National Physical Laboratory

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UK Particle Concentrations and Numbers, and Black Carbon Networks: Annual Report 2025

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National Physical Laboratory (NPL)

UK Particle Concentrations and Numbers, and Black Carbon Networks: Annual Report 2025

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We are the UK's National Metrology Institute (NMI), a world-leading centre of excellence that provides cutting-edge measurement science, engineering and technology that underpins prosperity and quality of life in the UK.

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Executive Summary

The National Physical Laboratory (NPL) is contracted to manage the UK Particle Concentrations and Numbers (PCN), and Black Carbon (BC) Networks (henceforth referred to as the Network). The Network measures and reports concentrations and chemical composition of particles in ambient air across the UK, with a focus on $PM_{2.5}$ (particulate matter with an aerodynamic diameter < 2.5 μm).

This report was prepared by NPL and the Environmental Research Group at Imperial College London as part of the Network contract. The contract is managed by the Environment Agency on behalf of the Department for the Environment, Food and Rural Affairs and the Devolved Administrations: the Northern Ireland Executive, the Scottish Government and the Welsh Government.

This annual report contains:

- a summary of the Network structure, its operation, and quality procedures;
- descriptions of the instruments used on the Network;
- the data capture recorded for each instrument;
- time series plots of all ratified Network data in 2025;

and, where applicable:

- plots of diurnal, weekly, and monthly variations in ratified Network data in 2025;
- plots of the long-term trends in ratified Network data;
- comparisons between pollutants measured by the Network;
- activities associated with the UK $PM_{2.5}$ MEP (monitoring expansion programme), to provide additional particulate matter (PM) speciation data to enhance the measurement evidence base associated with the $PM_{2.5}$ targets from the Environmental Targets (Fine Particulate Matter) (England) Regulations 2023[1].

In 2025, the Network operated at 27 UK monitoring sites with a mixture of site classifications: rural background, urban background, and urban traffic. A summary of the number of sites where each instrument was deployed is shown in Table 1. The full list of sites is detailed in Table 3 and Table 4. Fully ratified data from the Network can be downloaded from the Defra UK AIR website[2].

Table 1 - Summary of analytes and instruments across the Network in 2025.

Analyte	Instrument(s)	Interval	Sites
Particle number concentration in $PM_{2.5}$	Condensation particle counter (CPC)	Hourly	3
Particle size distribution in the range 10 nm – 1000 nm mobility diameter	Scanning mobility particle sizer (SMPS)	15 min	4
Mass concentrations of ammonium, nitrate, sulfate, and organic compounds in $PM_{2.5}$ or PM_1*	Aerosol chemical speciation monitor (ACSM)	Hourly	3
40 elements in $PM_{2.5}$ and PM_{10}*	X-ray fluorescence instrument (XRF)	Bi-hourly*	2
Mass concentrations of organic carbon and elemental carbon (OC/EC) in $PM_{2.5}$	Ambient air sampler and thermal/optical carbon analyser	Weekly or daily	4
Mass concentrations of BC and ultraviolet particulate matter (UVPM) in $PM_{2.5}$	Aethalometer	Hourly	26

* PM_1 and PM_{10} are particulate matter with an aerodynamic diameter < 1 µm and < 10 µm respectively, measured in alternating hourly intervals.

Some notable features from the Network data in 2025 are:

- The annual average particle number concentrations for 2025 at London Marylebone Road and London Honor Oak Park showed a decrease from the 2024 annual average. The particle number concentrations at the urban sites continued to remain lower than the pre-pandemic values, supporting the hypothesis that there has been a sustained reduction in local emissions relative to the pre-2020 annual average values.
- The peak shift in the SMPS particle size distributions seen in the 2023 and 2024 data at London Marylebone Road and London Honor Oak Park has been observed again in the 2025 data at those sites and also at Chilbolton Observatory. This supports the hypothesis that the peak shift is due to a change in monitoring equipment and not a change in the ambient aerosol[3].
- The annual average chemical mass concentration of secondary particles (nitrate, sulfate, and ammonium) and organic mass measured at London Marylebone Road and London Honor Oak Park remained similar to those in 2024.
- Of the 40 elements measured using XRF at London Honor Oak Park and London Marylebone Road, the elements that reported the highest annual average mass concentrations in PM_{10} were chlorine, iron, calcium and sulfur at both sites.

