

CLEAN AIR ADVISORY PANEL

Advice Note: Multi-pollutant advice regarding the setting of long-term targets under the Environment (Air Quality and Soundscape)(Wales) Act 2024

Part 1: Evidence-based assessment of the rationale for setting, or not setting, a target for Section 1 pollutants

Prepared for:

Welsh Government

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Terms of Reference

The Clean Air Advisory Panel (CAAP) is an independent committee that provides evidence-based advice and recommendations on air quality matters in Wales to the Welsh Government. At the request of the Welsh Government, CAAP's independent and expert advice informs and supports the development of air quality policy. Members of CAAP consist of multi-disciplinary policy makers, academics and air quality and public health practitioners.

CAAP's functions are to:

1. Independently advise on and provide scientific evidence to support the development of Welsh Government's policy, targets and interventions to address air quality.
2. Advise on and identify available evidence in relation to air quality and its relationship with associated environmental, public health, socio-economic and other relevant factors.
3. Contribute to developing the air quality evidence base in the following ways:
 - identify, analyse, interpret and synthesise evidence,
 - provide judgements on quality and relevance of evidence,
 - suggest priority areas for future work,
 - advise on the underpinning evidence in relation to air quality, and
 - identify synergies and conflicts with other priorities, for example climate change and nature recovery.
4. Collaboratively work to ensure that all actions taken to improve air quality in Wales are grounded in comprehensive and reliable evidence.
5. Provide advice on current and future air pollutant levels, trends, sources, and characteristics in Wales.
6. Encourage and maximise opportunities for the identification of innovative solutions which help to reduce levels of airborne pollution. Including identifying opportunities for assessment of data.

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Executive Summary

This Advice Note provides independent scientific advice from the Clean Air Advisory Panel (CAAP) to the Welsh Government, intended to inform and support Welsh Ministers' consideration of their obligations under Section 9 of the Environment (Air Quality and Soundscapes) (Wales) Act 2024 ('the Act'). Section 9 requires Ministers to lay and publish a report before Senedd Cymru on the consideration given during the reporting period to setting long-term targets under Section 1 for the listed pollutants for which no target has previously been set. These pollutants are ammonia (NH₃), nitrogen dioxide (NO₂), particles with a diameter of less than 10 micrometres (PM₁₀), ground-level ozone (O₃), sulphur dioxide (SO₂) and carbon monoxide (CO). This report constitutes Part 1 of CAAP's advice, providing an evidence-based assessment of the rationale for setting, or not setting, long-term targets for each Section 1 pollutant in Wales. It is intended to inform Welsh Ministers' statutory report to Senedd Cymru under Section 9 and does not presume that a target will be set for every pollutant.

The assessment draws upon the latest scientific evidence, including the latest World Health Organisation's (WHO) *Global Air Quality Guidelines (2021)*, existing Welsh and UK regulatory frameworks, and current and projected air quality data in relation to Wales. The panel reviewed each pollutant in relation to key criteria including sources, impacts on human health and ecosystems, opportunities for co-benefits or potential disbenefits, existing regulatory controls, and the feasibility of mitigation and monitoring.

The pollutants assessed show substantial variation in their sources, trends and impacts in Wales. It is important to consider the origins of air pollutant concentrations affecting Wales, i.e. the proportions due to in-country sources vs. import from other parts of the UK and transboundary sources, such as Ireland, continental Europe and international shipping. Ammonia emissions are dominated by agricultural sources, while combustion-related pollutants such as nitrogen dioxide, sulphur dioxide and carbon monoxide are mainly associated with transport, industry and energy use. Ground-level ozone is a secondary pollutant formed through atmospheric reactions involving precursor emissions and influenced by meteorology and transboundary pollution. PM₁₀ arises from a mixture of local primary emissions, secondary particle formation and natural sources (as well as transboundary contributions), and therefore needs to be considered separately from both gaseous pollutants and PM_{2.5}. The pollutants listed in the Act are considered to adversely affect human health, particularly upon the respiratory and cardiovascular systems, and can also damage ecosystems through eutrophication, acidification and plant toxicity; the pollutant-specific sections below set out these effects in relation to each specific pollutant identified for this report.

The analysis also highlights strong interdependencies between pollutants that can share sources or interact through atmospheric chemistry, with reactions between ammonia, sulphur dioxide and nitrogen oxides contributing to secondary particulate formation, and ozone produced through interactions between nitrogen oxides, volatile organic compounds and carbon monoxide. As a result, measures targeting one pollutant can produce wider air quality benefits but must be designed carefully to avoid unintended consequences.

Monitoring infrastructure for most pollutants is already established across Wales through national and locally managed networks, providing a basis for tracking concentrations and trends, although coverage and capability vary between pollutants. The report also highlights emerging pollutants, including ultrafine particles and other airborne contaminants, where evidence on exposure and impacts remains limited but may warrant future consideration.

This advice note represents the first phase of CAAP's advice to Welsh Government on long-term target setting for Section 1 pollutants, following separate advice on the PM_{2.5} target required under Section 2. It provides independent scientific advice to support Ministers' consideration of long-term air quality targets. The evidence reviewed in Part 1 is intended to inform subsequent pollutant-specific and more

detailed advice in Part 2, rather than to rank pollutants or predetermine which targets should be set. Part 2 will provide advice on target-setting approaches, proposed metrics, monitoring requirements and compliance considerations where these are relevant to Welsh Government's future regulations under Section 1 of the Act.

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1. Introduction

The Environment (Air Quality and Soundscapes) (Wales) Act 2024 (“the Act”)¹ seeks to improve air quality and reduce the impacts of airborne pollution on human health, nature, the environment and our economy. The Act states that Welsh Ministers may by regulations set long-term targets in respect of any matter relating to air quality in Wales.

Sections 1 and 2 establish the statutory basis for setting air quality targets in Wales. Section 1 gives Welsh Ministers powers to set long-term targets in respect of matters relating to air quality in Wales and requires them to set at least one long-term target in respect of one or more of the following pollutants: ammonia; PM₁₀; ozone; nitrogen dioxide; carbon monoxide; and sulphur dioxide. Section 2 requires Ministers to set at least one specific target for the annual mean concentration of PM_{2.5} in ambient air, ensuring that fine particulate matter is explicitly addressed within the national target setting framework. Following the introduction of the Act, the CAAP developed and submitted an advice note on PM_{2.5} target setting for Welsh Government in September 2025.

Sections 3 to 9 of the Act set out the governance framework for the development, implementation and oversight of air quality targets. Section 3 establishes the target-setting process, requiring Welsh Ministers to obtain independent expert advice, consider the latest scientific evidence and World Health Organization guidelines, and ensure targets are achievable. Section 4 places a duty on Welsh Ministers to ensure that targets are met, while Section 5 sets out reporting requirements to Senedd Cymru, including explanations and corrective action where targets are not achieved or where it cannot yet be determined whether a target has been met. Sections 6 and 7 require periodic reviews of targets and monitoring of progress using published air quality data, and Section 8 requires that once a target standard has been achieved by the set date it must be maintained, subject to limited conditions, and that appropriate reporting arrangements must be implemented.

Section 9 requires Welsh Ministers to lay and publish a report before Senedd Cymru on the consideration given during the reporting period to setting long-term targets in relation to the pollutants listed under Section 1. The report should address the listed pollutants for which a target has not previously been set, without implying that a target must be set for every pollutant. Reports are required at the end of each reporting period, defined as an initial two-year period subsequent to the coming into force of Section 1 of the Act and followed by annual reporting thereafter.

Welsh Government requested the expert scientific evidence and advice from the Clean Air Advisory Panel (CAAP) in relation to the setting of new national targets for the six (6) air pollutants listed in Section 1 of the Act. Advice provided by CAAP should have taken into regards any guidelines for pollutants published by the World Health Organisation (*WHO*) in its most recent *global air quality guidelines*². The CAAP may also provide advice based on consideration of any additional pollutants they believe pose significant risk at the national scale. Consequently, CAAP proposed consideration of ultra-fine particles (UFPs), with a diameter less than 100 nanometres (nm)) as an additional candidate pollutant to be considered for further target setting, given the potential significance of UFPs for public health at the national scale.

In consideration of long-term target setting for Section 1 pollutants, Welsh Government have requested advice from CAAP to inform two distinct outputs as notes.

1. The first note (Part 1, this document) should provide independent scientific advice to Welsh Government officials to aid development of a report to inform Welsh Ministers’ wider

¹ Environment (Air Quality and Soundscapes) (Wales) Act 2024. Available at: <https://www.legislation.gov.uk/asc/2024/2/data.pdf> (accessed June 2026)(accessed June 2026)

² WHO (2021). *WHO global air quality guidelines: particulate matter (PM_{2.5} and PM₁₀), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide*. World Health Organization.

consideration of setting long-term air quality targets for Section 1 pollutants as set out in Section 9 of the Act. CAAP members were asked to include consideration of the rationale for setting, or not setting, a target for each pollutant, having regard to all available data (current and historic trends, wider scientific evidence and expert judgement), existing target regulations and the relevant WHO guidelines. CAAP advice to Welsh Government to support the Section 9 report is required by 30 April 2026.

2. The second advice note (Part 2) is intended to inform the regulations required under Section 1, including the mandatory long-term target to be set for at least one Section 1 pollutant by 14 February 2030. CAAP will provide scientific advice on the form, metric, monitoring and feasibility of any candidate target or cross-cutting target approach, while Welsh Ministers will determine the target or targets to be proposed in regulations.

This Part 1 advice note constitutes the first phase of CAAP's response to Welsh Government's request for advice and is intended to inform the Section 9 report. For each Section 1 pollutant, as part of consideration for setting long-term air quality targets, the CAAP reviewed the following criteria:

- (i) sources
- (ii) health impacts
- (iii) ecological and environmental impacts
- (iv) opportunities for co-benefits, risk of secondary disbenefits
- (v) whether the pollutant is controlled under current legislation or other measures
- (vi) the feasibility of monitoring and of mitigation.

In developing this advice, CAAP also had regard to provisional interim modelling undertaken by Ricardo on behalf of Welsh Government³⁴, which explored the potential feasibility of achieving different target levels for each pollutant under three emission reduction scenarios (medium, high and speculative), together with associated health, environmental and economic impacts. The indicative modelling was presented to the CAAP. The CAAP acknowledge that as part of any policy considerations, updated policy-specific assessment (including modelling) should be completed and the modelling completed by Ricardo was treated as indicative.

Apart from UFP, monitoring capabilities for all air pollutants included in the review have been in place across the UK (including Wales) for some years (decades in some cases). Except for O₃, a significant contribution to each pollutant's presence in the atmosphere arises from primary sources, though a proportion of the sources (different for each pollutant) are outside Wales. Each pollutant poses threats to human health and/or the environment; however, these impacts vary by pollutant as does the ability of a government to mitigate sources, depending on whether the sources are within its territory.

Detailed advice on the target setting approach, proposed metrics, monitoring requirements and compliance considerations will be set out in the Part 2 advice note which will inform Welsh Ministers' consideration of which pollutant(s) to include in target regulations under Section 1 of the Act.

2. Consideration of Section 1 air pollutants for long-term target setting

This section provides an overview, in the context of its relevance in Wales, of each of the ambient air pollutants listed in the Act, other than PM_{2.5} (which is already covered by proposed targets) summarising sources, health, ecological and environmental impacts, opportunities for co-benefits and/or risk of secondary disbenefits, feasibility of mitigation and feasibility of monitoring. For human health impacts, more detail can be found in the WHO guidelines².

2.1. Ammonia (NH₃)

(i). Sources: Sources of ammonia emissions in Wales are dominated by agriculture (93% in 2023, see Figure 1), largely through emissions from livestock farming and fertiliser application to soils. In recent years, anaerobic digestion has been used increasingly to process livestock manures and other wastes to support GHG mitigation. This has increased NH₃ emissions. Emissions from storage and spreading of anaerobic digestate increased from 1% of UK total emissions in 1990 to 6% in 2020⁵. It is noteworthy that total NH₃ emissions in Wales have not changed greatly since ca. 2005 but increased slightly to 2023. ⁶A spatial emissions map for NH₃, derived from the National Atmospheric Emissions Inventory (NAEI), is provided in Appendix 1.

NH₃ does not show the substantial long-term decline seen for combustion-related pollutants. NAEI data for Wales indicate that total NH₃ emissions have remained broadly similar since around 2005, with a slight increase in recent years. SoNaRR 2025 reports that NH₃ emissions have increased, driven by agricultural intensification, including greater use of urea-based fertilisers and livestock housing. Ambient NH₃ concentrations remain strongly influenced by local agricultural sources and spatial variability, so trend assessment should use the NAMN/AGANet monitoring record alongside CBED/UKEAP modelled concentration and deposition fields.

For NH₃, WHO does not set an air quality guideline, but the modelled 2022–2024 Welsh annual mean range of 0.51–2.70 µg NH₃ m⁻³ spans the UNECE ecological critical level of 1 µg NH₃ m⁻³ for sensitive lichens and bryophytes, while remaining below the 3 µg NH₃ m⁻³ critical level for sensitive higher plants (see Appendix 2).

⁵ <https://www.gov.uk/government/statistics/emissions-of-air-pollutants/emissions-of-air-pollutants-in-the-uk-ammonia-nh3> (accessed June 2026) (accessed June 2026)

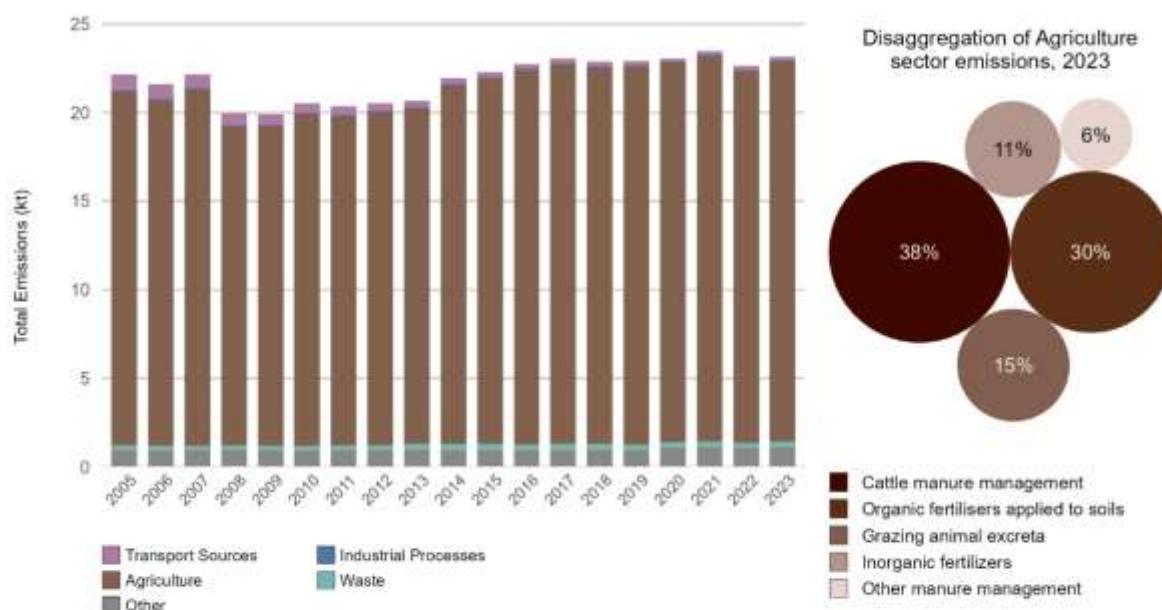


Figure 1. Trends in annual total ammonia emissions (kilotonnes $\text{NH}_3 \text{ yr}^{-1}$) in Wales, 2005-2023. Reproduced from National Atmospheric Emissions Inventory⁷.

(ii). Health Impacts: Once released, ammonia reacts with atmospheric chemistry products of nitrogen oxides and sulphur dioxide to form $\text{PM}_{2.5}$, a pollutant strongly linked to respiratory and cardiovascular disease, and loss of life expectancy⁸. Communities close to intensive farming activities may also experience direct irritation of the eyes, throat, and lungs. Nitrate contamination of drinking water is primarily associated with agricultural run-off, leaching and associated groundwater pollution; however, atmospheric ammonia deposition may also contribute to raising nitrate concentrations in surface and drinking waters, with associated risks of infant methemoglobinemia and certain cancers⁹.

(iii). Ecological and Environmental Impacts: Ammonia is a major cause of damage to ecosystems, through the following pathways:

- direct toxic effects especially on bryophytes and lichens and higher plants,
- its contribution to overall N deposition which causes eutrophication and drives species loss due to the dominance of rapidly growing plant species, and
- its contribution to ecosystem acidification.

