.

Strategies

In December 2013, the European Commission adopted a Clean Air Policy Package that includes a new Clean Air Programme for Europe with new air quality objectives for the period up to 2030. Hough noted that this has not been fully adopted into UK or Scottish legislation yet and might not be[4].

The UK Air Quality Strategy (2007) established a framework for air quality improvements across the UK which stipulated various air quality standards and objectives. The UK published a further Clean Air Strategy in 2019.

Air quality is a devolved matter and the Air Quality (Scotland) Regulations 2000 (with amendments in 2002 and 2016) as well as the Air Quality Standards (AQS) (Scotland) Regulations 2010 set out Scottish air quality targets in line with UK and EU limit and target values as well as some Scotland-specific limit values. The Scottish Government published its second Clean Air for Scotland Strategy (CAFS2) in July 2021.

CAFS2 is structured around 10 themes: i) health – a precautionary approach i.e. complying with standards and where possible going further; ii) integrated policy; iii) placemaking – ensuring the National Planning Framework 4 links to the air quality strategy; iv) data – addressing gaps in the quality and coverage of air quality, transport and human health data; v) public engagement and behaviour change; vi) industrial emissions regulation – maintaining or exceeding EU standards; vii) tackling non-transport emissions sources – including consideration of performance and standards for domestic fires, stoves and fuels and refreshing the approach to agricultural practice; viii) transport – active travel and public transport; ix) governance, accountability and delivery – simple and effective arrangements and joined up delivery; and x) further progress review – CAFS 2 will have a five year lifespan and a review will commence in 2024.

8. Annex: Current Air Quality Management Areas in Scotland

Local authority	AQMA Name	Pollutant
Aberdeen City	Aberdeen City Centre AQMA	NO_2, PM_{10}
	Wellington Road AQMA	NO_2, PM_{10}
	Anderson Drive AQMA	NO_2, PM_{10}
City of Edinburgh	Edinburgh AQMA No 1 City Centre	NO_2
	Edinburgh AQMA No 2 St John's Road	NO_2
	AQMA Inverleith Row 2013	NO_2
	Great Junction Street	NO_2
	AQMA Glasgow Road 2013	NO_2
	Salamander Street AQMA	PM_{10}
Dundee City	Dundee AQMA	NO_2, PM_{10}
East Dunbartonshire	Kirkintilloch Road AQMA	NO_2, PM_{10}
	East Dunbartonshire Council AQMA**	PM_{10} (NO_2)
East Lothian	High Street, Musselburgh	NO_2
Falkirk	Grangemouth AQMA	SO2
	Falkirk Council AQMA No 5 Order 2011	PM_{10}
	Falkirk Town Centre	NO_2, PM_{10}
	Falkirk AQMA (Annual Mean)	NO_2
Fife	Bonnygate AQMA Amendment Order 2021	PM_{10} (NO_2)
	Appin Crescent Dunfermline Amendment Order 2021	PM_{10} (NO_2)
Glasgow City	Byres Road/ Dumbarton Road AQMA	NO_2 (PM_{10})
	Glasgow City Centre AQMA	NO_2, PM_{10}
Highland	Inverness City Centre AQMA	NO_2
	Chapelhall AQMA *	NO_2, PM_{10}

North Lanarkshire	Motherwell AQMA *	NO_2, PM_{10}
	North Lanarkshire AQMA Croy 2011***	PM_{10}
	Coatbridge AQMA *	NO_2, PM_{10}
	Harthill AQMA***	PM_{10}
	North Lanarkshire AQMA Moodiesburn 2011***	PM_{10}
Perth and Kinross	Perth AQMA	NO_2, PM_{10}
	Perth No. 2 Crieff AQMA	NO_2, PM_{10}
Renfrewshire	Paisley AQMA amended	NO_2, PM_{10}
	Johnstone High Street	NO_2
	Renfrew Town Centre	NO_2
South Lanarkshire	Whirlies Roundabout AQMA	PM_{10}
	Lanark AQMA	NO_2
	Rutherglen AQMA	PM_{10}
West Lothian	Broxburn AQMA	NO_2, PM_{10}
	Newton AQMA	PM_{10}
	Linlithgow AQMA	NO_2, PM_{10}

Source: https://www.scottishairquality.scot/laqm/aqma, accessed 16 June 2022. Revoked pollutants are given in brackets.