- Compared with 2024, the 2025 annual average mass concentrations show increases in OC and EC at all sites. The most pronounced relative increases were observed at Auchencorth Moss, where OC and EC mass concentrations increased by 52 % and 18 % respectively. Increases at the other sites were smaller, ranging from 3 % to 16 % for OC and 7 % to 17 % for EC.
- Annual average mass concentrations of BC and UVPM were measured at all 26 BC sites in 2025, and both were broadly lower than or of a similar magnitude to those in 2024 (excluding the 12 sites opened in 2024, where this comparison is not possible). The largest increase in UVPM mass concentration was observed at the Cardiff Centre site from 0.01 μg m^{-3} in 2024 to 0.16 μg m^{-3} in 2025, whereas the largest increase in BC mass concentration was observed at the London Marylebone Road site from 0.73 μg m^{-3} in 2024 to 0.93 μg m^{-3} in 2025.
- Out of the 12 new BC Network sites opened in 2024, the highest annual mean BC mass concentration in 2025 was obtained for the Bradford Shipley Airedale Road site (2.1 μg m^{-3}), which is also the highest result across all BC sites in 2025.

The annual average data capture for each type of analyte across all Network sites was:

- 85 % for particle number concentration
- 83 % for particle size distribution
- 77 % for aerosol mass and chemical composition
- 82 % for elemental analysis
- 96 % for OC/EC
- 92 % for BC

1 Introduction

1.1 Overview

The National Physical Laboratory (NPL) is contracted to manage the UK Particle Concentrations and Numbers (PCN) and Black Carbon (BC) Networks (henceforth referred to as the Network). This report was prepared by NPL and the Environmental Research Group (ERG) at Imperial College London as part of the contract with the Environment Agency, on behalf of the Department for Environment, Food and Rural Affairs (Defra) and the Devolved Administrations: the Northern Ireland Executive, the Scottish Government and the Welsh Government.

The Network measures and reports the concentrations and chemical composition of particles in ambient air across the UK, with a focus on $PM_{2.5}$ (particulate matter with an aerodynamic diameter < 2.5 μm). A summary of the analytes measured and the types of instruments used on the Network is given in Table 2. The Network sites are located to maximise the benefit of the measurements made, so that sound conclusions can be drawn about the concentrations, chemical composition and sources of particles in ambient air at these locations. Details of site locations are given in section 2.2.

This report contains:

- a summary of the Network structure, its operation, and quality procedures;
- descriptions of the instruments used on the Network;
- the data capture recorded for each instrument;
- time series plots of all ratified Network data in 2025;

and, where applicable:

- plots of diurnal, weekly and monthly variations in ratified Network data in 2025;
- plots of the long-term trends in ratified Network data;
- comparisons between pollutants measured by the Network;
- activities associated with the UK $PM_{2.5}$ MEP (monitoring expansion programme).

Table 2 - Summary of analytes measured and instruments used on the Network in 2025.

Analyte(s)	Instrument(s)
Particle number concentrations in $PM_{2.5}$	Condensation particle counter (CPC)
Particle size distribution in the range 10 nm to 1000 nm mobility diameter	Scanning mobility particle sizer (SMPS)
Mass concentrations of ammonium, nitrate, sulfate, and organic compounds in $PM_{2.5}$ or PM_1*	Aerosol chemical speciation monitor (ACSM)
Mass concentrations of 40 elements in $PM_{2.5}$ and PM_{10}* (Ag, Al, As, Ba, Bi, Br, Ca, Cd, Ce, Cl, Co, Cr, Cu, Fe, Ga, Ge, Hg, In, K, La, Mn, Mo, Ni, P, Pb, Pd, Pt, S, Sb, Se, Si, Sn, Sr, Te, Ti, Tl, V, Y, Zn and Zr)	X-ray fluorescence (XRF)
Mass concentrations of organic carbon and elemental carbon (OC/EC) in $PM_{2.5}$	Ambient air sampler and thermal/optical carbon analyser
Mass concentrations of BC and ultraviolet particulate matter (UVPM) in $PM_{2.5}$	Aethalometer