Ammonia pollution is worst close to emission sources, although a proportion is dispersed over large distances. The relevant thresholds for the assessment of environmental impacts of gaseous ammonia are the critical levels, above which direct adverse effects may occur. These are set by the UN ECE and regularly reviewed by the scientific community¹⁰:

- $1 \mu\text{g NH}_3 \text{ m}^{-3}$ annual average concentration for nitrogen sensitive lichens and bryophytes

⁷ <https://naei.energysecurity.gov.uk/air-pollutants> (accessed June 2026) (accessed June 2026)

⁸ Lelieveld, J. et al. (2015). The contribution of outdoor air pollution sources to premature mortality on a global scale. *Nature*, 525, 367–371.

⁹ Ward, M.H. et al. (2018). Drinking water nitrate and human health: An updated review. *IJERPH*, 15(7), 1557.

¹⁰ Latest version: <https://unece.org/sites/default/files/2022-08/Item%20%20Conference%20Proceedings%20on%20Ammonia%20Dessau%202022%20FINALdraft.pdf> (accessed June 2026)(accessed June 2026)

- 3 $\mu\text{g NH}_3 \text{ m}^{-3}$ annual average concentration for nitrogen sensitive higher plants.

There are some more remote areas in Wales with few local NH_3 sources, resulting in concentrations considerably below the 1 $\mu\text{g NH}_3 \text{ m}^{-3}$ critical level for lichens and bryophytes. Particularly sensitive species seem to be affected even by lower concentrations and have become locally extinct at all but the cleanest sites¹¹. This means that the rare habitats and endangered species currently depending on clean air are at risk if local emissions increase.

In 2021, ammonia made up 74% of the total UK deposition of reactive nitrogen, and 66% of the total deposition of acidifying pollutants¹², both key threats to sensitive habitats and designated nature conservation sites.

Brown et al. (2025)¹³ estimated that emissions within Wales were the largest contributor to N deposition in Wales, at 38%, with the next largest contributors being England (27%, continental Europe (16%), offshore/international shipping (9%), the Republic of Ireland (6%) and Scotland and Northern Ireland at <2% each. The N deposited in Wales that originates from Welsh emission sources in 2018 was mostly (90%) from ammonia emission sources, with only 10% due to NO_2 emissions. The report concludes: *"When taking into account atmospheric N input from all sources (Wales-internal and beyond), a substantial proportion of the [ammonia-derived] NH_x deposition is from sources within Wales (55%), while [NO_2 -derived] NO_y deposition may be harder to tackle, with 90% being imported from the rest of the UK, the Republic of Ireland and the rest of Europe, including from international shipping."*

Ammonia has a strongly alkalising effect when first deposited, which contributes to its toxicity¹⁴, but after processing in soil it has a net acidifying effect. The initial alkalisation seems to be a key reason for its toxicity for many bryophytes and lichens, which lack a protective cuticle. Conversely, the acidifying effects of N uptake and leaching mean that sensitive habitats are not recovering from the effects of acid rain¹⁵. Comparatively few plant species can tolerate the toxic aluminium and manganese ions that are released into soil solution under acidic conditions, and across habitats lower pH values are associated with a smaller number of species. Acidification also affects freshwater habitats and species, leading to decalcification of invertebrate shells and the loss of sensitive fish species.

The alkalising and acidifying effects of ammonia are undoubtedly harming Welsh ecosystems, but arguably the greatest impact is via eutrophication. Background deposition rates for N, representing relatively pristine conditions, are estimated at around 3 $\text{kg N ha}^{-1} \text{ yr}^{-1}$ (David Fowler, pers. com.). In most natural terrestrial ecosystems, plant productivity is limited by N availability. Species have different strategies for growing and reproducing despite this limitation, and so can grow together, maintaining biodiversity. Typical deposition rates of atmospheric N in Wales are around 25 $\text{kg N ha}^{-1} \text{ yr}^{-1}$ onto woodland and 15 $\text{kg N ha}^{-1} \text{ yr}^{-1}$ onto open habitats¹⁶, i.e. around 8 times or 5 times the background deposition rate, respectively. This excess fertilisation from the air causes a large increase in growth rates

¹¹ Turner, A., (2021) Surveillance of the montane macrolichen *Alectoria nigricans* in Snowdonia, 2020. Natural Resources Wales. NRW Evidence Report 509., p. 35.

¹² Rowe, E.C. et al. (2024) Air Pollution Trends Report 2024: Critical Load and Critical Level exceedances in the UK.

¹³ Brown, R., Carnell, E. & Dragosits, U. (2025). ERAMMP Report-97: Estimates of Atmospheric Nitrogen Deposition in Wales: Made in Wales vs Imported/Exported (2018 data). Report to Welsh Government (Contract C210/2016/2017)(UKCEH 06297) https://erammp.wales/sites/default/files/2025-12/ERAMMP%20Report-97%20Nitrogen-Deposition-in-Wales%20v1.0.0_EN_0.pdf (accessed June 2026)(accessed June 2026)

¹⁴ Sutton, M.A. et al. (2020) Alkaline air: changing perspectives on nitrogen and air pollution in an ammonia-rich world. *Philosophical Transactions of the Royal Society a-Mathematical Physical and Engineering Sciences* 378: 20190315. DOI: 10.1098/rsta.2019.0315

¹⁵ Evans, C.D. et al. (2014) Persistent surface water acidification in an organic soil-dominated upland region subject to high atmospheric deposition: The North York Moors, UK. *Ecological Indicators* 37, 304-316.

¹⁶ Rowe, E.C. et al. (2024) Air Pollution Trends Report 2024: Critical Load and Critical Level exceedances in the UK.

for species that are adapted for high fertility. The shade cast by the taller vegetation, together with the production of more plant litter, means that small-growing plant species cannot survive. The resulting biodiversity loss can readily be reproduced under experimental conditions¹⁷. The effects of N pollution on the UK flora have been clear and striking – smaller-growing plant species are much more likely to be threatened¹⁸.

Globally, the combination of toxic, acidifying and eutrophying effects means that reactive nitrogen pollution ranks third among the causes of biodiversity loss¹⁹. In Europe, air pollution has driven shifts in the ranges of species greater than those caused by climate change²⁰. Reactive nitrogen pollution has caused the local extinction of plant and lichen species across the UK^{21, 22}.

(iv). Opportunities for co-benefits / risk of secondary disbenefits: As noted above, ammonia reacts with other pollutants to form fine particulates which have adverse human health effects. The fertilising effect of ammonia deposition (and total nitrogen deposition more generally) could be argued to provide some benefit for agricultural and forest production. However, the wet deposition component is strongly correlated to precipitation patterns, and the ammonia-related dry component largely deposits to semi-natural vegetation and cannot be diverted/re-directed to specific geographic areas.

(v). Pollutant controls under current legislation and policies applicable in Wales: The UK is a signatory of the UNECE Convention on Long Range Transboundary Air Pollution (CLRTAP), and commitments in the National Emissions Ceilings Regulations in 2018 (NECR)²³. Under the NECR, the UK is obliged to achieve national emission reductions for the air pollutants SO₂, NO_x, PM_{2.5}, NH₃, and NMVOC, with the devolved governments contributing a percentage share to the UK-wide emission reduction commitments. For NH₃, the UK's 2030 target is to reduce emissions by 16% compared with 2005 levels. Only ammonia emissions from larger poultry and pig units above legally prescribed thresholds are currently controlled under intensive farming permitting in the UK (N.B. permitting and requirement for the use of Best Available Technology only applies to livestock houses and manure stores, but not to land-spreading of the manures). Emissions from cattle and sheep farming and from smaller intensive livestock units are not directly regulated through mandatory ammonia-specific controls, as are emissions from anaerobic digestion and the application of digestate to land. A voluntary Code of Good Agricultural Practice (COGAP) for Reducing Ammonia Emissions²⁴ was introduced in Wales in 2019. The code explains how changes in livestock diets, housing, slurry and manure storage, slurry application and urea fertilisers can reduce agricultural ammonia emissions. Alongside this, Welsh Government published an interactive tool on the Farming Connect website²⁵ that demonstrates which areas on the farm can be improved and how.

(vi). Feasibility of Mitigation: Most ammonia is emitted from dispersed sources such as the application of livestock manures and synthetic fertilisers, livestock housing and slurry/manure stores. Reductions in

¹⁷ Hautier, Y. et al. (2009) Competition for light causes plant biodiversity loss after eutrophication. *Science* 324, 636-638.

¹⁸ Hodgson et al. (2014) Changing leaf nitrogen and canopy height quantify processes leading to plant and butterfly diversity loss in agricultural landscapes. *Functional Ecology* 28, 1284-1291.

¹⁹ Sala, O.E., et al. (2000) Biodiversity - Global biodiversity scenarios for the year 2100. *Science* 287, 1770-1774.

²⁰ Sanczuk, P. et al. (2024) Unexpected westward range shifts in European forest plants link to nitrogen deposition. *Science* 386, 193-198.

²¹ Emmett, B.A. et al. (2011) Interpretation of evidence of nitrogen impacts on vegetation in relation to UK biodiversity objectives. JNCC Report 449. pp. 105.

²² Maskell, L.C. et al. (2010) Nitrogen deposition causes widespread loss of species richness in British habitats. *Global Change Biology* 16, 671-679.

²³ NECR <https://www.legislation.gov.uk/ukxi/2018/129/contents/made> (accessed June 2026)(accessed June 2026)

²⁴ <https://www.gov.wales/sites/default/files/publications/2019-04/code-of-good-agricultural-practice-guidance-on-reducing-ammonia-emissions.pdf> (accessed June 2026)(accessed June 2026)

²⁵ <https://businesswales.gov.wales/farmingconnect/> (accessed June 2026)(accessed June 2026)

ammonia concentrations sufficient to influence environmental outcomes would require changes in agricultural practices across large areas of Wales, as reflected in the Nitrogen Futures evidence base²⁷. Potential control measures include optimising fertiliser inputs or dietary protein to maximise nitrogen use; covering slurry stores; using low-emission slurry application equipment such as trailing shoe, trailing hose or injection systems; improving livestock housing and manure management; and targeting action close to nitrogen-sensitive protected sites and habitats, for example through Shared Nitrogen Action Plans (SNAPs). Significant decreases in ammonia emissions can be achieved without reducing livestock populations through improved technology and changes to land and livestock management practices. This is consistent with European and international reviews of agricultural ammonia mitigation, including UNECE's 2020 Assessment Report on Ammonia, the European Topic Centre on Human Health and the Environment's 2023 review of ammonia and methane emissions from livestock farming, and Hu et al. (2024) on implementation of ammonia abatement policy in Germany. Very large reductions, of the scale envisaged by the Climate Change Committee in its Net Zero Carbon Budget analyses, may ultimately require reductions in livestock numbers linked to dietary change, but this should not be presented as a prerequisite for meaningful progress.

For NH₃, the evidence for environmental harm is strong, particularly in relation to nitrogen deposition, eutrophication, acidification and effects on sensitive habitats and species. The main uncertainties are therefore practical and design-related: how best to define a target that reflects both ambient concentrations and habitat protection; how representative the monitoring network needs to be; how spatial variability near agricultural sources should be handled; and what scale and pace of agricultural mitigation would be needed. These uncertainties suggest the need for a carefully designed target framework, potentially supported by enhanced monitoring, clear siting criteria, source attribution, and targeted measures near sensitive ecosystems.

(vii). Feasibility of monitoring progress towards meeting a target: Ammonia can be monitored using passive samplers that are replaced and analysed periodically (e.g. monthly). This type of monitoring was implemented in the UK in the National Ammonia Monitoring Network (NAMN) in the mid-1990s at a monthly frequency, funded by Defra, with several long-term monitoring sites in Wales over the time period²⁶. This sampling method is calibrated against another Defra monitoring network (AGANet) that uses active samplers (see the latest UKEAP ²⁷ (2024) annual report for details²⁸). The NAMN method (ALPHA® (Adapted Low-cost Passive High Absorption) sampler²⁹) was developed specifically for long-term ambient monitoring of atmospheric NH₃ including at locations with relatively low concentrations (below 2 µg NH₃ m⁻³) and where high accuracy is required. It has a very low limit of detection for monthly sampling, at ~ 0.03 µg NH₃ m⁻³. The use of triplicate samplers at each NAMN location is useful for quantifying uncertainty in the measurements.

For statutory target purposes, the existing NAMN and AGANet datasets provide a strong basis for assessing long-term trends and background concentrations of atmospheric ammonia. However, if ammonia were used for a statutory target, the target framework would need to define the monitoring method, siting criteria, data capture requirements, treatment of uncertainty, and the role of passive

²⁶ <https://uk-air.defra.gov.uk/interactive-map?network=namn> (accessed June 2026) – map of current UK NAMN sites (accessed June 2026)

²⁷ <https://uk-air.defra.gov.uk/networks/network-info?view=uheap> (accessed June 2026) (UKEAP network description) (accessed June 2026)

²⁸ [https://uk-air.defra.gov.uk/assets/documents/reports/cat05/2509300430_2024_Annual_Report_for_the_Eutrophying_and_Acidifying_Atmospheric_Pollutants_\(UKEAP_\(accessed_June_2026\)\).pdf](https://uk-air.defra.gov.uk/assets/documents/reports/cat05/2509300430_2024_Annual_Report_for_the_Eutrophying_and_Acidifying_Atmospheric_Pollutants_(UKEAP_(accessed_June_2026)).pdf) (accessed June 2026)

²⁹ Tang Y S, Cape J N & Sutton M A (2001) Development and types of passive samplers for monitoring atmospheric NO₂ and NH₃ concentrations. In Proceedings of the International Symposium on Passive Sampling of Gaseous Pollutants in Ecological Research. *TheScientificWorld*, 1, 513-529. <https://onlinelibrary.wiley.com/doi/abs/10.1100/tsw.2001.82?msocid=0ae82a4d97ea69371f013f929651680e> (accessed June 2026) (accessed June 2026)

and active sampling methods. Local or site-specific ammonia monitoring networks, including those established around designated habitats, provide valuable supplementary evidence on spatial gradients and local source influence, but should not be treated as the primary compliance dataset unless method equivalence, QA/QC procedures and uncertainty treatment are specified in regulation or guidance. An analysis commissioned by the Welsh Government³⁰ provided options for the design of a representative monitoring network at three levels of ambition (basic, enhanced, comprehensive), suggesting a range of 10-35 sampling sites (Northern Ireland started trials of a new NH₃ network in 2019, and 25 sites were incorporated into the UK NAMN in 2022, together with the three pre-existing sites³¹). There are also several local NH₃ networks established across several designated nature conservation sites, funded by NRW, to quantify local spatial variability and atmospheric N pollution gradients across sensitive habitats. The monthly temporal resolution of the existing monitoring methods is sufficient for comparison with existing critical thresholds (critical levels) for NH₃, which are based on annual average values (a monthly critical level exists but is very uncertain). A summary of existing monitoring for ammonia in Wales can be found in Appendix 3: Summary of air quality monitoring in Wales3.

2.2. Nitrogen dioxide (NO₂)

(i). Sources: During the combustion of fossil fuels, nitric oxide (NO) and nitrogen dioxide (NO₂), together referred to as nitrogen oxides (NO_x), are produced. The exact ratio of NO and NO₂ produced will depend on fuel type and combustion temperature, but the proportion is typically around 90% and 10%, respectively. NO is rapidly converted to NO₂ in the atmosphere. Total NO_x emissions in Wales have reduced substantially (63% since 2005) but transport emissions still represent around 39% of the total in 2023 (Figure 2).

The Welsh Government report Air Quality in Wales 2024/25 states that the measured annual mean concentration of NO₂ at Welsh urban traffic sites has exhibited an overall decline from 33.8 µg/m³ in 2008 to 19.4 µg/m³ in 2024, and that long-running urban background sites reached their lowest annual mean concentration to date in 2024, at 11.6 µg/m³.³² NO₂ reached a record low during the COVID-19 restrictions, with a subsequent increase as restrictions were eased, but concentrations have since continued to decline. The 2024 Welsh urban background annual mean of 11.6 µg/m³ is slightly above the WHO annual guideline of 10 µg/m³, while the urban traffic mean of 19.4 µg/m³ remains substantially above it; the 2025 AURN site range of 2 - 33 µg/m³ indicates that some sites are below and others remain above the WHO annual guideline (Appendix 2). While emissions have notably decreased, NO₂ concentrations are not declining at the same pace, especially in urban areas where roadside and traffic-influenced locations remain higher than urban background locations.

Under the Local Air Quality Management (LAQM) process, which has been in operation for >25 years, local authorities are required to review and assess air pollution in their administrative area and if an exceedance(s) of an air quality objective(s) is identified, local authorities are required to declare an Air Quality Management Area (AQMA) and prepare an action plan specifying the measures intended to secure achievement of the relevant objectives, including dates by which measures are to be carried out; AQMAs are normally revoked only once sustained compliance has been demonstrated. There are currently 34 AQMAs in 11 local authorities in Wales. Except for the Neath Port Talbot AQMA, 33 have been declared for NO₂, with transport identified as the primary source of concern. A spatial emissions map for NO₂, derived from the NAEI, is provided in Appendix 1.