* Indicates that the ESS air quality investigation found that the AQMA had been amended to include NO_2 although this wasn't specified on the Scottish Air Quality website at the point it was accessed for this review.

** Indicates that the ESS air quality investigation found that the AQMA had recently been revoked for NO_2 although this wasn't clear at the point the Scottish Air Quality website was accessed for this review.

*** Included on the Scottish Air Quality website but local authority website indicates it has been revoked.

9. End notes

All references accessed August 2022 unless otherwise stated.

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[1] Scottish Government, *Cleaner Air for Scotland 2, Towards a Better Place for Everyone*, July 2021, https://www.gov.scot/publications/cleaner-air-scotland-2-towards-better-place-everyone/.

[2] Scottish Government, *Environment, natural resources and agriculture research: strategy 2022 to 2027*, March 2021, https://www.gov.scot/publications/strategy-environment-natural-resources-agriculture-research-2022-2027/documents/.

[3] Public Health England, *Health Matters: Air Pollution*, November 2018, https://www.gov.uk/government/publications/health-matters-air-pollution/health-matters-air-pollution.

[4] Hough, R.L. 2021, Identifying Environmental Priorities and Analytical Requisites for Environmental Standards Scotland (ESS), SEFARI Fellowship Report, SEFARI Gateway, Edinburgh, https://sefari.scot/sites/default/files/documents/SEFARI%20Fellowship_Hough_Identifying%20environmental%20priorities%20%26%20analytical%20requisites.pdf.

[5] Department for Environment, Food and Rural Affairs, The Scottish Government, The Welsh Government and The Northern Ireland Department of the Environment, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/69336/pb12654-air-quality-strategy-vol1-070712.pdf.

[6] Department for Environment, Food and Rural Affairs, UK AIR, UK Air Quality Limits, https://uk-air.defra.gov.uk/air-pollution/uk-eu-limits.

[7] Scotland's Environment, Air Quality in Scotland, *Standards,* https://www.scottishairquality.scot/air-quality/standards.

[8] *The Air Quality (Scotland) Regulations 2000*, https://www.legislation.gov.uk/ssi/2000/97/contents/made.

[9] *The Air Quality (Scotland) Amendment Regulations 2002*, https://www.legislation.gov.uk/ssi/2002/297/contents/made.

[10] *The Air Quality (Scotland) Amendment Regulations 2016,* https://www.legislation.gov.uk/ssi/2016/162/contents/made.

[11] Scottish Government, *Local air quality management for Scotland: policy guidance*, March 2016, https://www.gov.scot/publications/local-air-quality-management-policy-guidance-scotland/pages/9/.

[12] *The Air Quality Standards (Scotland) Regulations 2010,* https://www.legislation.gov.uk/ssi/2010/204/contents/made.

[13] World Health Organization, *WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide*, 2021, License: CC BY-NC-SA 3.0 IGO, https://apps.who.int/iris/handle/10665/345329.

[14] Ricardo Energy & Environment (Ricardo), Report for The Department for Environment, Food and Rural Affairs, The Welsh Government, The Scottish Government and The Department of the Environment
for Northern Ireland, *Technical report on UK supplementary assessment under The Air Quality*

Directive (2008/50/EC), The Air Quality Framework Directive (96/62/EC) and Fourth Daughter Directive (2004/107/EC) for 2019, February 2021, https://uk-air.defra.gov.uk/assets/documents/reports/cat09/2102111100_2019_PCM_technical_report.pdf .

[15] Department for Environment, Food and Rural Affairs, *Air Quality Compliance Assessment Map and Data Hub, Guidebook,* December 2021, https://uk-air.defra.gov.uk/assets/documents/ComplianceDataAppHub_guidebook_2021.pdf.

[16] Department for Environment, Food and Rural Affairs, *Air Pollution in the UK 2020,* September 2021, https://uk-air.defra.gov.uk/library/annualreport/viewonline?year=2020_issue_1#report_pdf.

[17] Department for Environment, Food and Rural Affairs, *Air Pollution in the UK 2019*, September 2020, https://uk-air.defra.gov.uk/library/annualreport/assets/documents/annualreport/air_pollution_uk_2019_Compliance_Assessment_Summary_Issue1.pdf.