* PM_1 and PM_{10} are particulate matter with an aerodynamic diameter < 1 µm and < 10 µm respectively.

1.2 Background

Prior to 2020, these data were reported in two separate annual reports, one for the PCN Network and one for the BC Network. As these two Networks are closely linked, they are now reported in one annual report to provide administrative cost savings to the Environment Agency and Defra.

The PCN Network began operation in November 2001. Since then, the number and location of sites, and monitoring methodologies have transitioned through several iterations. NPL, supported by ERG, have operated the PCN Network contract since 2005. In 2025, it comprised five sites (Auchencorth Moss, Chilbolton Observatory, Horley, London Marylebone Road, and London Honor Oak Park). Multiple instruments are operated at most sites under this Network, with the purpose of providing data to improve understanding of airborne particulate matter (PM), with a focus on $PM_{2.5}$ and monitoring compliance with limits set out in the UK's Air Quality Standards regulations (AQSR) 2010[4-7], and all associated amendments, which reference the EU Ambient Air Quality Directive 2008[8,9], and support objectives set out in the UK's Clean Air Strategy 2019[10] and Environmental Improvement Plan 2023[11].

The purpose of the BC Network is to continue a historical dataset on black smoke (which dates back to the 1920s) and monitor BC mass concentrations. NPL was awarded the contract to restructure and run this Network in September 2006. In 2025, the BC Network comprised 26 sites (listed in Table 4).

Following the Environment Act 2021[12] and the new legally binding $PM_{2.5}$ targets published through the Environmental Targets (Fine Particulate Matter) (England) Regulations 2023[1], Defra requested an expansion of the Network to provide additional PM speciation data to enhance the measurement evidence base associated with the $PM_{2.5}$ environmental targets. This is referred to as the $PM_{2.5}$ MEP throughout this report. In 2025, the Network team were involved in various activities for expanding the Network.

2 Network infrastructure and operation

2.1 Overview

In 2025, the Network was managed in the same way as the previous year; no sites were commissioned or decommissioned. Further details are given in the sections below.

2.2 Network sites

In 2025, the Network comprised 27 sites (four PCN and BC, one PCN-only, and 22 BC-only). A map of all the sites is given in Figure 1. A list of PCN sites and instruments operating during 2025 is shown in Table 3. The locations for the BC sites are given in Table 4. Site details are available through Defra's UK Air Information Resource (AIR) website[2].

Four of the five sites that comprise the PCN Network (Auchencorth Moss, Chilbolton Observatory, London Marylebone Road, and London Honor Oak Park) are located to provide $PM_{2.5}$ OC/EC mass concentration data to assist in requirements of AQSR 2010. They also allow the benefit of the measurements made to be maximised, both in terms of drawing conclusions about the concentrations and chemical composition of particles in ambient air and understanding pollutant sources at these locations. A fifth site was incorporated into the PCN Network in 2024: an SMPS was installed at the Horley site, in collaboration with the Local Authority, Reigate and Barnstead Borough Council, to provide additional data in the proximity of Gatwick airport.

The 26 BC Network sites target the measurement of traffic emissions in urban areas, solid fuel and biomass burning emissions especially in Northern Ireland and Cardiff. They comprise a number of new urban and rural background sites added to the Network in 2024. For the purpose of presenting the data, the 26 BC sites are organised into six groups:

- **Northern Ireland:** Ballymena Ballykeel; Belfast Centre; Kilmakee Leisure Centre; Strabane 2.
- **Scotland**: Auchencorth Moss; Glasgow High Street; Glasgow Townhead.
- **Wales and the Midlands**: Birmingham A4540 Roadside; Birmingham Ladywood; Cardiff Centre; Derby Stockbrook; Shrewsbury Underdale.