³⁰ <https://erammp.wales/sites/default/files/2023-06/ERAMMP%20Report-92%20Options%20for%20an%20enhanced%20ammonia%20monitoring%20network%20for%20Wales%20v1.0.0.pdf> (accessed June 2026)(accessed June 2026)

³¹ https://uk-air.defra.gov.uk/library/reports?report_id=1191 (accessed June 2026)(accessed June 2026)

³² https://www.airquality.gov.wales/sites/default/files/documents/2025-12/AQ-2025-English-Final_0.pdf (accessed June 2026)(accessed June 2026)

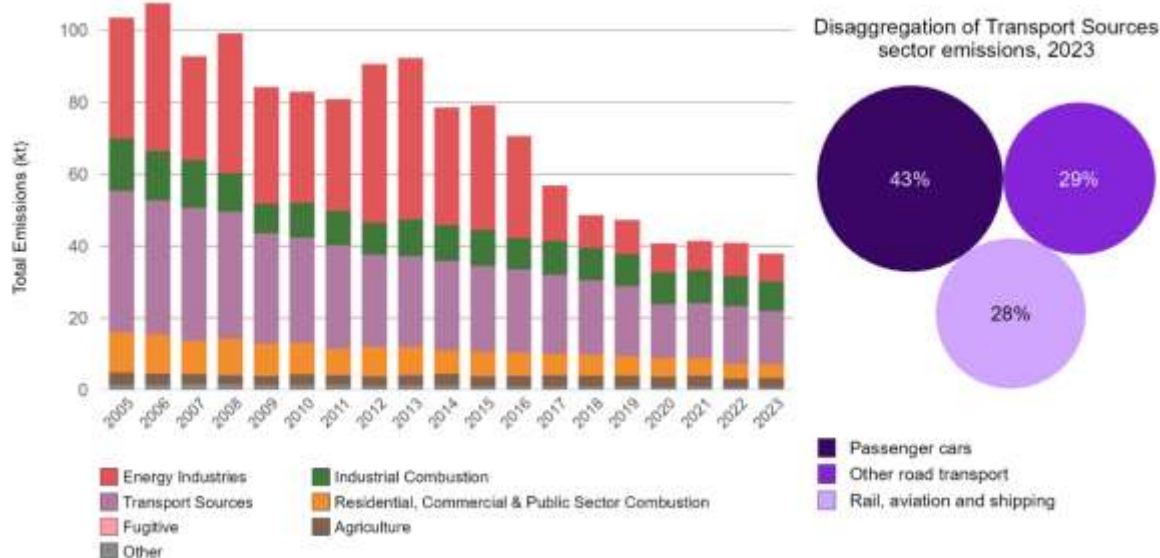


Figure 2. Trends in annual total NO_x emissions (kilotonnes NO₂ yr⁻¹) in Wales, 2005-2023. Reproduced from National Atmospheric Emissions Inventory³³.

(ii). Health Impacts: NO₂ is a key component of photochemical smog in instances of strong sunlight in the UK. It can affect human health by inflaming the airways in the lungs, reduce lung function over time and exacerbate existing respiratory issues such as asthma. In 2018, the UK Committee on the Medical Effects of Air Pollutants (COMEAP) published a detailed report on mortality associated with long-term average concentrations of NO₂; it judged that the mortality associated with long-term average concentrations of NO₂ was likely to be caused by NO₂ itself, rather than other correlated or co-emitted pollutants from the same sources³⁶. Public Health Wales estimates the burden of long-term air pollution exposure to be around the equivalent of 1,000 to 1,400 deaths each year considering the combined effects of PM_{2.5} and NO₂³⁷. Research has shown that air pollution inequalities exist across Wales, with people who live in the most deprived areas of Wales also more likely to be harmed by NO₂ exposure³⁸. A recent Cochrane review of evidence on the effectiveness of interventions to reduce NO₂ concentrations found little direct evidence of measurable health improvements, mainly because high-quality studies isolating NO₂-specific health effects were limited³⁹. However, the wider epidemiological evidence indicates that reducing NO₂ and related combustion emissions should contribute to respiratory and cardiovascular health protection, particularly where measures also reduce exposure to co-emitted pollutants such as PM_{2.5}.

(iii). Ecological and Environmental Impacts: As part of the overall input of reactive nitrogen to habitats, NO₂ has important ecological and environmental impacts in the UK, both directly and indirectly. When deposited on land or water, NO₂ contributes to acidification and eutrophication processes that alter soil chemistry, mobilise toxic metals, and enrich ecosystems with nitrogen. This favours fast-growing, nitrogen-tolerant species and suppresses more sensitive plants, leading to long-term declines in biodiversity in habitats such as heathlands, grasslands, and upland ecosystems³⁴. These processes are essentially the same as those caused by NH₃ deposition, with NO₂-derived N deposition making up 28% of the total N deposition load in Wales³⁵. Additionally, NO₂ has direct toxic effects on plants. A critical

³³ <https://naei.energysecurity.gov.uk/air-pollutants> (accessed June 2026) (accessed June 2026)

³⁴ RoTAP (2012). Review of Transboundary Air Pollution: Acidification, Eutrophication, Ground Level Ozone and Heavy Metals in the UK. Centre for Ecology & Hydrology.

³⁵ Rowe, E.C. et al. (2024) Air Pollution Trends Report 2024: Critical Load and Critical Level exceedances in the UK.

level of 30 $\mu\text{g}/\text{m}^3$ (annual mean) has been established, above which there is a risk of harm to ecosystems and biodiversity. However, this critical level is currently only exceeded in a small area of Wales³⁶. It should be noted that NO_x includes chemical species other than NO_2 .

NO_2 also acts as a precursor to ground-level ozone and secondary particulate matter, amplifying their effects on human health, vegetation, forests, and crop yields³⁷. In urban environments, high NO_2 levels can cause direct leaf injury and contribute to the soiling and degradation of building materials. Overall, NO_2 is a major driver of ecosystem change in the UK, reducing biodiversity and weakening the resilience of sensitive habitats.

(iv). Opportunities for co-benefits / risk of secondary disbenefits: Reducing NO_2 offers a cascade of co-benefits for other pollutants as well as wider societal benefits. Given the common sources and relationships with other pollutants, reducing NO_2 through strategies to reduce fossil fuel use would have a positive impact on PM_{10} , $\text{PM}_{2.5}$, CO_2 and ground-level O_3 . Equally, existing and future strategies to reduce PM and CO_2 emissions, especially through fossil fuel decarbonisation, would reduce NO_2 emissions. Wider societal benefits include public health gains (reduced respiratory illness, reduced cardiovascular risks, lower healthcare costs), healthy liveable urban spaces, economic productivity and greater social equity. However, care is needed to ensure that secondary disbenefits do not emerge through unintended consequences of interventions (e.g. a rapid transition to a disruptive intervention such as banning a vehicle type may disproportionately affect low-income communities or small businesses). It should be noted that these co-benefits for NO_2 (and wider NO_x) only arise where combustion sources are fully removed. Switching to lower-carbon synthetic or bio-derived fuels (e.g. biodiesel, sustainable aviation fuel) does not improve air quality per se, as these fuels still produce NO_x during combustion. Given declining contributions from power generation and road transport, the scale of NO_x emissions from building space-heating is an increasingly important consideration for future policy, particularly in the context of decarbonisation strategies. Furthermore, given the central role of NO_x in ozone chemistry, actions taken to reduce NO_x emissions in Wales will have direct consequences for ground-level ozone formation. Reductions in NO_x are one of the most direct levers available for managing ozone in Wales, although the non-linear nature of ozone chemistry means that NO_x reductions alone may not always reduce ozone, particularly in VOC-limited urban environments where reductions in NO_x can temporarily increase ozone through reduced titration effects (see Section 2.6 for detail).

(v). Pollutant controlled under current legislation or other measures: Wales limit values for NO_2 concentration (40 $\mu\text{g m}^{-3}$ annual mean and 200 $\mu\text{g m}^{-3}$ hourly mean) were established and Welsh ministers are required to ensure that these limits are not exceeded³⁸. NO_x emissions in Wales were estimated at 38 kt in 2023, and to have decreased by 63% since 2005, largely linked to transport and power generation sources³⁹. For NO_2 , the UK's 2030 target under the NECR is to reduce emissions by 73% compared with 2005 levels. Substantial progress has been made in reducing emissions over the last two decades and these reductions are expected to continue with ongoing measures to decrease fossil fuel use, especially in the transport sector. Key interventions include a cleaner national fleet due to a shift in consumer purchasing patterns from diesel and petrol to hybrid and electric vehicles; stricter EU and UK emission standards resulting in cleaner engines; local enabling strategies to encourage modal shift to public transport and active travel; and the adoption of an avoid-shift-improve package of

³⁶ https://icpvegetation.ceh.ac.uk/sites/default/files/NOx_critical_levels_workshop_REPORT.pdf (accessed June 2026)(accessed June 2026)

³⁷ EEA (2019). Air pollution sources: Nitrogen oxides (NO_x). European Environment Agency.

³⁸ <https://www.legislation.gov.uk/wsi/2010/1433/contents> (accessed June 2026) (accessed June 2026)

³⁹ https://naei.energysecurity.gov.uk/sites/default/files/2025-09/DG_AP_Inventory_2005-2023_Report_FINAL_for_publication.pdf (accessed June 2026)(accessed June 2026)

interventions to decarbonise the transport system to achieve net zero in Wales⁴⁰. Additionally, wider ongoing mitigation in other sectors has been achieved through Wales's broader net zero strategy⁴¹.

(vi). Feasibility of Mitigation: Existing interventions to date have illustrated that the feasibility of continued mitigation of NO₂ is high, but it is heavily reliant on sustained and accelerated policy action, investment and public engagement. The observed long-term decline in Welsh NO₂ concentrations, together with the reduction in Welsh NO_x emissions since 2005, indicates that transport, power generation and combustion-related controls can deliver measurable improvements^{34,45}. Further reductions are likely to depend on continued fleet renewal and electrification, reduced fossil-fuel combustion, modal shift to public transport and active travel, demand management, planning decisions that reduce exposure, and effective local authority delivery. Welsh transport decarbonisation policy already frames this as an avoid-shift-improve package of interventions⁴⁶, while Net Zero Wales provides a wider policy context for reducing combustion emissions across sectors⁴⁷. A Welsh long-term target would therefore need to be supported by proportionate levers within Welsh Ministers' control, especially in relation to transport, planning, public behaviour change and local authority delivery.

For NO₂, the evidence base is comparatively mature. Monitoring is well established, sources are well understood, and concentrations have shown a long-term decline, particularly as transport emissions have fallen. The main uncertainties relate to the remaining delivery challenge: the pace of further reductions at roadside and traffic-influenced locations; how quickly fleet change, modal shift, planning and local traffic measures will reduce exposure; and whether improvements will be distributed equitably across communities. A new NO₂ target could provide additional policy leverage beyond existing statutory limits, particularly if framed around continued exposure reduction, remaining hotspots, and health inequalities.

(vii). Feasibility of monitoring: The NO₂ monitoring network is well established in Wales. NO₂ monitoring is undertaken by local authorities as part of the Local Air Quality Management process (LAQM) and through national networks operated by the Welsh Government and UK Government. NO₂ can be continuously monitored in real-time using automatic analysers (1-hour and annual mean), but these units have high capital and operational costs. In addition, the NO₂ automatic monitoring network is supplemented by lower-cost monitoring using passive samplers such as diffusion tubes (monthly and annual mean). NO₂ monitoring is managed through different networks and processes including the UK Automatic Urban and Rural Network (AURN), the UK Urban NO₂ Network (UUNN) and the LAQM process. At the end of 2024, Welsh reporting identified 43 active automatic monitoring sites across Wales; there were also several hundred diffusion tubes measuring monthly mean NO₂ levels.³⁴ NO₂ measurements in Wales are underpinned by well-defined national and international reference methods, with established limits of detection and quantified uncertainty ranges that are routinely audited and reported. These standards provide a robust and legally defensible basis for assessing progress towards statutory air quality targets, particularly for data generated by the AURN and other automatic reference-grade monitoring networks. Although useful as supplementary spatial data, local authority diffusion tube data are not directly applicable to the assessment of statutory national targets. A summary of existing monitoring for NO₂ in Wales can be found in Appendix 3.

2.3. Ambient carbon monoxide (CO)

(i). Sources: Carbon monoxide (CO) is produced during incomplete combustion. Road transport has historically been the largest source of ambient UK CO emissions, primarily from petrol engines. Based on UK NAEI reporting from 1990 to 2023, overall, UK emissions have reduced by about 84%, and emissions from petrol vehicles having declined by 96% (from 68% to 17% of overall emissions) for the

⁴⁰ <https://www.wcpp.org.uk/wp-content/uploads/2024/03/WCPP-Decarbonising-Wales-transport-system-while-connecting-people-and-places-Background-paper.pdf> (accessed June 2026)(accessed June 2026)

⁴¹ <https://www.gov.wales/sites/default/files/publications/2021-10/net-zero-wales-summary-document.pdf> (accessed June 2026)(accessed June 2026)

same period linked to improvements in performance exhaust treatment⁴². Similarly, UK industrial emissions significantly decreased as production and solid fuel use have declined. Residential combustion has not reduced at the same rate and is therefore becoming a relatively significant source (Figure 3).

In Wales, CO emissions decreased from 252 kt in 2005 to 125 kt in 2023, a 50% reduction. CO emissions from transport have decreased, from 77 kt CO in 2005 to 11.5 kt in 2023. Other emission sectors decreased to a lesser degree, and conversely fugitive emissions increased over that period, from 3 to 10 kt CO. A spatial emissions map for CO, derived from the NAEI, is provided in Appendix 1.

Current ambient CO concentrations are well below the Welsh objective; the Air Quality in Wales 2024/25 report recorded no CO objective exceedances in 2024.³⁴ Ambient concentrations have decreased substantially over the long term and the latest Welsh 8-hour mean concentrations of 0.0–0.2 mg m⁻³ are far below both the WHO 24-hour guideline of 4 mg m⁻³ and the Welsh objective of 10 mg m⁻³ as a maximum daily running 8-hour mean (Appendix 2).

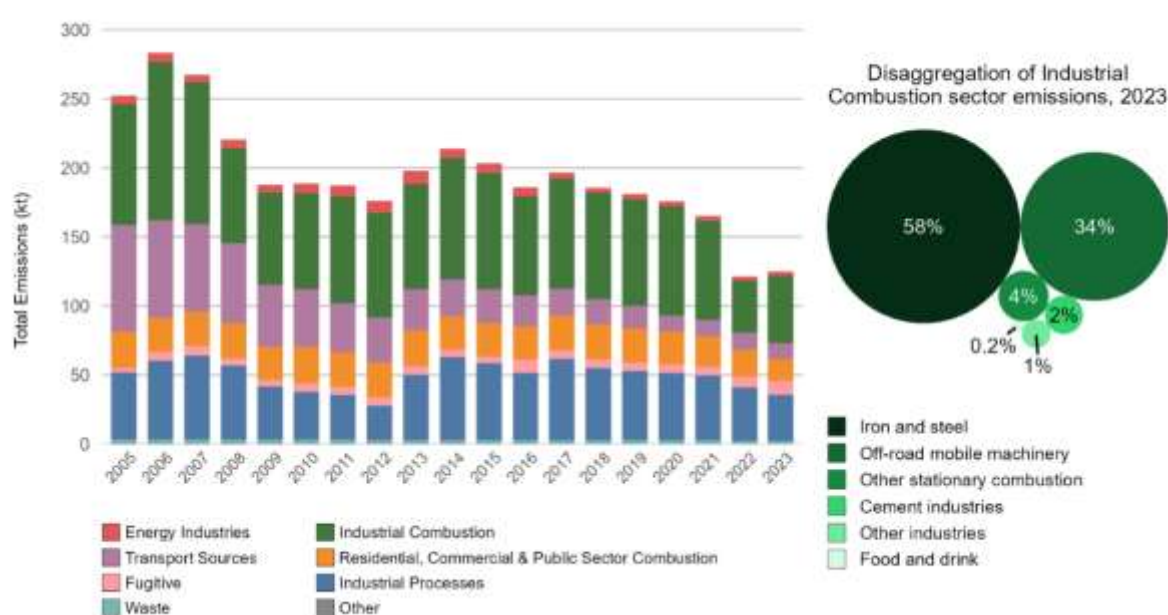


Figure 3. Trends in annual total CO emissions (kilotonnes CO yr⁻¹) in Wales, 2005-2023. Reproduced from National Atmospheric Emissions Inventory⁴³.