[18] Department for Environment, Food and Rural Affairs, *Air Quality Statistics,* April 2022, https://www.gov.uk/government/statistics/air-quality-statistics.

[19] Department for Environment, Food and Rural Affairs, *Concentrations of particulate matter (PM10 and PM2.5),* April 2022, https://www.gov.uk/government/statistics/air-quality-statistics/concentrations-of-particulate-matter-pm10-and-pm25.

[20] Department for Environment, Food and Rural Affairs, *Concentrations of ozone,* April 2022, https://www.gov.uk/government/statistics/air-quality-statistics/concentrations-of-ozone.

[21] Guidance on the Commission Implementing Decision laying down rules for Directives 2004/107/EC and 2008/50/EC of the European Parliament and of the Council as regards the reciprocal exchange of information and reporting on ambient air (Decision 2011/850/EU). Air Policy - Library (europa.eu)

[22] Ricardo Energy & Environment (Ricardo), *Scottish Air Quality Database, Annual Report 2020*, Report for Scottish Government – ED11194, December 2021, https://www.scottishairquality.scot/sites/default/files/publications/2021-12/SAQD_Annual_Report_2020_Issue_1.pdf.

[23] Ricardo Energy & Environment (Ricardo), *Scottish Air Quality Database, Air Quality in Scotland 2020*, Report for Scottish Government, https://www.scottishairquality.scot/sites/default/files/publications/2022-01/Air_Quality_Scotland_Brochure_2020.pdf.

[24] Environment Agency, *Automatic Urban and Rural Network (AURN) LSO Manual – Essential Background Reading*, February 2021, https://uk-air.defra.gov.uk/assets/documents/reports/empire/lsoman/AURN_LSO_Manual_Essential_Background_Reading_Version_1_February_2021.pdf.

[25] Department for Environment, Food and Rural Affairs, *Diffusion Tubes Overview,* https://laqm.defra.gov.uk/air-quality/air-quality-assessment/diffusion-tubes-overview/ (accessed August 2022).

[26] Scotland's Environment, Air Quality in Scotland Database, *Measurement and Annual Statistics, https://www.scottishairquality.scot/data/data-selector.*

[27] Ricardo Energy & Environment (Ricardo), Scottish Air Quality Maps, Report for Scottish Government, September 2021,

https://www.scottishairquality.scot/sites/default/files/orig/assets/documents/Scottish_mapping_report_2019.html.

[28] Department for Environment, Food and Rural Affairs, UK Air, *Daily Air Quality Index*, https://uk-air.defra.gov.uk/air-pollution/daqi.

[29] Department for Environment, Food and Rural Affairs, UK Air, *What is the Daily Air Quality Index* https://uk-air.defra.gov.uk/air-pollution/daqi?view=more-info&pollutant=pm10#pollutant.

[30] Scotland's Environment, Air Quality in Scotland Database, *Local Air Quality Management*, https://www.scottishairquality.scot/laqm/aqma (accessed 16 June 2022).

[31] Department for Environment, Food and Rural Affairs, UK Air, *Summary AQMA data*, https://uk-air.defra.gov.uk/aqma/summary.

[32] Scotland's Environment, Air Quality in Scotland Database, *Local Air Quality Management*, *Annual Statistics Reports*, https://www.scottishairquality.scot/laqm/statistics.

[33] Department for Environment, Food and Rural Affairs, Air Quality Compliance Data Hub, https://compliance-data.defra.gov.uk/.

[34] Department for Environment, Food and Rural Affairs, Air Quality Compliance Data Hub, *Nitrogen Dioxide Annual Mean Fixed Measurements 2020,* December 2021, https://compliance-data.defra.gov.uk/datasets/Defra::nitrogen-dioxide-annual-mean-fixed-measurements-2020/explore.

[35] Department for Environment, Food and Rural Affairs, Air Quality Compliance Data Hub, *Nitrogen Dioxide Annual Mean Modelled Roadside 2020,* December 2021, https://compliance-data.defra.gov.uk/datasets/Defra::nitrogen-dioxide-annual-mean-modelled-roadside-2020/explore.

[36] Department for Environment, Food and Rural Affairs, Air Quality Compliance Data Hub, *Nitrogen Dioxide Annual Mean Modelled Background 2020,* December 2021, https://compliance-data.defra.gov.uk/datasets/Defra::nitrogen-dioxide-annual-mean-modelled-background-2020/explore (Scotland data filtered by selecting local authority codes beginning with S, accessed August 2022).