- **London area**: London Honor Oak Park; London Marylebone Road; London North Kensington; London Teddington Bushy Park.
- **Northern England**: Barnsley Gawber; Blackburn Audley Park; Bradford Shipley Airedale Road; Glazebury; Newcastle Centre.
- **Other rural background sites**: Chilbolton Observatory; Detling; Ladybower; St Osyth; Wicken Fen.

The expanded Network builds on the original 14 sites and the London Honor Oak Park site, which became affiliated with the BC Network in 2024, to increase representation of urban background locations within London.

Ten new Aethalometers were installed at sites in England during 2024 as part of the $PM_{2.5}$ MEP, and one instrument was installed at London Teddington Bushy Park as part of an equivalence measurement campaign associated with the $PM_{2.5}$ MEP.

Figure 1 - Map of monitoring sites comprising the Network during 2025.
Key: orange = PCN and BC; yellow = PCN (SMPS only); black = BC (BAU, "business as usual"); blue = BC ($PM_{2.5}$ MEP); number = multiple sites in area.

Table 3 - List of sites comprising the PCN Network in 2025, including name, zone, UK AIR ID[2], and type and frequency of measurements.

Site Name	Designated zone for air quality assessment	UK AIR ID	Site Type [1]	Particle number concentration in $PM_{2.5}$	Particle size distribution (mobility diameter range 10 nm to 1000 nm)	Aerosol mass and speciation	40 elements in $PM_{2.5}$ and PM_{10} [2]	OC/EC in $PM_{2.5}$
Auchencorth Moss	Scotland - Central	UKA00451	RB	-	-	-	-	Weekly
Chilbolton Observatory	England - Southeast	UKA00614	RB	Hourly	15-minute	Hourly, $PM_{2.5}$	-	Daily
Horley	England - Southeast	UKA00511	SI	-	15-minute	-	-	-
London Marylebone Road	England - London	UKA00315	UT	Hourly	15-minute	Hourly, PM_{1}	Alternating hourly	Daily
London Honor Oak Park	England - London	UKA00656	UB	Hourly	15-minute	Hourly, $PM_{2.5}$	Alternating hourly	Daily

[Note 1] Site Type: RB = Rural Background; UB = Urban Background; UT = Urban Traffic; SI = Suburban Industrial.

[Note 2] The XRFs have a switching size fraction sampling inlet, measuring $PM_{2.5}$ and PM_{10} on alternate hours.

Table 4 - List of sites comprising the hourly Aethalometer measurements on the BC Network in 2025, including name, zone, network group, UK AIR ID[2], site type.