(ii). Health Impacts: For the purposes of this advice note, the relevant issue is ambient outdoor carbon monoxide (CO), rather than acute indoor CO poisoning. At high concentrations, CO reduces the blood's capacity to carry oxygen and can cause serious health effects; however, current ambient outdoor concentrations in Wales are generally far below levels associated with acute toxicity. The principal acute health risk from CO remains indoor or enclosed-space exposure, particularly where combustion appliances, poor ventilation or solid-fuel use are present. This distinction is important for target setting: an ambient air quality target would address outdoor concentrations and their contribution to atmospheric chemistry, but it would not directly address most indoor CO poisoning incidents, which are more appropriately managed through building standards, appliance safety, ventilation, alarms and public-health messaging. Ambient CO is still relevant because it contributes to ground-level ozone

⁴² <https://naei.energysecurity.gov.uk/air-pollutants/carbon-monoxide> (accessed June 2026)

⁴³ <https://naei.energysecurity.gov.uk/air-pollutants> (accessed June 2026)

formation and affects atmospheric oxidative capacity, while increases in domestic solid-fuel use may have both indoor and outdoor implications in some locations.

(iii). Ecological and Environmental Impacts: CO has relatively limited direct ecological impacts in the UK, as it is not phytotoxic at ambient concentrations, but it plays an important indirect role in atmospheric chemistry with consequences for ecosystems and biodiversity. CO reacts with hydroxyl radicals (OH) in the atmosphere, reducing the capacity of the air to break down other pollutants; this extends the lifetime of methane and contributes to the formation of ground-level ozone⁴⁴. Since ozone is a major stressor on UK vegetation, forests, crops, and semi-natural habitats, CO indirectly exacerbates damage to biodiversity, reducing crop yields, forest productivity, and the resilience of sensitive habitats such as heathlands and grasslands. Thus, although CO itself is not a primary ecological toxin, its role as a precursor to climate-active gases and ozone makes it environmentally significant.

(iv). Opportunities for co-benefits / risk of secondary disbenefits: Ambient CO levels have decreased very significantly from the 1970s, linked initially to decreasing industrial emissions and latterly to reduced transport emissions. Ongoing reductions will have an impact on the oxidative capacity of the environment with secondary benefits, for example in relation to methane uptake, but also potential disbenefits, for example through the formation of tropospheric/ground-level O₃. Acute exposure in indoor and semi-enclosed public spaces is still a priority area in reducing mortality. This is historically linked to socio-economic deprivation but potentially has an increasing impact outside these groups, associated with increasing domestic biomass burning for aesthetic reasons.

(v). Pollutant controlled under current legislation or other measures: CO is regulated in Wales under the Air Quality Standards (Wales) Regulations 2010, which set a limit value of 10 mg m⁻³ as a maximum daily 8-hour mean⁴⁴. Current ambient CO concentrations in Wales are well below this existing limit value, and the 2024/25 Air Quality in Wales report states that no Welsh monitoring sites exceeded the national air quality objective or corresponding AQS(W)R 2010 limit value for CO in 2024³⁴. The long-term decrease in CO emissions is consistent with reduced emissions from road transport, improved combustion efficiency, industrial change and wider decarbonisation policies⁴⁸. On the current evidence, any additional Welsh long-term target for ambient CO would therefore need to demonstrate added value beyond maintaining compliance with existing limit values and preventing future deterioration.

(vi). Feasibility of Mitigation: Historical legislation, technology change and wider economic shifts have already delivered large reductions in ambient CO emissions. Further mitigation is feasible through continued decarbonisation of transport, industrial combustion and domestic fuel use, but the scope for a long-term ambient CO target to drive substantial additional health benefit appears limited because current ambient concentrations are already low relative to existing standards. Welsh Ministers hold some proportionate levers through transport policy, planning, domestic combustion controls, building standards and public-health guidance. However, these levers are likely to be more effective in maintaining low ambient CO concentrations and reducing indoor or enclosed-space risks than in delivering large further reductions in ambient outdoor CO. A Welsh long-term target for CO could therefore be framed as a maintenance or non-deterioration target, but the case for an additional reduction target is likely to be weaker unless future evidence shows rising ambient CO concentrations or specific local exposure concerns. The relevant uncertainty is whether an outdoor ambient air quality target would address the most important exposure pathway.

(vii). Feasibility of monitoring: Monitoring for CO is widespread indoors in terms of alarms for exceedance above a given danger level. The availability of actual ambient measurements of CO is

⁴⁴ Derwent, R.G. (2017). Air chemistry and air pollution: 50 years of UK research. *Atmospheric Environment*, 165, 293–300.

limited and has decreased significantly since the 1990s. Currently the AURN⁴⁵ operates 7 CO sites across the UK, 2 of which are in South Wales. Hourly CO can be monitored using commercially available continuous analysers with high capital and operational costs (analogous to NO_x measurements). Relatively cheaper monitoring using low time resolution (months) with passive diffusion tube sampling is possible but not widely undertaken (unlike their widespread use for NO₂). Emerging so-called 'lower cost' sensors are being shown to be effective in observing CO but are currently not a part of the accredited regulatory system⁴⁶.

For statutory target purposes, continuous reference-grade CO monitoring, such as that undertaken within the AURN, would provide the most robust basis for assessing compliance because the methods are standardised, quality-assured and capable of producing hourly data. However, the current ambient CO monitoring network in Wales is limited, with only a small number of sites, and therefore may not be sufficient on its own to demonstrate national compliance or localised peak exposure. A summary of existing CO monitoring can be found in Appendix 3.2.4. Sulphur dioxide (SO₂)

(i). Sources: Total SO₂ emissions in the UK have reduced by approximately 97% since 1990 (mainly through reductions in coal and other fossil fuel use (Figure 4). In Wales, emissions have reduced from 61 kt in 2005 to 10 kt in 2023; a reduction of 84%. Currently the largest SO₂ emission source sector in Wales is industrial combustion which makes up 45% of the total, followed by the energy sector and fugitive processes. A spatial emissions map for SO₂, derived from the NAEI, is provided in Appendix 1.

The Air Quality in Wales 2024/25 report recorded no moderate, high or very high SO₂ pollution days and no SO₂ objective exceedances in 2024. At present levels, short-term percentile metrics are more informative than annual mean SO₂ trends for target-setting purposes.³⁴ The Welsh concentrations have decreased markedly over recent decades and are now generally low and stable across Welsh monitoring sites. Short-term percentile concentrations reported for 2024 are also well below the WHO 24-hour guideline of 40 µg/m³, (Appendix 2).

⁴⁵ <https://uk-air.defra.gov.uk/> (accessed June 2026)

⁴⁶ PAS 4023 - Low-Cost Air Quality Sensor Systems in Outdoor Ambient Air

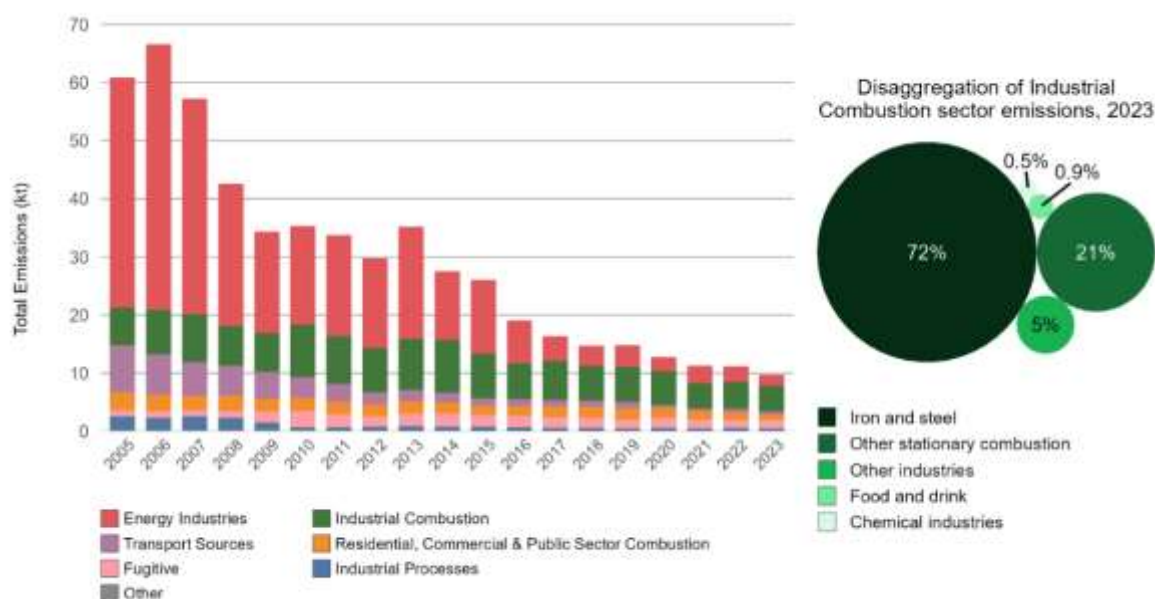


Figure 4. Trends in annual total SO₂ emissions (kilotonnes SO₂ yr⁻¹) in Wales, 2005-2023. Reproduced from National Atmospheric Emissions Inventory⁴⁷.

(ii). Health Impacts: At elevated concentrations, SO₂ is a respiratory irritant and can cause airways to narrow, particularly in people with asthma and other respiratory conditions. A systematic review commissioned by WHO has examined the relationship between short-term exposure and asthma admissions and mortality, although there has not been a separate, independent assessment of the mechanistic, toxicological and human clinical evidence for SO₂ equivalent to that available for some other pollutants. The available intervention evidence should be interpreted cautiously, because many studies were not designed to isolate SO₂-specific health effects from wider changes in industrial, transport or combustion-related air pollution. The nature of SO₂ sources means that inequalities in exposure and health outcome may still occur near specific industrial or combustion sources. For target-setting purposes, the key question is therefore whether a further Welsh ambient SO₂ target would add value beyond existing Air Quality Standards (Wales) Regulations 2010 limit values, the UK NECR 2030 emissions-reduction commitment and permitting controls for major sources. Current Welsh monitoring evidence indicates that SO₂ concentrations are now low relative to existing standards, with the 2024/25 Air Quality in Wales report recording no SO₂ objective exceedances in 2024³⁴. This suggests that any additional SO₂ target would need to be justified primarily by the benefits of maintaining low concentrations, guarding against localised source-related exceedance, or setting a more precautionary benchmark, rather than by evidence of widespread current non-compliance.

(iii). Ecological and Environmental Impacts: In the atmosphere, SO₂ can undergo oxidation to form acids that are excellent condensation nuclei leading to secondary organic aerosol formation. Sulphur deposition has an acidifying effect on ecosystems, but decreases in sulphur emissions mean that around 90% of UK acid deposition is now made up by nitrogen pollution⁴⁸.

Direct exposure causes visible leaf injury, reduced growth, and increased susceptibility to stress in sensitive species such as lichens, bryophytes, and conifers, many of which declined sharply in polluted

⁴⁷ <https://naei.energysecurity.gov.uk/air-pollutants> (accessed June 2026) (accessed June 2026)

⁴⁸ Rowe, E. et al. (2024) Air Pollution Trends Report 2024: Critical Load and Critical Level exceedances in the UK. CEH report to Defra. https://uk-air.defra.gov.uk/library/reports?report_id=1157. (accessed June 2026)(accessed June 2026)

areas during the 20th century⁴⁹. Acid deposition in soils and surface waters depletes essential nutrients and mobilises toxic metals such as aluminium. These processes have reduced biodiversity in upland lakes, streams, and heathlands, with fish, invertebrate, and plant populations severely affected⁵⁰. However, there are now signals that recovery may be under way.

(iv). Opportunities for co-benefits / risk of secondary disbenefits:

Mitigating SO₂ emissions offers co-benefits, particularly in reducing the formation of secondary particulate matter. Measures such as transitioning to cleaner energy sources not only cuts SO₂ but also reduces emissions of nitrogen oxides and PM_{2.5}, improving overall air quality. SO₂ contributes to the formation of sulphate aerosols, which can scatter sunlight and may exert a cooling effect on the climate. As these aerosols diminish, their cooling influence may weaken. The substantial reduction in SO₂ in the atmosphere through successful policies in the UK and internationally has led to decreased formation of ammonium sulphate, thereby extending the atmospheric lifetime of ammonia, a known issue.

(v). Pollutant controlled under current legislation or other measures: SO₂ is regulated in Wales under the Air Quality Standards (Wales) Regulations 2010, which set limit values of 350 µg/m³ as a 1-hour mean, not to be exceeded more than 24 times per calendar year, and 125 µg/m³ as a 24-hour mean, not to be exceeded more than three times per calendar year⁴⁴. SO₂ is also subject to emissions-reduction obligations through the National Emission Ceilings Regulations 2018; for SO₂, the UK's 2030 target under the NECR is to reduce emissions by 88% compared with 2005 levels²⁴. Under the Environmental Permitting Regulations, installations emitting SO₂ must obtain permits that set emission limits and may also require flue gas treatment, regular monitoring and enforcement action if conditions are breached. The Environment (Air Quality and Soundscapes) (Wales) Act 2024 has strengthened controls on domestic combustion, and Welsh Government policy promotes fuel switching, public awareness and enhanced enforcement through the Clean Air Plan. Current monitored concentrations are well below existing standards, and the 2024/25 Air Quality in Wales report states that no Welsh monitoring sites exceeded the national air quality objective or corresponding AQS(W)R 2010 limit value for SO₂ in 2024³⁴. Any new SO₂ target would therefore need to be justified not by widespread current non-compliance, but by whether a more protective standard would add value for health, ecosystems, industrial-source management, or future-proofing against localised emissions.

(vi). Feasibility of Mitigation:

UK emissions of SO₂ have fallen by 97% since 1990, largely due to the decline of coal use in energy production, stricter fuel standards, and the adoption of flue gas desulphurisation technologies. Continued mitigation is achievable through further electrification of industry, tighter controls on domestic fuel use, and support for low-sulphur alternatives.

For SO₂, current concentrations are generally low and existing controls appear effective. The relevant uncertainty is whether there are future localised risks from industrial sources, fuel-use changes or other combustion activities that would justify a new national target. This suggests that SO₂ may be better suited to continued surveillance and source-specific regulation unless evidence emerges that a long-term national target would add clear additional protection.

(vii). Feasibility of monitoring:

⁴⁹ RoTAP (2012) Review of transboundary air pollution: Acidification, eutrophication, ground level ozone and heavy metals in the UK. CEH Contract Report to Defra.

⁵⁰ Fowler, D. et al. (2007). Atmospheric composition change: Ecosystems–Atmosphere interactions. *Atmospheric Environment*, 41, 2067–2101.

Monitoring of SO₂ in Wales and the UK is well-established. A range of methods are employed, including automatic point monitoring and passive diffusion tubes. While passive methods are cost-effective for baseline assessments, automatic systems offer greater accuracy and temporal resolution.

For statutory target purposes, automatic reference-equivalent SO₂ monitoring would provide the most appropriate basis for assessing progress towards any ambient SO₂ target, particularly where short-term concentration peaks are relevant. These methods are standardised and subject to established QA/QC procedures, whereas passive or locally managed monitoring is better suited to screening, spatial context or supplementary trend assessment. If a new SO₂ target were considered, the compliance framework would need to specify the monitoring method, siting criteria, averaging period, data capture requirements, treatment of uncertainty and the extent to which existing monitoring coverage in Wales is sufficient to provide a legally robust assessment. A summary of existing monitoring can be found in Appendix 3.

2.5. Particles with a diameter of less than 10 µm (PM₁₀)

(i). Sources: Overall, primary PM₁₀ emissions in the UK have reduced by about 66% from 1990-2023 (Figure 5). Emissions from large combustion sources, e.g. coal-based power plants, decreased from 23% in 1990 to 1% in 2022. All vehicles emit PM₁₀, but road transport remains a significant contributor, particularly through non-exhaust emissions (NEE) such as tyre and brake wear and road surface abrasion. Where road transport dominates PM₁₀ sources, this is more accurately linked to vehicle type and mass (e.g. buses, HGVs, LGVs) rather than powertrain or fuel type alone; new Euro 7 regulations now include standards for tyre and brake wear particles. It is worth noting that the use of wood as a fuel in homes has led to an absolute increase in residential combustion sources of PM₁₀. In Wales, primary PM₁₀ emissions decreased from 12.7 kt in 2005 to 7.6 kt in 2023, with industrial processes as the largest source at 43% of the total, followed by transport at 16% and agriculture at 13%.