[37] Department for Environment, Food and Rural Affairs, Air Quality Compliance Data Hub, *PM2.5 annual mean modelled roadside 2020,* December 2021, https://compliance-data.defra.gov.uk/datasets/Defra::pm2-5-annual-mean-modelled-roadside-2020/explore.

[38] Department for Environment, Food and Rural Affairs, Air Quality Compliance Data Hub, *PM2.5 annual mean modelled background 2020,* December 2021, https://compliance-data.defra.gov.uk/datasets/Defra::pm2-5-annual-mean-modelled-background-2020/explore (Scotland data filtered by selecting local authority codes beginning with S, accessed August 2022).

[39] Department for Environment, Food and Rural Affairs, Air Quality Compliance Data Hub, *PM2.5 annual mean fixed measurements 2020,* December 2021, https://compliance-data.defra.gov.uk/datasets/Defra::pm2-5-annual-mean-fixed-measurements-2020/explore.

[40] Department for Environment, Food and Rural Affairs, Air Quality Compliance Data Hub, *PM2.5 annual mean modelled roadside 2020,* December 2021,https://compliance-data.defra.gov.uk/datasets/Defra::pm10-annual-mean-modelled-roadside-2020/explore.

[41] Department for Environment, Food and Rural Affairs, Air Quality Compliance Data Hub, *PM10 annual mean modelled background 2020,* December 2021, https://compliance-data.defra.gov.uk/datasets/Defra::pm10-annual-mean-modelled-background-2020/explore (Scotland data filtered by selecting local authority codes beginning with S, accessed August 2022).

[42] Department for Environment, Food and Rural Affairs, Air Quality Compliance Data Hub, *PM10 annual mean fixed measurements 2020,* December 2021, https://compliance-data.defra.gov.uk/datasets/Defra::pm10-annual-mean-modelled-background-2020/explore.

[43] *The National Emission Ceilings Regulations 2018,* https://www.legislation.gov.uk/uksi/2018/129/contents/made.

[44] *Directive 2001/81/EC of the European Parliament and of the Council*, https://www.legislation.gov.uk/eudr/2001/81/2016-12-31.

[45] *Directive (EU) 2016/2284 of the European Parliament and of the Council of 14 December 2016 on the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/E,* https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2016.344.01.0001.01.ENG.

[46] UNECE, *The Air Convention and its Protocols, The Convention and its Achievements,* https://unece.org/convention-and-its-achievements.

[47] National Atmospheric Emissions Inventory, *UK Informative Inventory Reports*, https://naei.beis.gov.uk/reports/reports?report_id=1071.

[48] National Atmospheric Emissions Inventory, Prepared by Aether Ltd for the Department for Environment, Food & Rural Affairs, The Scottish Government, The Welsh Government and The Northern
Ireland Department for Agriculture, Environment and Rural Affairs, *Air Quality Pollutant Inventories for England, Scotland, Wales and Northern Ireland: 2005–2019*, September 2021, https://naei.beis.gov.uk/reports/reports?report_id=1030 (accessed August 2021).

[49] Scotland's Environment, *Scottish Pollutant Release Inventory,* https://informatics.sepa.org.uk/SPRI/.

[50] SEPA, Policy Statement, *2020 Emissions Data Shows Impact of COVID-19 on Scottish Industry,* https://media.sepa.org.uk/media-releases/2022/2020-emissions-data-shows-impact-of-covid-19-on-scottish-industry.aspx.

[51] Rowe EC, Sawicka K, Tomlinson S, Levy P, Banin LF, Martín Hernandez C & Fitch A (2021) Trends Report 2021: Trends in critical load and critical level exceedances in the UK. Report to Defra under Contract AQ0849, UKCEH project 07617. https://uk-air.defra.gov.uk/library/reports?report_id=1020.

[52] OECD Data, Air Pollution Effects, https://data.oecd.org/air/air-pollution-effects.htm#indicator-chart.

[53] Scottish Government, *Environment, natural resources and agriculture research: strategy 2022 to 2027*, March 2021, https://www.gov.scot/publications/strategy-environment-natural-resources-agriculture-research-2022-2027/documents/.

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