Site Name	Designated zone for air quality assessment	Network Group	UK AIR ID	Site Type [1]
Auchencorth Moss	Scotland - Central	Scotland	UKA00451	RB
Ballymena Ballykeel	Northern Ireland	Northern Ireland	UKA00503	UB
Barnsley Gawber	England - Yorkshire & Humberside	Northern England	UKA00353	UB
Belfast Centre	Northern Ireland	Northern Ireland	UKA00212	UB
Birmingham A4540 Roadside	England - West Midlands	Wales and the Midlands	UKA00626	UT
Birmingham Ladywood	England - West Midlands	Wales and the Midlands	UKA00655	UB
Blackburn Audley Park	England - North-west & Merseyside	Northern England	UKA01025	UB
Bradford Shipley Airedale Road	England - Yorkshire & Humberside	Northern England	UKA01090	UT
Cardiff Centre	Wales - South	Wales and the Midlands	UKA00217	UB
Chilbolton Observatory	England - South-east	Rural	UKA00614	RB
Derby Stockbrook	England - East Midlands	Wales and the Midlands	UKA01027	UB
Detling	England - South-east	Rural	UKA00481	RB
Glasgow High Street	Scotland - Central	Scotland	UKA00602	UT
Glasgow Townhead	Scotland - Central	Scotland	UKA00576	UB
Glazebury	England - North-west & Merseyside	Northern England	UKA00170	RB
Kilmakee Leisure Centre	Northern Ireland	Northern Ireland	UKA00570	UB
Ladybower	England - East Midlands	Rural	UKA00171	RB
London Honor Oak Park	England - London	London	UKA00656	UB
London Marylebone Road	England - London	London	UKA00315	UT
London North Kensington	England - London	London	UKA00253	UB
London Teddington Bushy Park	England - Greater London	London	UKA00572	UB
Newcastle Centre	England - North-east	Northern England	UKA00213	UB
Shrewsbury Underdale	England - West Midlands	Wales and the Midlands	UKA01055	UB
St Osyth	England - Eastern	Rural	UKA00445	RB
Strabane 2	Northern Ireland	Northern Ireland	UKA00393	UB
Wicken Fen	England - Eastern	Rural	UKA00362	RB

[Note 1] Site Type: RB = Rural Background; UB = Urban Background; UT = Urban Traffic.

2.3 Network management

The day-to-day operation of the Network is set up to mirror that of the Automatic Urban and Rural Network (AURN), which includes a central management and control unit (CMCU) and a quality assurance and quality control (QA/QC) unit. In 2025, NPL continued its role as the CMCU and QA/QC unit, with significant support from ERG.

CMCU activities include management of equipment, consumables, and health and safety; management of subcontractors such as local site operators (LSOs) and equipment support units (ESUs); collection and storage of data; reporting; and providing technical advice to the Environment Agency. QA/QC activities include ensuring adherence to the appropriate technical standards; training and auditing LSOs; managing equipment services and calibrations; and data ratification and submission to the data dissemination unit (DDU).

For CPC, SMPS, OC/EC, and Aethalometers, NPL perform the majority of the CMCU and QA/QC duties, with support from ERG, who are responsible for collecting and storing the CPC, SMPS, and BC data; and manage the ESU emergency callouts and scheduled services and calibration for the Aethalometers. NPL have continued to undertake OC/EC analyses in-house, including associated QA/QC activities.

ERG have continued to undertake the majority of the CMCU and QA/QC activities for the ACSM and XRF equipment, with support from NPL.

Further details of the operation of the instruments on the Network are given in section 2.5 and section 3.

2.4 Notable changes and activities

2.4.1 Overview

Notable changes and activities are detailed below.

2.4.2 Particle number concentration

The Network CPC at Birmingham Ladywood continued not to be operational during 2025. Discussions about preparing the site for installation of the equipment are currently on hold.

In 2025, there were two changes to the Network CPCs and their calibrations in order to align with the standard EN 16976:2024[13]: the 'd_{50}' size cut-off for the CPCs was changed from 7 nm to 10 nm, and the post-service linearity calibration was carried out using silver aerosols (rather than soot).

2.4.3 Particle size distribution

As part of the $PM_{2.5}$ MEP, the new SMPS (GRIMM, model 5420-TR-CEN) at Horley ran for a full year in 2025 and the data from this instrument was ratified and reported for the first time.

2.4.4 Aerosol mass speciation and composition

Prior to 2025, ACSM calibrations were carried out using the on-site SMPS. In 2025, an SMPS system containing a water-based CPC and an X-ray source neutraliser were procured for calibration use only and subsequently used for all calibrations.

2.4.5 Elemental analysis

In 2025, the analytical conditions were changed for a number of elements to extend the life of the X-ray tube in instrument. This change was carried out after recommendation by the manufacturer during service. This resulted in a small increase in the limit of detection for the following elements in both size fractions: Al, Ba, Ca, Ce, Cl, Cr, K, La, Mn, P, S, Si, Ti and V.