Transboundary and long-range contributions can also be important for ambient PM₁₀ concentrations, particularly where secondary inorganic aerosol, sea salt and dust contribute to measured mass. A spatial emissions map for PM₁₀, derived from the NAEI, is provided in Appendix 1. Long-running Welsh monitoring sites show a clear long-term reduction in annual mean PM₁₀. The Air Quality in Wales 2024/25 report states that urban background annual mean PM₁₀ declined from 34.4 µg/m³ in 1997 to 14.4 µg/m³ in 2024, while urban traffic PM₁₀ declined from 21.7 µg/m³ in 2007 to a record low of 13.5 µg/m³ in 2024 where both figures are just below the WHO annual guideline of 15 µg/m³. Recent years show some variability, with localised contributions from construction, weather, non-exhaust road dust and domestic combustion.³⁴

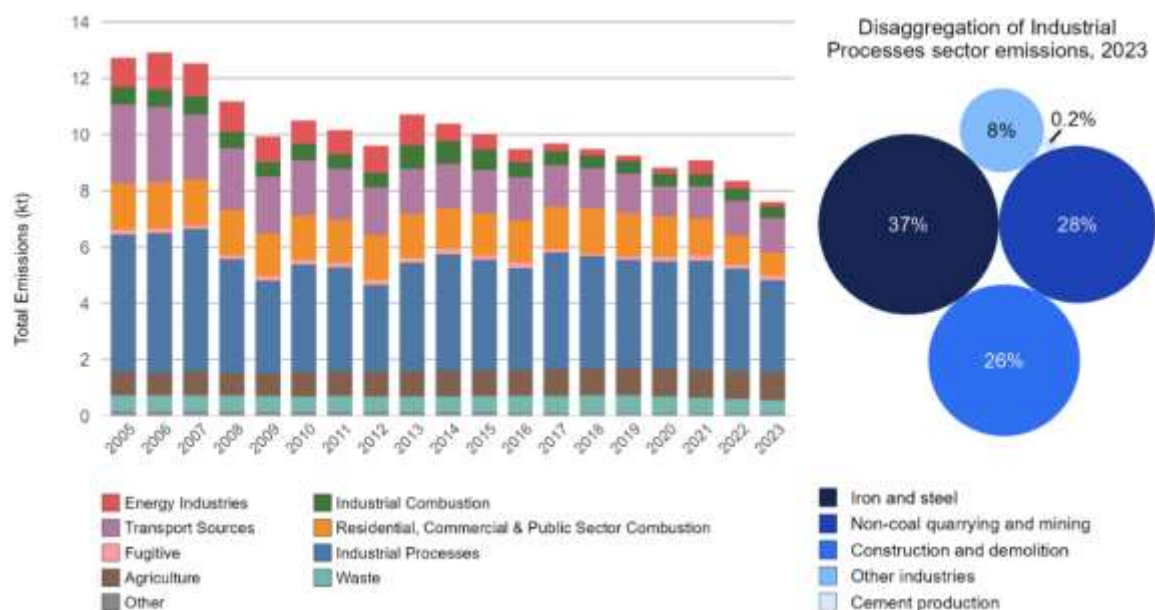


Figure 5. Trends in annual total PM₁₀ emissions (kilotonnes PM₁₀) in Wales, 2005-2023. Reproduced from National Atmospheric Emissions Inventory⁵¹.

(ii). Health Impacts: For the purposes of this advice note, we consider primary sources of PM₁₀ but note that secondary sources are significant. Each source of PM₁₀ will lead to a characteristic particle composition, with different loadings of pollutants such as metals and PAHs (polyaromatic hydrocarbons), for example, and therefore the toxicity will vary considerably. Exposure to PM₁₀ is strongly associated with adverse health effects, as these particles penetrate the respiratory system and cause inflammation. COMEAP reports that both short-term and long-term exposure to PM₁₀ increases hospital admissions for respiratory and cardiovascular disease(s) and can contribute to premature mortality⁵². The WHO similarly concludes that there is no safe threshold of exposure, with risks including reduced lung function, exacerbation of asthma, chronic bronchitis, heart disease, and shortened life expectancy⁵³. It is important to note that PM₁₀ and PM_{2.5} are not independent pollutants: the PM_{2.5} fraction of PM₁₀ constitutes at least 50% of the PM₁₀ mass in most environments, and exposure to PM₁₀ in the air necessarily includes co-exposure to the PM_{2.5} component. Consequently, many of the health effects attributed to PM₁₀ are mediated through this finer fraction. Interventions targeting PM_{2.5} and its precursors will therefore directly and substantially reduce PM₁₀ concentrations.

(iii). Ecological and Environmental Impacts: PM₁₀ exerts a range of ecological and environmental impacts, though they are less direct than for gaseous pollutants. PM₁₀ particles, derived from combustion, traffic, industry, agriculture, and natural sources such as dust and sea salt, can deposit on vegetation, impairing photosynthesis by blocking stomata and reducing light availability, as well as causing physical leaf damage in sensitive species⁵⁴. Many PM₁₀ particles contain acidic or nutrient-rich compounds which, once deposited, contribute to soil and water acidification or eutrophication, thereby

⁵¹ <https://naei.energysecurity.gov.uk/air-pollutants> (accessed June 2026) (accessed June 2026)

⁵² COMEAP (2002). Quantification of the health effects of air pollution in the UK for revised PM₁₀ objective analysis. <https://uk-air.defra.gov.uk/reports/cat02/aeat-env-r-1162.pdf> (accessed June 2026)(accessed June 2026)

⁵³ WHO (2021). *WHO global air quality guidelines: particulate matter (PM_{2.5} and PM₁₀), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide*. World Health Organization.

⁵⁴ AQEG (2005). *Particulate Matter in the United Kingdom*. Air Quality Expert Group, Department for Environment, Food & Rural Affairs.

altering species composition and reducing biodiversity in nitrogen-sensitive habitats such as heathlands and grasslands⁵⁵. In urban areas, particulate deposition accelerates the soiling and erosion of buildings and monuments, while regionally, PM₁₀ affects visibility and contributes to climate forcing through interactions with radiation. Overall, PM₁₀ pollution indirectly weakens ecosystems and biodiversity by compounding the effects of other pollutants. It should be noted that coarse mode particles (the 2.5–10 µm fraction) can act as a physical vector for the deposition of nitrogen and sulphur compounds, contributing to nutrient and acid loading in sensitive ecosystems. However, primary coarse mode particles themselves are not directly additional nitrogen or sulphur inputs to ecosystems in the same way that gaseous NH₃ or SO₂ are; rather, they may be a source of micronutrients and ecotoxins depending on their composition and origin.

(iv). Opportunities for co-benefits / risk of secondary disbenefits: There is a constant risk that PM₁₀ can mix with gases in the environment (e.g., NO₂/NO_x), contributing towards human health effects. Notably, the impact of PM₁₀ is predominantly caused by the PM_{2.5} fraction (at least 50%). PM₁₀ reduction measures often create valuable co-benefits, such as lowering emissions of PM_{2.5}, NO₂ and greenhouse gases through cleaner transport, improved heating efficiency or better dust control, but they can also carry risks of secondary disbenefits if poorly designed.

(v). Pollutant controlled under current legislation or other measures: PM₁₀ is regulated in Wales under the Air Quality Standards (Wales) Regulations 2010, which set limit values of 40 µg/m³ as an annual mean and 50 µg/m³ as a 24-hour mean, not to be exceeded more than 35 times per calendar year⁴⁴. The 2024/25 Air Quality in Wales report states that no Welsh monitoring sites exceeded the national air quality objective or corresponding AQS(W)R 2010 limit value for PM₁₀ in 2024, although PM₁₀ was still responsible for a number of days in the moderate, high and very high Daily Air Quality Index bands³⁴. In considering any further PM₁₀ target, it is important to recognise that the WHO annual guideline is substantially lower than the current Welsh annual mean limit value, and that natural and transboundary contributions, including sea salt, dust and secondary particles, may be significant in Wales. This means that the locally controllable fraction of PM₁₀ may be modest in some locations, and that any target would need to be supported by evidence on sources, feasibility, monitoring uncertainty and proportionality.

(vi). Feasibility of Mitigation: Mitigation of exposure to PM₁₀ can be challenging, since it is readily produced by a number of different sources (e.g. road, sea, air transport) at different stages of combustion as well as via indirect means (e.g. road wear) and natural sources (e.g. sea salt) and biological sources (e.g. pollen), as well as from houses, public spaces and industrial sources. It is constantly produced across all seasons, and without significant interventions towards normal human activity, the levels of PM₁₀ are hard to mitigate, beyond current statutory limit values under the Air Quality Standards (Wales) Regulations 2010. However, it should not be implied that there are no effective mitigation options for coarse PM.

Practical and well-established approaches to reduce dust emissions already exist and are in active use in the UK, including suppression and enclosure techniques in industrial operations, and dust management plans on construction sites. These measures are capable of delivering meaningful reductions in locally generated coarse PM, and their application should be recognised within the feasibility assessment. Additionally, as noted above, new Euro 7 regulations will introduce standards for non-exhaust particle emissions from tyre and brake wear, providing a further regulatory lever for coarse PM from road transport.

For PM₁₀, the uncertainties are more about source attribution and controllability. PM₁₀ includes local primary emissions, secondary particles, resuspended dust, sea salt, natural particles and transboundary

⁵⁵ RoTAP, (2012) Review of transboundary air pollution: Acidification, eutrophication, ground level ozone and heavy metals in the UK. Contract Report to the Department for Environment, Food and Rural Affairs. Centre for Ecology & Hydrology.

contributions. This does not rule out target setting, but it means that any target would need to account for the proportion of concentrations that Welsh policy can reasonably influence, and for the role of natural or episodic events. This may make PM₁₀ less straightforward than NO₂ as an immediate target candidate, unless the target is clearly linked to controllable sources or supported by appropriate exclusions and interpretation rules.

(vii). Feasibility of monitoring: For statutory target purposes, PM₁₀ measurements from AURN or equivalent reference-grade monitoring would provide the most robust basis for compliance assessment, because these methods are standardised, audited and subject to defined QA/QC procedures. Local authority monitoring and other locally managed particulate monitoring can provide useful supplementary information on spatial variation, source influence and local trends, but it may not be directly applicable to statutory national target assessment where measurement objectives, siting criteria, instrumentation, data capture and quality-assurance requirements differ. Any PM₁₀ target framework would therefore need to specify the approved measurement methods, method equivalence, uncertainty treatment, data capture requirements and the role of natural and transboundary contributions such as sea salt, dust and secondary particles. A summary of existing PM₁₀ monitoring can be found in Appendix 3.

2.6. Ozone (O₃)

(i). Sources: Ozone is not directly emitted in meaningful quantities; it is formed by chemical reaction of precursor emissions, primarily NO_x and Non-Methane Volatile Organic Compounds (NMVOCs). Major domestic source sectors of the precursor emissions for ozone include road transport, industrial processes, fuel combustion, and solvent use (Figure 6 for NMVOC and Figure 2 for NO₂). O₃ can also be transported long distances across national borders, meaning UK levels are influenced by formation in continental Europe. As a result, ozone pollution episodes in the UK are most common during warm, sunny periods in spring and summer, when photochemical activity is high and precursor emissions accumulate under stagnant weather conditions⁵⁶. Elevated CO and VOC concentrations, together with NO_x and sunlight can lead to high levels of ozone formation downwind of pollution sources.

Most of the high ozone episodes experienced in Wales come from transboundary pollution from England and continental Europe. It used to be that rural areas experienced higher levels of ozone than urban areas. This was because the high levels of nitric oxide (NO), emitted from vehicles and industry, react with ozone to form NO₂ and oxygen (O₂), thus removing it from the atmosphere. This process, referred to as ozone titration, did not happen so readily in rural areas where the number of vehicles is not as numerous. In more recent years, the increase in cleaner vehicles and industrial controls on emissions has reduced the emissions of NO_x in cities, leading to less ozone titration and consequently greater build-up of the pollutant in cities. Complicated reactions with ozone mean that ozone formation is non-linear. In some areas, reducing NO_x can paradoxically lead to increases in ozone, especially in VOC-limited environments (common in urban areas).

Ozone does not show the same simple downward trend as the primary combustion pollutants. The Air Quality in Wales 2024/25 report describes a noticeable increasing trend in rural O₃ concentrations over time and a more marked long-term increase at Cardiff Centre, reflecting the inverse relationship with falling NO_x emissions. The mean annual O₃ concentration at long-running rural sites was 62.8 µg m⁻³ in 2024, 7.3% lower than 2023, but within a variable long-term pattern influenced by meteorology and transboundary transport.³⁴ The 2024 mean of 62.8 µg/m³ at long-running rural sites is not directly comparable with the WHO ozone guideline because WHO uses peak-season and daily maximum 8-hour metrics rather than an annual mean; however, the value indicates that ozone remains close to the WHO peak-season benchmark of 60 µg/m³.

⁵⁶ Defra (2023). Air pollution in the UK 2022: Compliance assessment summary. Department for Environment, Food & Rural Affairs.

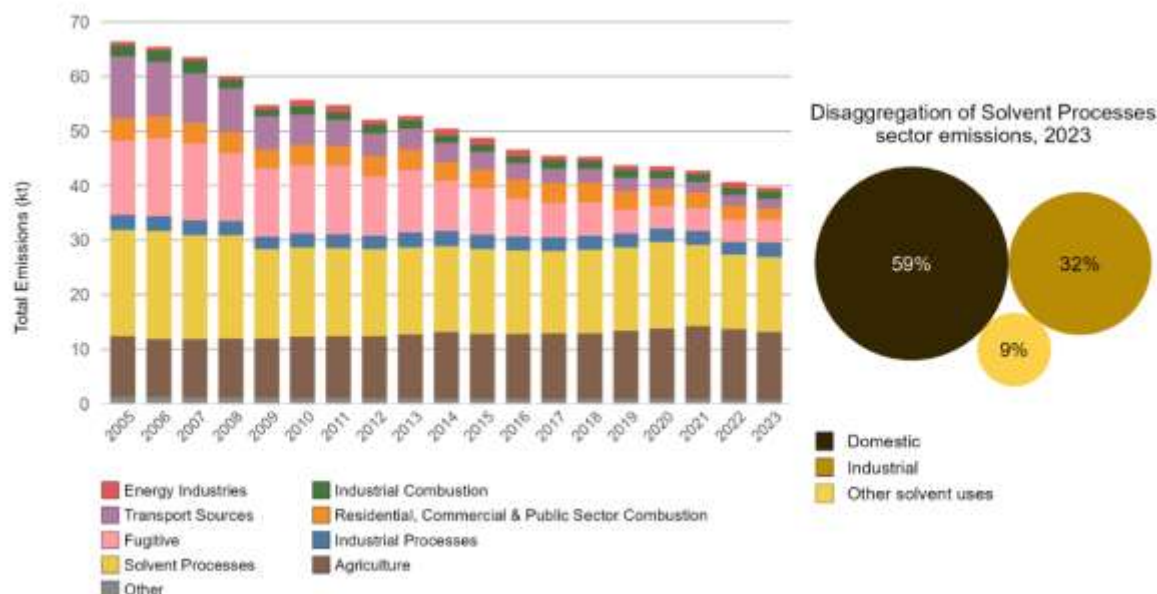


Figure 6 Trends in annual total emissions of the ozone precursor Non-Methane Volatile Organic Compounds (kilotonnes NMVOC yr⁻¹) in Wales, 2005-2023. Reproduced from National Atmospheric Emissions Inventory⁵⁷.

(ii). Health Impacts: Ozone damages human health, causing irritation of the respiratory tract, eyes, nose and throat, as well as asthma attacks. It can react with other chemicals in the air to form particulate matter, or smog, which is also harmful to health. Ozone also indirectly affects human health by damaging crops, forests and some materials. For O₃ the greatest average concentrations tend to occur during the spring and summer months when stagnant air can lead to the build-up of precursor pollutants, and more sunlight and higher temperatures can increase the rates of chemical reactions that generate ozone. There are likely to be inequalities associated with exposure to, and health harms associated with, O₃ pollution. COMEAP has quantified the mortality and hospital admissions associated with ground-level ozone exposure in the UK, concluding that ozone makes a measurable independent contribution to mortality and respiratory hospital admissions.⁵⁸ Further quantification of ozone health effects is provided in the COMEAP report on air pollutants and quantification of associated health effects.⁵⁹

(iii). Ecological and Environmental Impacts: Ground-level ozone is one of the most damaging widespread air pollutants to vegetation in the UK, with significant economic, ecological and biodiversity impacts. Ozone enters plants through leaf stomata, where it disrupts photosynthesis, accelerates ageing, and increases susceptibility to pests, diseases, and drought. This leads to reduced growth and visible foliar injury in sensitive species, in particular fast-growing crops such as wheat and potatoes, and native trees such as beech and birch⁶⁰. Ozone impacts on semi-natural habitats are less clear-cut, but ozone exposure alters competitive balances in heathlands, moorlands, and grasslands, by suppressing ozone-

⁵⁷ <https://naei.energysecurity.gov.uk/air-pollutants> (accessed June 2026) (accessed June 2026)

⁵⁸ COMEAP (2015) Quantification of Mortality and Hospital Admissions Associated with Ground-level Ozone. Available at: <https://www.gov.uk/government/publications/comeap-quantification-of-mortality-and-hospital-admissions-associated-with-ground-level-ozone> (accessed June 2026). (accessed June 2026)

⁵⁹ COMEAP Air Pollutants, Quantification of Associated Health Effects. Available at: <https://www.gov.uk/government/publications/air-pollutants-quantification-of-associated-health-effects> (accessed June 2026) (accessed June 2026)

⁶⁰ Royal Society (2008). Ground-level ozone in the 21st century: Future trends, impacts and policy implications. The Royal Society, London.

sensitive species, reducing plant diversity, and weakening ecosystem resilience⁶¹. Long-term effects include losses in crop yields, diminished forest carbon sequestration, and degradation of habitats of conservation importance, making ozone a continuing threat to UK biodiversity and ecosystem services despite emission reductions in recent decades. Changes in ground-level ozone concentrations were modelled to estimate potential effects on wheat yield^{Error! Bookmark not defined.}. The analysis assessed how ozone uptake by plant leaves may reduce photosynthesis and crop growth, producing an estimated change in wheat production (tonnes) and associated economic value based on farmgate wheat prices.