2.4.6 OC/EC

A notable operational change in 2025 was the introduction of an autoloader on one of the two Sunset Laboratory Inc. L5 thermal/optical carbon analysers used at NPL for OC/EC analysis of Network filters.

2.4.7 BC and UVPM

No notable changes were implemented in 2025.

2.5 Instrumentation

2.5.1 Particle number concentration

Particle number concentrations were measured using a TSI 3750-CEN10 CPC (Figure 2) or a 3772-CEN10 CPC, depending on the monitoring site.

The CPCs operate by drawing a continuous airborne particle sample through a heated saturator, in which butanol is vapourised and diffuses into the sample stream. The particle sample and butanol vapour pass into a cooled condenser, where the butanol vapour becomes supersaturated. Under these conditions, the butanol vapour condenses on the particles (down to 10 nm in size), growing quickly into larger droplets and enabling them to be counted optically *via* an optical detector. These CPCs are sensitive to particles from 10 nm up to a few micrometres in size and have a concentration measurement range from zero to 50 000 cm^{-3} or 100 000 cm^{-3} depending on the model.

The TSI 3772-CEN10 CPC was developed to comply with the requirements of the European Committee for Standardization (Comité Européen de Normalisation, CEN) Technical Specification CEN/TS 16976:2016[14], which has since been superseded by EN 16976:2024[13]. The CPC 3750-CEN10 meets all criteria specified in EN 16976:2024[13]. The CPCs operate in single particle counting mode with continuous real-time coincidence correction for particle concentrations up to 50 000 cm^{-3} for TSI 3772-CEN10 and up to 100 000 cm^{-3} for TSI 3750-CEN10. EN 16976:2024[13] outlines the measurement criteria for the control of humidity in the sampled aerosol.

The TSI 3750200 sampling system (Figure 2), shared between the SMPS and stand-alone CPC, was operating at London Marylebone Road, London Honor Oak Park and Chilbolton Observatory in 2025.

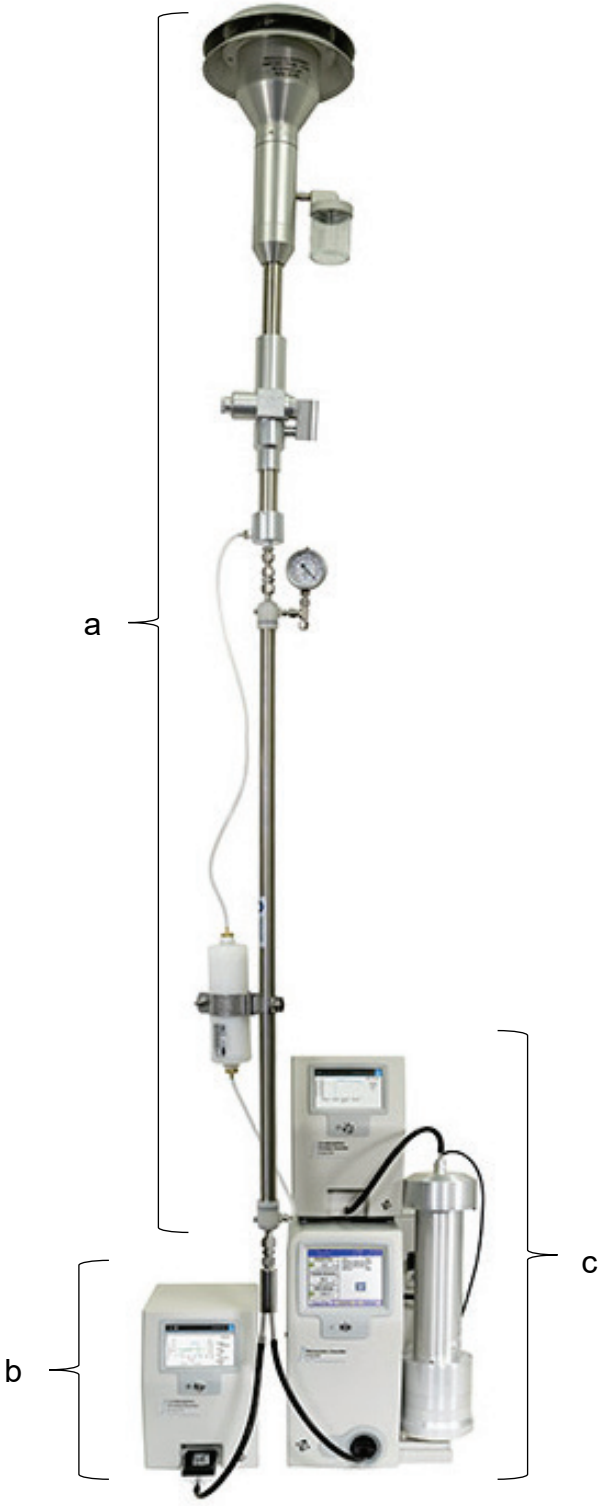

Figure 2 - a) TSI 3750200 sampling/drying system; b) TSI 3750-CEN10 CPC; c) TSI 3938W50-CEN-10 SMPS, consisting of TSI 3750-CEN10 CPC (top) and TSI 3082 electrostatic classifier and TSI 3083 DMA (bottom).
Photograph courtesy of TSI Incorporated.

2.5.2 Particle size distribution

Particle size distributions were measured using a TSI 3938W50-CEN10 SMPS (Figure 2) at London Marylebone Road, London Honor Oak Park and Chilbolton Observatory.

The TSI 3938W50-CEN10 SMPS system was used across the Network starting in 2025. It has a broader size range (nominally 10 nm - 800 nm) than the older TSI 3936 model (nominally 16 nm - 600 nm). It consists of a TSI 3750-CEN10 CPC combined with a TSI 3082 electrostatic classifier and a new TSI 3083 Vienna-type differential mobility analyser (DMA). The charge neutraliser in the electrostatic classifier brings the airborne particles in the sample to a known steady-state charge distribution and, at a specific voltage, the DMA allows particles of a specific electrical mobility (a quantity related to particle diameter) to pass to the CPC. By varying the operating voltage of the DMA, the size of particles sent to the CPC can be changed and a size distribution of particles in the sample is obtained. This SMPS is compliant with the CEN Technical Specification CEN/TS 17434:2020[15].

Using the TSI 3938W50-CEN10 SMPSs on the Network, it is possible to reliably determine the total particle number concentration (TNC) from the weighted combination of the concentrations from all SMPS size bins (TNC-SMPS). This, therefore, allows TNC-SMPS to be reported to UK AIR. Prior to 2024, the only TNC data reported was for TNC-CPC (using data from the standalone CPCs). It should be noted that the EN 16976:2024[13] standard method for determining TNC stipulates the use of a CPC. Variations between TNC-SMPS and TNC-CPC may be due to the effects of differing proportions of sub-20 nm particles in the sample – this is currently under further investigation in CEN TC264 WG32 (Air quality - Determination of the particle number concentration).

Figure 2 shows the new configuration of the SMPS, CPC, and sampling system typically found at Network sites. Note that instead of a TSI 3772-CEN10 CPC, a TSI 3750-CEN10 CPC is shown in the figure (as used at London Marylebone Road).

A GRIMM 5420-TR-CEN (Figure 3) was installed at the Horley site in October 2024. The GRIMM 5420-TR-CEN is a 19″ rack-mounted CPC, with an integrated DMA voltage controller, so it can be operated as a fully equipped SMPS system. Integrated pumps allow for an aerosol inlet flow rate of 0.6 L min^{-1} and a sheath-air flow rate of 3.0 L min^{-1}. The GRIMM 5420-TR-CEN is fully compliant with CEN/TS 17434:2020[15].

Figure 3 - GRIMM 5420-TR-CEN SMPS system. Photograph copyright of DURAG GROUP.