(iv). Opportunities for co-benefits / risk of secondary disbenefits:

Reduced levels of ozone would result in a decrease in respiratory and cardiovascular health issues, as well as decreases in the incidence of asthma attacks and premature deaths. The corresponding reduction in hospital admissions would help to reduce the burden on the NHS. Measures that reduce ozone are likely to result in broader overall improvements in air quality as reductions in particulate matter, NO_x and VOCs could in turn lead to related health gains. By reducing the concentrations of ozone precursor pollutants more benefits to the general urban environment are likely.

As ozone is one of the short-lived climate pollutants, reduction would likely be beneficial for near term climate mitigation. Chemical synergies with methane exist as methane is a precursor to ozone. Reducing methane emissions would benefit both air quality and climate. As mentioned earlier, ozone is phytotoxic, and high concentrations are detrimental to crops and the natural ecosystems. Reductions in its concentrations will lead to reduced stress on vegetation and improved ecosystem and crop resilience and therefore overall improvement in crop yields/food security.

There are however potential risks of secondary dis-benefits, related to the complex chemistry involved. As mentioned earlier, in VOC-limited areas (such as urban locations) reducing NO_x can temporarily increase ozone due to reduced ozone titration. Emission reduction in one area can also sometimes shift the ozone formation further downwind. Using alternative fuels can inadvertently lead to increases in PM or ammonia. For example, although not related to ozone chemistry but impactful on integrated air quality management, switching to biomass combustion (using wood pellets, chips) often produces more PM_{2.5} and PM₁₀ than diesel, especially if the combustion system is not efficient or not well maintained. Such incomplete combustion processes may lead to more soot, ash and organic aerosols. Where a combustion process uses nitrogen-rich fuels (like manure or agricultural residues), ammonia is released which acts as a precursor to secondary particulates (in the form of ammonium nitrate or ammonium sulphate) which lead to health impacts as well as the development of haze. It is therefore important to consider whole-system impacts when contemplating fuel switching or other mitigation strategies. The point is not to rank pollutants, but to ensure that ozone precursor management (NO_x, VOCs and methane) is assessed alongside potential co-benefits or disbenefits for particulate matter and ammonia.

(v). Pollutant controlled under current legislation or other measures:

Control of ground-level ozone is treated differently from most other pollutants because it is a secondary pollutant and is not controlled through a conventional ambient limit value in the same way as NO₂, SO₂, CO or PM₁₀. The Air Quality Standards (Wales) Regulations 2010 set ozone target values and long-term objectives, including a target value for the protection of human health of 120 µg/m³ as a maximum daily 8-hour mean, not to be exceeded on more than 25 days per calendar year averaged over three years⁴⁴. The 2024/25 Air Quality in Wales report also notes that three Welsh sites exceeded the ozone air quality objective of 100 µg/m³ as a maximum daily 8-hour mean on more than the permitted 10 occasions in 2024³⁴. Ozone is strongly influenced by meteorology, regional formation and transboundary precursor emissions, and the Welsh Air Quality website notes that ozone is outside the direct control of Welsh Government and local authorities. On this evidence, CAAP's view is that a Welsh ambient concentration

⁶¹ Mills, G. et al. (2011). Evidence of widespread effects of ozone on crops and (semi-)natural vegetation in Europe. *Global Change Biology*, 17(1), 592–613.

target for ozone would have limited effectiveness unless it were framed around precursor control, because ozone concentrations are driven by NO_x, VOC and methane emissions from both Welsh and non-Welsh sources, together with meteorological variability and long-range transport. The more appropriate policy route is likely to be control of ozone precursor emissions, especially NO_x, VOCs and methane, through NECR/Göteborg Protocol obligations, UK-wide action and Welsh measures where proportionate. Section 1 of the Environment (Air Quality and Soundscapes) (Wales) Act 2024 includes ozone among the pollutants for which Welsh Ministers must consider long-term target setting, but any such consideration should account for precursor control, transboundary influence and model uncertainty. This includes the following control measures relevant to ozone precursor pollutants:

- Local Air Quality Management (LAQM) Reform
 - Annual air quality reviews by local authorities.
 - Mandatory action plans with compliance timelines agreed with the Welsh Minister.
- National air quality targets
 - Welsh Ministers may set long-term targets for ozone and/or relevant precursor pollutants, subject to evidence on feasibility, achievability and monitoring.
 - Targets must be measured and time bound.
- Smoke control enforcement
 - Civil penalties for breaches in smoke control areas.
 - Primarily reduces PM and SO₂ from domestic solid fuel use; any ozone relevance is indirect and should be treated as a co-benefit rather than a primary ozone-control measure.
- Promotion of active travel
 - Supports reducing emissions of VOCs and PM.
- Public awareness campaigns
 - Supports and promotes behavioural change by educating the public on pollution risks and mitigation.
 - The duty under section 10 of the Act on Welsh Ministers to promote awareness of the risks of air pollution to human health and ways of reducing or limiting air pollution.

(vi). Feasibility of Mitigation: Mitigation in Wales should focus on measures that can reduce ozone precursor emissions where there are credible Welsh or local levers, while recognising that a substantial proportion of ozone and its precursors is transboundary. Relevant areas include transport NO_x reductions, evaporative and exhaust VOC controls, solvent and product-use VOC reductions, industrial permitting and fugitive emissions control, methane reduction, and agricultural or waste-sector measures where they affect methane or VOC emissions. Smoke control, domestic fuel quality and biomass policies remain important for PM and SO₂ and may provide air-quality co-benefits, but they should not be presented as primary ozone-control measures unless a clear precursor pathway is demonstrated. Challenges that provide a relatively large degree of uncertainty remain:

- The nonlinear chemistry of ozone means that reducing NO_x in VOC-limited areas may result in a temporary increase in ozone.
- Agricultural ammonia emissions and biomass burning may offset urban gains unless tightly managed.
- Effective mitigation requires cross-sector coordination and sustained investment.
- A substantial proportion of the precursor emissions are difficult to control within Wales.

(vii). Feasibility of monitoring: For statutory target purposes, ozone measurements from AURN or equivalent reference-grade monitoring would provide the most robust basis for assessing ambient concentrations, as these methods are standardised, quality-assured and capable of capturing the temporal variability relevant to ozone exposure. However, ozone is a secondary pollutant with strong regional, meteorological and transboundary influences, and concentrations may not be well

represented by a sparse local monitoring network alone. Locally managed monitoring and modelled evidence can provide useful supplementary information, but any statutory target framework would need to define the monitoring method, siting criteria, averaging period, data capture requirements, uncertainty treatment and the role of modelling in assessing national exposure and compliance. A summary of existing monitoring for ozone in Wales can be found in Appendix 3.

2.7. Emerging and other pollutants

Whilst the aforementioned pollutants are paramount in terms of their risk towards public and environmental health (based upon the evidence provided within the epidemiological, toxicological and exposure literature), there remain a vast number of emerging and other pollutants which are strongly considered to pose significant risk to both human and environmental health. The WHO 2021 guidelines refer to such 'emerging pollutants' and highlights that urgent efforts are required to gather imperative empirical evidence due to their likely high risk towards human and environmental health⁶².

Such emerging pollutants include, but are not limited to;

- Ultrafine Particles (UFPs)
- Micro-, Nanoplastics (MNPs)
- Biologically based Aerosols (Bioaerosols)
- Electronic Waste (e-waste)
- Black Carbon/Elemental Carbon (BC/EC)
- Amines
- Airborne PFAS
- Sandstorms/Sand dust
- Indoor dust/Indoor Pollution (*e.g.*, VOCs, mould)
- Wildfire and peatland fire emissions (including PM_{2.5}, PM₁₀, CO, VOCs, PAHs and black carbon)

There is a paucity of exposure monitoring within Wales and the UK towards these additional pollutant types. Thus, it is difficult to understand to what extent the Welsh population is exposed to any of the pollutants in the above list, both spatially and temporally. Yet, based upon current scientific evidence, and the observation that these pollutants are associated with driving (negative) acute, and long-term human/environment health effects, focus should be given towards elucidating the potential risk posed⁶². Notably, the pollutants individually are considered to pose a threat, although the consideration of the pollutants mixing with others, and creating a multi-pollutant cumulative impact to human/environment health is an additional risk that needs to be strongly considered.

Wildfire and peatland fire emissions are episodic but can contribute substantially to short-term PM_{2.5} and PM₁₀ concentrations over wide areas, alongside CO, VOCs, PAHs and black carbon. The public health consequences of such episodes can be significant, especially for vulnerable groups. While monitoring capability for these pollutants exists within existing UK monitoring networks, the relative sparsity of rural monitoring sites and the location of fires mean that specific attribution is unlikely to be straightforward, and forecasting capacity for wildfire smoke in Wales remains limited.

2.8. Interdependencies among pollutants and potential impact on multiple pollutants by measure

The earlier sections established some key interdependencies of the pollutants discussed. Combustion of fuels produces NO_x, CO, SO₂, PM_{2.5}, PM₁₀ and UFP (and NH₃), which are therefore related by common sources. O₃ is a secondary pollutant formed when NO₂ undergoes photolysis, producing O atoms that generate ozone, and this process is amplified by reactions involving VOCs and CO, which create peroxy

⁶² <https://assets.publishing.service.gov.uk/media/639aeb81e90e0721889bbf2f/chief-medical-officers-annual-report-air-pollution-dec-2022.pdf> (accessed June 2026) (accessed June 2026)

radicals (HO_2 and RO_2) that drive further O_3 formation. Consequently, O_3 production depends on concentrations and ratios of NO_x , CO and VOCs.

NH_3 is somewhat distinct in that its primary sources are agricultural. However, it combines with sulphur and nitrogen compounds in the atmosphere to form sulphate and nitrate salts, producing secondary inorganic particles. Thus, NH_3 , SO_2 , O_3 and NO_2 all contribute to secondary PM formation, and a fraction of PM_{10} and $\text{PM}_{2.5}$ originates from these processes. A further important interdependency is the role of volatile organic compound (VOC) emissions in the formation of secondary organic aerosols (SOA), which contribute significantly to ambient $\text{PM}_{2.5}$ concentrations. VOC oxidation in the atmosphere produces low-volatility products that condense to form SOA, linking VOC emission sources, including transport, solvents, and vegetation, directly to $\text{PM}_{2.5}$ and PM_{10} burdens. VOC controls could therefore provide co-benefits for both PM and O_3 .

These relationships are non-linear. For example, reductions in NO_x under VOC-limited conditions may increase O_3 concentrations (NO_x titration effect), while reductions in SO_2 and NO_x can decrease the formation of particulate matter from ammonium salts⁶³. Interdependencies are also influenced by meteorology. O_3 formation peaks in warm, sunny conditions, whereas secondary PM and NH_3 reactions dominate in cooler, more humid periods⁶⁴.

From a management perspective, some interventions affect multiple pollutants simultaneously⁶⁵. Measures that reduce combustion (e.g. traffic and domestic burning controls) decrease NO_x , CO, SO_2 and primary PM simultaneously, while also limiting precursors for O_3 and secondary PM. NH_3 abatement in agriculture lowers secondary $\text{PM}_{2.5}$ but has limited effect on O_3 ⁶⁶, whereas VOC controls provide co-benefits for both PM and O_3 ⁶⁷.

Ultrafine particles should remain in scope as an emerging evidence need because they share major combustion sources with NO_x , CO and particulate matter, but current monitoring coverage and exposure-response evidence are not yet sufficient to support a robust statutory target without further methodological development.

⁶³ <https://doi.org/10.5194/acp-22-1311-2022> (accessed June 2026) (accessed June 2026)

⁶⁴ <https://doi.org/10.5194/acp-23-6083-2023> (accessed June 2026) (accessed June 2026)

⁶⁵ <https://doi.org/10.1016/j.jenvman.2025.124655> (accessed June 2026) (accessed June 2026)

⁶⁶ <https://doi.org/10.1016/j.jenvman.2022.116285> (accessed June 2026) (accessed June 2026)

⁶⁷ <https://doi.org/10.5194/acp-24-10717-2024> (accessed June 2026) (accessed June 2026)

3. Summary of evidence, evidence gaps and target-setting considerations

The evidence reviewed by CAAP indicates that the case for target setting differs between pollutants, not only because current concentrations and trends differ, but because the strength of the evidence base, monitoring capability, source controllability, existing statutory controls and likely effectiveness of a target as a policy lever also vary. The evidence base already includes monitoring data, emissions inventories, source information, scenario modelling, health and ecosystem evidence, and assessment of potential mitigation pathways. The points below therefore should not all be read as evidence gaps in the sense of missing analysis. Rather, they identify some issues that would need to be resolved or specified if a pollutant were taken forward for long-term target development, including the target metric, monitoring approach, uncertainty treatment, source attribution, delivery pathway, costs and barriers, and the added value of a statutory target compared with existing controls.

For NH_3 , there is strong evidence of environmental impact from ammonia and nitrogen deposition, particularly in relation to sensitive habitats, eutrophication, acidification and biodiversity loss. There is no WHO air quality guideline for NH_3 , so the most relevant benchmarks are the UNECE critical levels for ecological protection. The key target-design question is how an NH_3 target would be expressed and delivered: whether it should be based on ambient concentration, deposition, protection of sensitive habitats, or a combination of these. NH_3 is a strong candidate for further consideration because of the scale and ecological significance of nitrogen impacts in Wales, but target development would need to account for the strong spatial gradients around agricultural sources, local source proximity, habitat sensitivity and the relationship between national concentration trends and site-specific ecological protection. Monitoring methods for NH_3 are well established and capable of measuring low concentrations, but a statutory framework would need to define siting criteria, data capture, uncertainty treatment, method equivalence and the relationship between national trend monitoring and local habitat-focused monitoring. The main delivery considerations relate to the pace, scale, uptake, cost and practicalities of agricultural mitigation measures (e.g. manure and slurry management, livestock housing, fertiliser use, anaerobic digestion/digestate management and targeted action near sensitive sites). Consideration would need to focus on designing a target framework that is measurable, attributable, deliverable and clearly linked to ecological outcomes.

For NO_2 , the evidence base for health impacts, monitoring and source attribution is comparatively strong. NO_2 is already subject to statutory limit values and is routinely monitored through established automatic and diffusion-tube networks. Concentrations have declined substantially over time, particularly at traffic-influenced sites, but some locations remain above the WHO annual guideline and traffic-related exposure remains an important public-health and equity issue. The potential benefit of a long-term NO_2 target would be to support continued exposure reduction, strengthen action on remaining roadside and traffic-influenced hotspots, and help focus policy on communities with higher exposure. NO_2 is therefore also a credible candidate for further target consideration, although the target-design question is different from NH_3 . For NO_2 , the issue is not whether it can be measured or whether sources are understood, but whether a new long-term target would add useful policy leverage beyond existing statutory limits and Local Air Quality Management duties. Monitoring is sufficiently mature for statutory assessment. Relevant delivery considerations include the future pace of fleet change, modal shift, planning and local traffic interventions, the distribution of benefits across

communities, and the extent to which further reductions would be achieved through existing policies compared with additional target-driven action.

For PM₁₀, monitoring is well established and concentrations in Wales have generally declined, but target design is more complex because PM₁₀ arises from a mixed set of sources. These include controllable local emissions, secondary particles, resuspended dust, construction and demolition activity, non-exhaust traffic emissions, domestic combustion, industrial sources, sea salt, natural particles and transboundary pollution. A long-term PM₁₀ target could help maintain progress and support control of local sources, but the target framework would need to distinguish between reductions that can reasonably be influenced by Welsh policy and variation driven by meteorology, natural particles, episodic events or imported pollution. The key target-design issue is therefore source controllability and interpretation, rather than absence of monitoring capability. Further specification would be needed around source apportionment, treatment of natural or episodic events, the contribution of non-exhaust traffic emissions, the role of domestic combustion and construction dust, and whether existing monitoring and reporting arrangements are sufficient for a more stringent target.

For O₃, the evidence indicates that ozone is important for health, vegetation and ecosystem protection, but its suitability as a direct Welsh ambient concentration target is less straightforward. As a secondary pollutant, O₃ is strongly influenced by precursor emissions, sunlight, meteorology and regional and transboundary transport. Reducing NO_x and VOC emissions remains important, but changes in measured Welsh ozone concentrations may not respond simply or predictably to Welsh precursor reductions alone. The response can be non-linear, particularly in urban areas where reductions in NO_x may reduce ozone scavenging. The target-design issue is therefore whether a direct concentration target would be the most effective policy mechanism, or whether ozone is better addressed through precursor controls, continued monitoring, modelling and UK or international cooperation.

Current concentrations of SO₂ are generally low and existing statutory objectives and regulatory controls appear to provide a high level of protection at national scale. The remaining issues are more likely to be localised and source-specific, particularly around industrial processes, fuel-use changes, shipping or other combustion sources. The target-design question is whether a new national long-term target would provide additional benefit beyond existing permitting, regulation and surveillance. A target could help guard against future reversal, but current evidence suggests that continued control through existing regulatory mechanisms may be proportionate unless evidence indicates emerging risk, localised exposure concern or changes in major source activity. Monitoring methods for SO₂ are established, but a more stringent long-term target would need to confirm that existing infrastructure can measure relevant lower concentrations reliably within appropriate limits of detection and uncertainty ranges.

Ambient outdoor concentrations of CO in Wales are very low and well below existing objective and guideline values. Existing ambient monitoring remains useful for surveillance and for understanding broader combustion-related air quality, but the major public-health risk from CO is usually indoor or enclosed-space exposure from combustion appliances, poor ventilation, solid-fuel use, accidental poisoning or occupational and enclosed settings. The target-design question is therefore whether an ambient outdoor target would address the most relevant exposure pathway. A new outdoor concentration target may add limited benefit unless evidence emerges of increased outdoor concentrations or specific local sources. If a lower ambient target were considered, it would need to confirm measurement capability, data capture and uncertainty treatment at very low ambient concentrations.

Overall, the evidence does not point to a single uniform approach across all Section 1 pollutants. For pollutants such as NH₃ and NO₂, where there is clear evidence of ecological or health impacts and

plausible Welsh policy relevance, the remaining issues are primarily about target design, monitoring, delivery mechanisms, costs, barriers and the additional value of a statutory target. For PM₁₀ and O₃, the key issue is the extent to which measured concentrations can be attributed to and controlled by mitigation action in Wales, and whether target metrics can account for natural, meteorological and transboundary influences. For SO₂ and CO, current concentrations are low, so the issue is whether a new national target would add meaningful protection beyond existing controls and surveillance. These distinctions help identify where long-term targets could be most effective, where the existing evidence needs to be translated into a more specific target framework, and where alternative policy mechanisms may provide a more proportionate route to continued improvements in air quality across Wales.

Appendix 1: National Atmospheric Emissions Inventory emissions maps 2023

All maps have been taken from the latest available UK report: Air Pollutant Inventories for England, Scotland, Wales and Northern Ireland: 2005-2023, published in 2025⁶⁸.

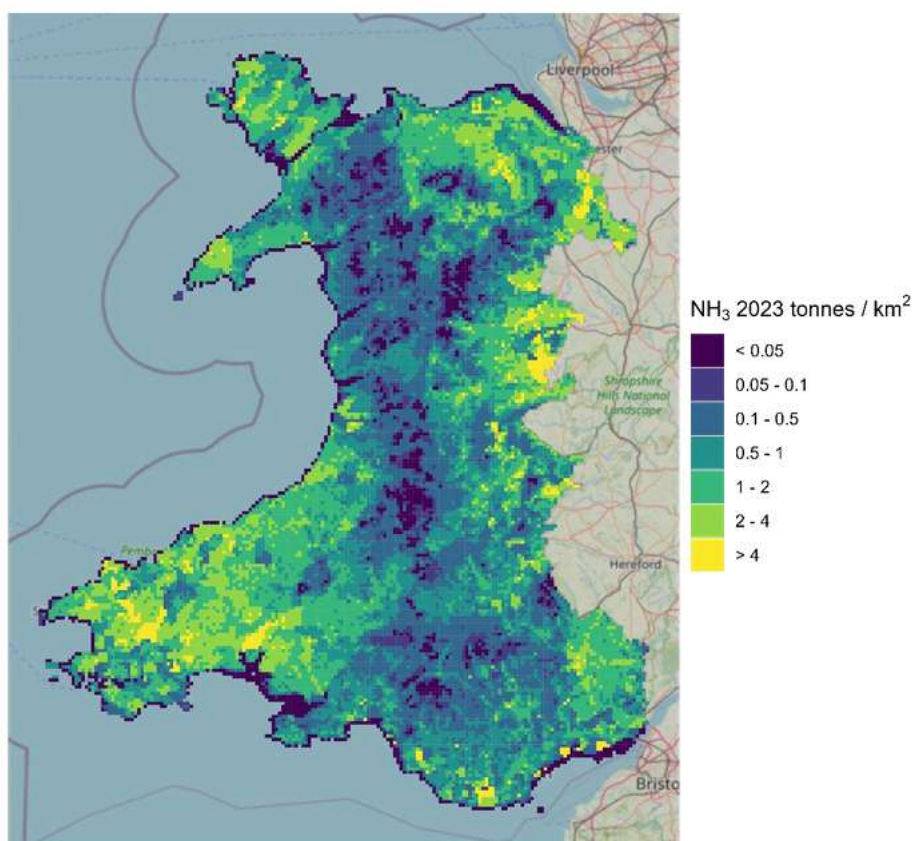


Figure A1.1: Spatial distribution of NH₃ emissions in Wales (1 km × 1 km resolution) based on NAEI data.

⁶⁸ https://naei.energysecurity.gov.uk/sites/default/files/2025-09/DG_AP_Inventory_2005-2023_Report_FINAL_for_publication.pdf (accessed June 2026)(accessed June 2026)

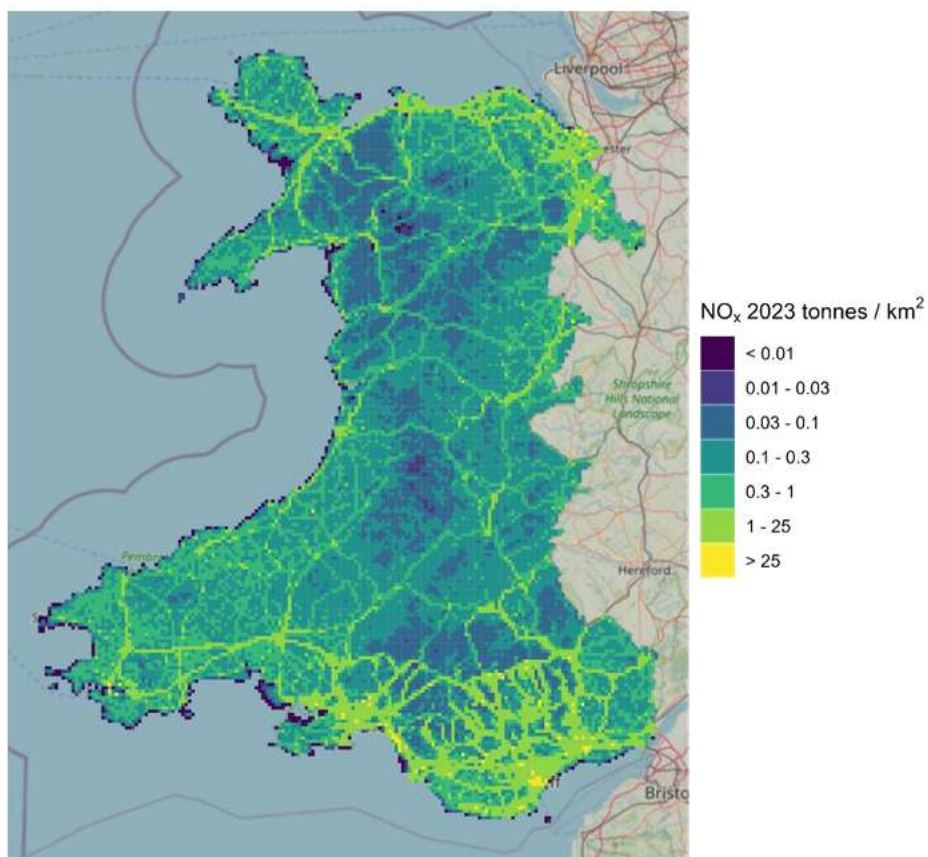


Figure A1.2: Spatial distribution of NO_x emissions in Wales (1 km × 1 km resolution) based on NAEI data.

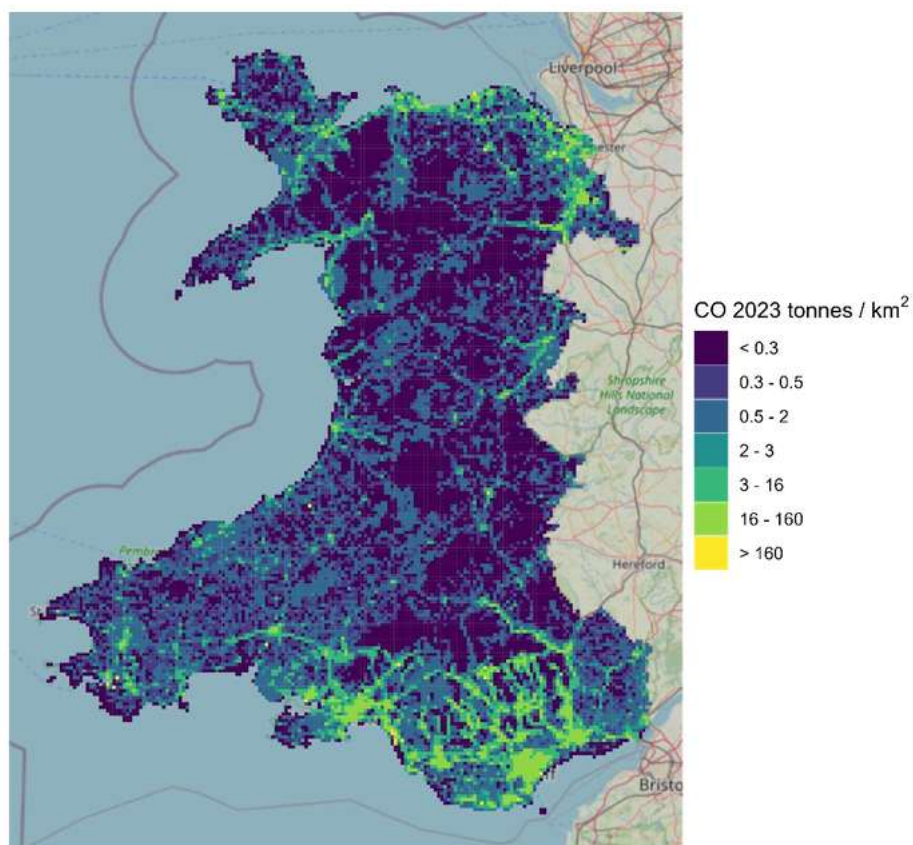


Figure A1.3: Spatial distribution of CO emissions in Wales (1 km × 1 km resolution) based on NAEI data.

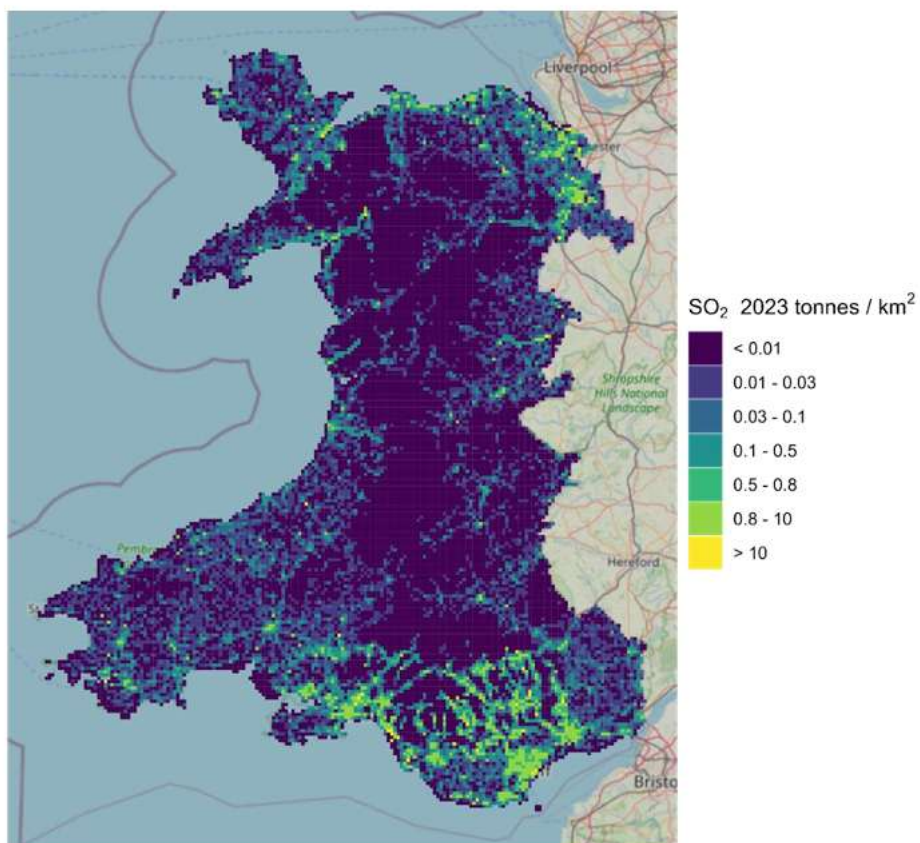


Figure A1.4: Spatial distribution of SO₂ emissions in Wales (1 km × 1 km resolution) based on NAEI data.

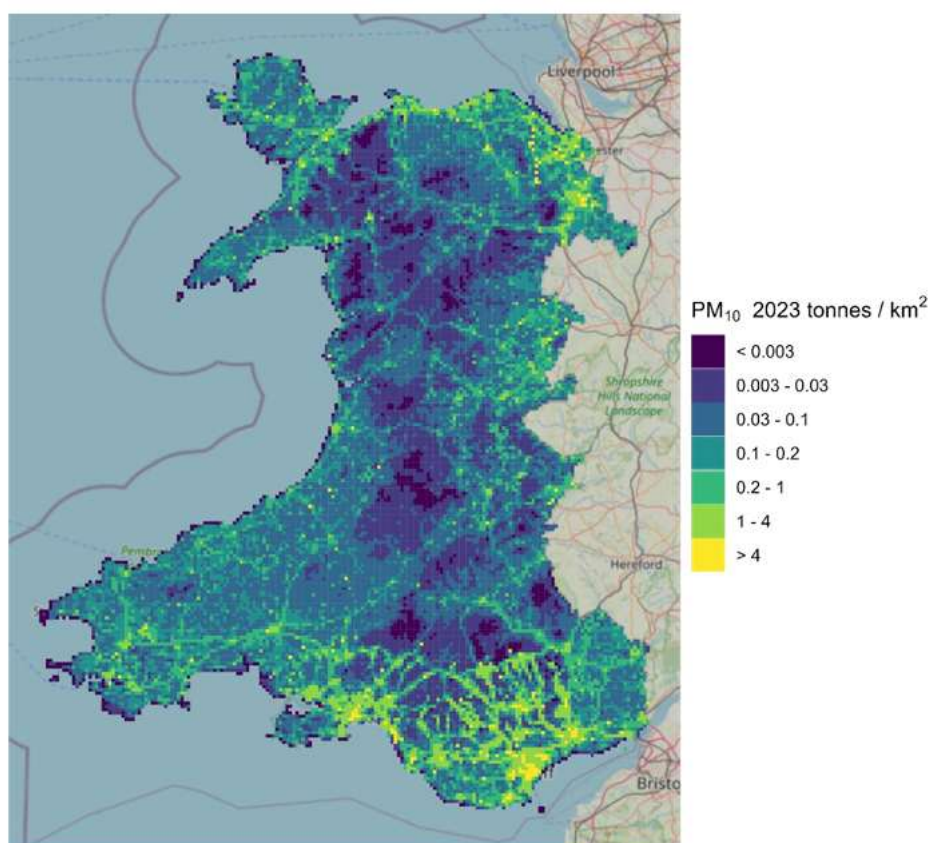


Figure A1.5: Spatial distribution of PM₁₀ emissions in Wales (1 km × 1 km resolution), based on NAEI data.

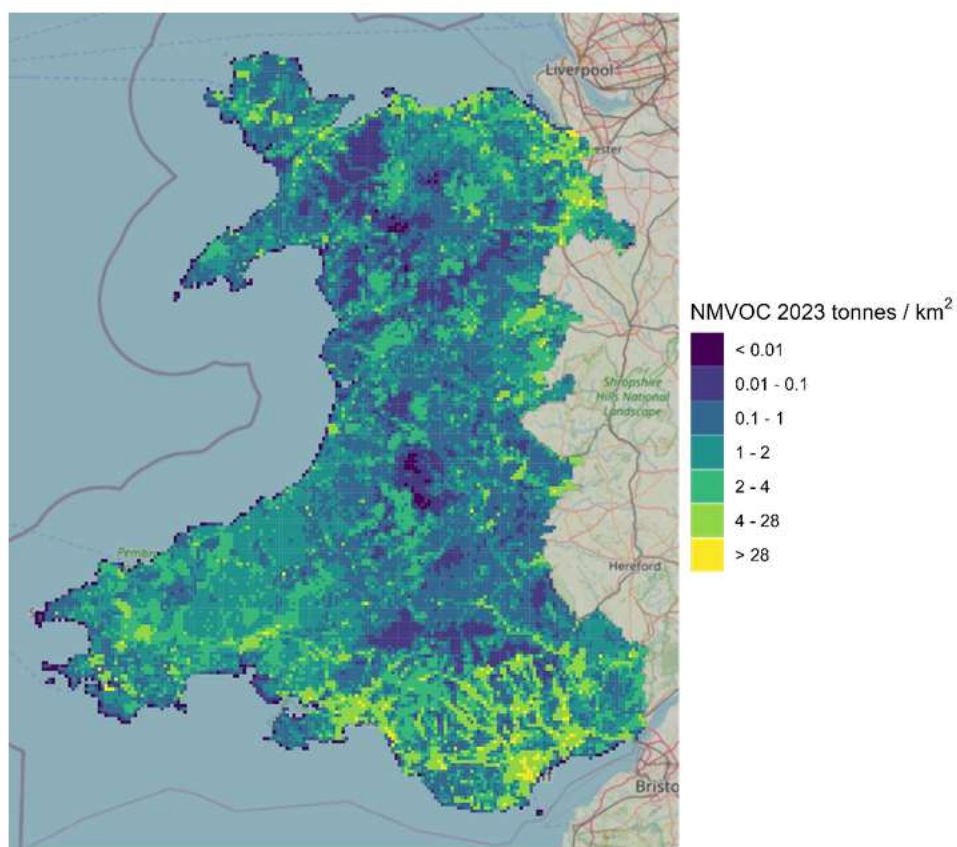


Figure A1.6: Spatial distribution of Non-Methane Volatile Organic Compounds (NMVOC) emissions in Wales (1 km x 1 km resolution), based on NAEI data.

Appendix 2: Recent air pollutant concentrations in Wales and guideline levels

This section summarises recent concentrations of the Section 1 pollutants in Wales, using the best available Welsh evidence from national reporting, monitoring data, modelling and expert judgement. The data are intended to provide a present-day context for considering whether long-term targets may be appropriate and should be read alongside the pollutant-specific sections above, where sources, impacts, trends, feasibility of mitigation and monitoring considerations are discussed in more detail. Recent concentrations are presented in Table A2.1 alongside relevant WHO guideline levels, or other recognised environmental benchmarks where WHO has not set an air quality guideline. For some pollutants, the routinely reported Welsh statistic does not exactly match the WHO metric; where this is the case, the metric used is stated explicitly in the table.

Table A2.1: Summary of recent air pollutant concentrations in Wales and relevant guideline levels

Pollutant	Recent reported concentrations in Wales	Units / metric	WHO / other guideline level	Source / notes
NH ₃	0.51-2.70	µgm ⁻³ ; annual mean; 1 km ² modelled grid; 1st-99th percentile; 2022-2024 three-year mean	No WHO AQG. UNECE critical levels: 1 µg NH ₃ m ⁻³ annual mean for sensitive lichens/bryophytes; 3 µg NH ₃ m ⁻³ annual mean for sensitive higher plants.	CBED modelled concentrations calibrated to UKEAP/NAMN/AGANet measurements. Sources: UK-Air UKEAP and NAMN/AGANet network information (https://uk-air.defra.gov.uk/networks/network-info?view=uheap ; https://uk-air.defra.gov.uk/interactive-map?network=namn ; accessed June 2026).
NO ₂	11.6 urban background; 19.4 urban traffic; 2025 AURN site range: 2-33	µgm ⁻³ ; annual mean	WHO AQG: 10 µg/m ³ annual mean; 25 µg/m ³ 24-hour mean.	Air Quality in Wales 2024/25 report and Welsh Air Quality Database/AURN. The Welsh annual report uses long-running sites to avoid bias from changes in network composition. ³⁴ Sources: Air Quality in Wales 2024/25 (https://www.airquality.gov.wales/sites/default/files/documents/2025-12/AQ-2025-English-Final_0.pdf ; accessed June 2026) and Welsh Air Quality Database/AURN (https://www.airquality.gov.wales/ ; accessed June 2026).

Pollutant	Recent reported concentrations in Wales	Units / metric	WHO / other guideline level	Source / notes
PM ₁₀	14.4 urban background; 13.5 urban traffic	µgm ⁻³ ; annual mean	WHO AQG: 15 µg/m ³ annual mean; 45 µg/m ³ 24-hour mean (99th percentile).	Air Quality in Wales 2024/25 report; long-running Welsh urban background and urban traffic sites. ³⁴ Source: Air Quality in Wales 2024/25 (https://www.airquality.gov.wales/sites/default/files/documents/2025-12/AQ-2025-English-Final_0.pdf ; accessed June 2026).
O ₃	62.8 long-running rural sites	µgm ⁻³ ; annual mean. Note: annual mean is not the WHO compliance metric.	WHO AQG: 60 µg/m ³ peak-season daily maximum 8-hour mean; 100 µg/m ³ daily maximum 8-hour mean (99th percentile).	Air Quality in Wales 2024/25 report. O ₃ is regional/transboundary and shows strong meteorological variability. ³⁴ Source: Air Quality in Wales 2024/25 (https://www.airquality.gov.wales/sites/default/files/documents/2025-12/AQ-2025-English-Final_0.pdf ; accessed June 2026).
SO ₂	15-min 99.9th percentile: 3-6; hourly 98th percentile: 1-4; daily 99th percentile: 3-6	µgm ⁻³ ; short-term percentile statistics	WHO AQG: 40 µg/m ³ 24-hour mean (99th percentile).	Welsh Air Quality Database/AURN short-term statistics; Air Quality in Wales 2024/25 reports no moderate/high SO ₂ days and no SO ₂ objective exceedances in 2024. ³⁴ Sources: Air Quality in Wales 2024/25 (https://www.airquality.gov.wales/sites/default/files/documents/2025-12/AQ-2025-English-Final_0.pdf ; accessed June 2026) and Welsh Air Quality Database/AURN (https://www.airquality.gov.wales/ ; accessed June 2026).

Pollutant	Recent reported concentrations in Wales	Units / metric	WHO / other guideline level	Source / notes
CO	0.0-0.2	mgm ⁻³ ; latest 8-hour means at Welsh CO sites	WHO AQG: 4 mg m ⁻³ 24-hour mean. Wales objective: 10 mg m ⁻³ maximum daily running 8-hour mean.	Air Quality in Wales site latest data for Cardiff Centre and Port Talbot Margam. Air Quality in Wales 2024/25 reports no CO objective exceedances in 2024. ³⁴ Sources: Air Quality in Wales 2024/25 (https://www.airquality.gov.wales/sites/default/files/documents/2025-12/AQ-2025-English-Final_0.pdf ; accessed June 2026) and Welsh Air Quality Database/AURN (https://www.airquality.gov.wales/ ; accessed June 2026).

Notes: WHO guideline levels are from WHO Global Air Quality Guidelines (2021). WHO does not set a guideline for ammonia; for NH₃ the relevant ecological benchmarks are UNECE critical levels. For pollutants where the WHO guideline is not an annual mean (SO₂, CO and O₃ short-term metrics), the table reports the closest routinely available Welsh monitoring statistic and states the metric used. AURN = Automatic Urban and Rural Network; UKEAP = UK Eutrophying and Acidifying Atmospheric Pollutants monitoring programme; CBED = Concentration Based Estimated Deposition. The WHO guideline and UNECE critical-level sources are cited earlier in this advice note. WHO guideline source: <https://www.who.int/publications/i/item/9789240034228> (accessed June 2026). UNECE ammonia critical-level source: <https://unece.org/sites/default/files/2022-08/Item%20%20Conference%20Proceedings%20on%20Ammonia%20Dessau%202022%20FINALdraft.pdf> (accessed June 2026).

Appendix 3: Summary of air quality monitoring in Wales

The following section summarises the existing monitoring networks in Wales for the main pollutants considered in this report. Further details on different pollutants and networks are provided below but a summary is provided in Table A3.1: **Summary count of monitoring in Wales for key pollutants**. The information is accurate as of 12th March 2026 and taken from the UK-AIR website (<https://uk-air.defra.gov.uk/> (accessed June 2026)).

Counts should be interpreted as network and method counts rather than unique monitoring locations where methods are co-located. This is particularly relevant for ammonia, where NAMN and AGANet measurements are deliberately co-located at some sites for method comparison and validation.

Table A3.1: Summary count of monitoring in Wales for key pollutants

	NH ₃	NO ₂	SO ₂	PM ₁₀	CO	O ₃
National Ammonia Monitoring Network (NAMN)	5	-	-	-	-	-
Long-Term Monitoring Network (LTMN)	1	-	-	-	-	-
UKEAP: Acid Gas and Aerosol Network (AGANet)	3†	-	3†	-	-	-
Automatic Urban and Rural Network (AURN)	-	11	2	8	2	4
Locally Managed Automatic Monitoring Network	-	42	10	43	-	19
Rural NO ₂ Network	-	3	-	-	-	-
Urban NO ₂ Network	-	2	-	-	-	-
Total	8†	58*	15†	51	2	23
* Excludes NO ₂ diffusion tube sites used for Local Air Quality Management						
** At one site, NAMN and AGANet NH ₃ monitoring is co-located. There are 8 separate locations in Wales with NH ₃ monitoring.						

† AGANet values are included to show the additional active acid-gas/aerosol method coverage for NH₃ and SO₂. They should not be added uncritically to NAMN/LTMN totals as unique monitoring locations where co-location occurs.

Ammonia monitoring

Ammonia in Wales is primarily monitored through the UKEAP: National Ammonia Monitoring Network (NAMN), which quantifies temporal and spatial changes in air concentrations and deposition of ammonia (NH₃) and ammonium (NH₄⁺) on a long-term basis. The network provides baseline data for assessing responses to changes in the agricultural sector and verifying compliance with international agreement targets. There are five active NAMN sites in Wales (Table A3.2). Fenn's Moss is included separately because it is a cross-border site relevant to Wales and is part of the Long-Term Monitoring Network (LTMN).

Table A3.2: Ammonia monitoring in Wales

Site Name	UK-Air ID	Type	Pollutants Measured	Method
Narberth	UKA00323	Rural Background	NH ₃ (passive & active), NH ₄ ⁺	ALPHA & DELTA
Cardigan	UKA00321	Rural Background	NH ₃ (passive)	ALPHA
Cwmystwyth	UKA00325	Rural Background	NH ₃ (active), NH ₄ ⁺	DELTA
Llyn Llydaw	UKA00268	Rural Background	NH ₃ (passive)	ALPHA

Plas Y Brenin	UKA00493	Rural Background	NH ₃ (active), NH ₄ ⁺	DELTA
Fenn's Moss	UKA00642	Rural Background	NH ₃ (passive)	ALPHA
Method	An ALPHA sampler is a passive device that captures ammonia on an acid-coated filter. It typically provides a monthly time resolution. A DELTA sampler is an active denuder system that collects gaseous and particulate nitrogen compounds using pumped airflow. It typically provides a monthly time resolution.			

Other monitoring networks that are relevant for ammonia and/or the direct and indirect impacts of ammonia include:

- **UKEAP: Precip-Net** which measures the chemical composition of rainwater including estimates of wet deposition of sulphur and nitrogen chemicals. There are six sites active in Wales.
- **UKEAP: Acid Gas and Aerosol Network** which measures concentrations of acid gases and inorganic aerosol composition. There are active AGANet sites in Wales, including co-located active and passive ammonia sampling at Narberth; counts should therefore distinguish monitoring methods from unique site locations.

Other pollutant monitoring

Other air pollutants (NO₂, SO₂, PM₁₀, CO and O₃) are monitored through several networks that often assess different pollutants and integrate different monitoring methods on a single site. As such, the monitoring summary below is provided by monitoring network rather than by pollutant to avoid duplication.

Automatic Urban and Rural Network (AURN) is the UK's largest automatic monitoring network. The AURN provides hourly data to determine compliance against statutory air quality standards and targets; information for the public; supporting the UK Local Air Quality Management (LAQM) process; assessing long-term trends; and assessing effectiveness of policies. There are eleven AURN sites across Wales - eleven measuring NO/NO₂/NO_x, two measuring SO₂, eight measuring PM₁₀/PM_{2.5} two measuring CO and four measuring O₃ (Table A3.3: **AURN monitoring in Wales**).

Table A3.3: AURN monitoring in Wales

Site Name	UK-Air ID	Type	Pollutants Measured	Method
Aston Hill	UKA00137	Rural Background	O ₃ , NO, NO ₂ , NO _x (as NO ₂)	1, 2
Cardiff Centre	UKA00217	Urban Background	O ₃ , NO, NO ₂ , NO _x (as NO ₂), PM ₁₀ , PM _{2.5} , CO	1, 2, 4, 6
Narberth	UKA00323	Rural Background	O ₃ , NO, NO ₂ , NO _x (as NO ₂), SO ₂ , PM ₁₀ , PM _{2.5}	1, 2, 3, 5
Newport	UKA00380	Urban Background	NO, NO ₂ , NO _x (as NO ₂), PM ₁₀ , PM _{2.5}	2, 5
Wrexham	UKA00440	Urban Traffic	NO, NO ₂ , NO _x (as NO ₂), PM ₁₀ , PM _{2.5}	2, 5
Swansea Roadside	UKA00497	Urban Traffic	NO, NO ₂ , NO _x (as NO ₂), PM ₁₀ , PM _{2.5}	2, 4
Port Talbot Margam	UKA00501	Urban Industrial	NO, NO ₂ , NO _x (as NO ₂), PM ₁₀ , PM _{2.5} , SO ₂ , CO	1, 2, 3, 4, 6

Chepstow A48	UKA00515	Urban Traffic	NO, NO ₂ , NO _x (as NO ₂), PM ₁₀ , PM _{2.5}	2, 4
Cardiff Newport Road	UKA00653	Urban Traffic	NO, NO ₂ , NO _x (as NO ₂), PM ₁₀	2, 4
Cwmbran Crownbridge	UKA00819	Urban Background	O ₃ , NO, NO ₂ , NO _x (as NO ₂)	1, 2
Hafod-yr-ynys Hill Roadside	UKA01037	Urban Traffic	NO, NO ₂ , NO _x (as NO ₂)	2
Method	1. O ₃ measured by UV absorption 2. NO/NO ₂ measured by Chemiluminescence 3. SO ₂ measured by UV fluorescence 4. PM ₁₀ /PM _{2.5} measured by Beta Attenuation Monitor (BAM) 5. PM ₁₀ /PM _{2.5} measured by Fine Dust Analysis System (FIDAS) 6. CO measured by IR absorption			

Locally Managed Automatic Monitoring Network (LMMN) represents automatic monitoring from across Wales that is not part of the UK national monitoring strategy. These are sites operated in most cases by local authorities but may also include monitoring from other programmes. The location and purpose of these sites differ from the AURN which is governed by strict rules for assessing compliance, therefore, there is a broad range of site types, equipment and data quality practices. Due to the large number of sites, methods and pollutants monitored it is not possible to provide a summary table like the AURN table above but a simple count is:

- NO₂ – 42 sites
- SO₂ – 10 sites
- PM₁₀ – 43 sites
- PM_{2.5} - 16 sites
- O₃ – 19 sites

Other monitoring networks active in Wales include:

- **Local Air Quality Management NO₂ Monitoring** which measures NO₂ using passive diffusion tubes as part of a local authority's statutory requirements under the Local Air Quality Management process. Monthly NO₂ diffusion tubes provide useful long-term trend data, but their low temporal resolution and higher uncertainty mean they're generally better for screening rather than demonstrating strict air-quality compliance. There are several hundred sites active across Wales.
- **UKEAP: Rural NO₂ Network** which measures long-term trends in background concentrations. There are three sites active in Wales.
- **UK Urban NO₂ Network** which measures NO₂ at key locations using passive diffusion tubes. There are two sites active in Wales.
- **Non-Automatic Hydrocarbon Network** which measures benzene concentrations. There are two sites active in Wales.
- **Polycyclic aromatic hydrocarbons (PAHs)** which measures a group of persistent organic compounds. There are five sites active in Wales.
- **Toxic Organic Micro Pollutants (TOMPs)** which generates long-term ambient air trend data for a range of Persistent Organic Pollutants (POPs). There is one site active in Wales.
- **Black Carbon Network** which measures black carbon. There is one site active in Wales.

- **UK Heavy Metals Network** which measures lead, arsenic, cadmium, nickel and mercury. There are six sites active in Wales.