2.5.3 Aerosol mass and chemical composition

The Aerodyne Research Inc. (ARI) quadrupole Q-ACSM measures in real-time the mass and chemical composition of non-refractory aerosol particles in ambient air. It uses established aerosol mass spectroscopy technology to provide quantitative chemical composition measurements for particulate ammonium, nitrate, sulfate, and organics. It is designed for continuous monitoring of aerosol composition with long-term (typically, many weeks) unattended operation.

The instrument operates by sampling air into a high vacuum system through a size-selective particle aerodynamic lens at either PM_1 or $PM_{2.5}$. The aerodynamic lens focuses particles into a narrow beam which is directed to a resistively heated particle vaporiser, typically operated at 600 °C, mounted inside the electron impact ionisation chamber of a mass spectrometer, where non-refractory components in/on the particle flash vaporise. The vaporised constituents are ionised by electron impact and subsequently analysed with a quadrupole mass spectrometer which reports aerosol mass spectra (< 200 amu). These spectra are used to extract the chemically speciated aerosol mass loadings.

The reported mass concentration of each measurand is determined as the difference between a full spectrum scan of ambient air and a full spectrum scan taken through a HEPA filter (where no particles are present). Each scan takes just over 1 min to complete. Twenty-eight scans (14 of sampled air and 14 of air passed through the filter) over averaged over this 30 min period and then further averaged up to provide mean hourly mass concentrations. Figure 4 shows a schematic diagram of the set up.

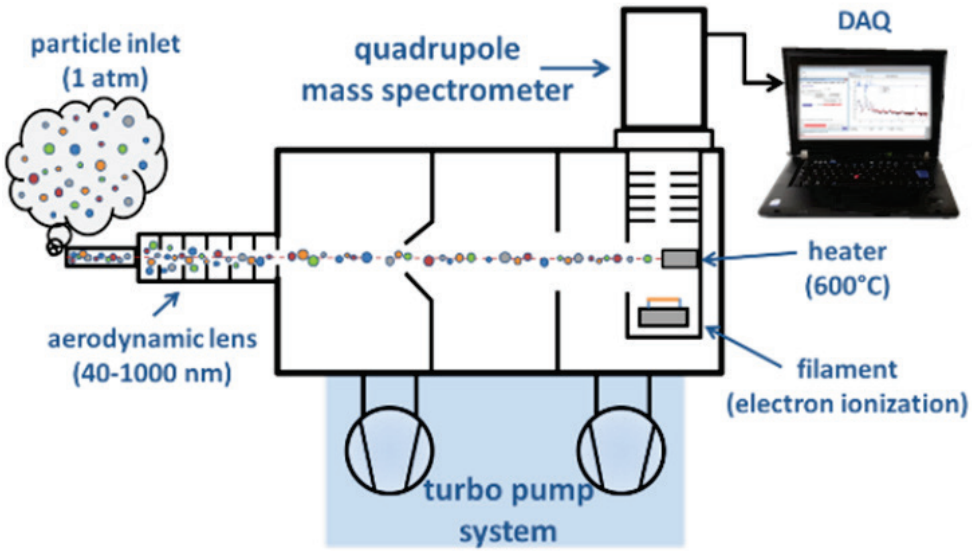

Figure 4 - ARI Q-ACSM schematic diagram (DAQ = Data acquisition and control). Image copyright of Deutscher Wetterdienst (DWD).

A Q-ACSM instrument was installed at London North Kensington in 2013 with a standard vaporiser and PM_1 aerodynamic lens. It was moved to London Honor Oak Park in November 2018 and the standard vaporiser was changed to a capture vaporiser and the aerodynamic lens changed to $PM_{2.5}$. The Q-ACSM instrument installed at London Marylebone Road in July 2020 has a capture vaporiser and PM_1 aerodynamic lens. At Chilbolton Observatory, a Q-ACSM with a capture vaporiser and $PM_{2.5}$ aerodynamic lens was installed in April 2022.

Following the acquisition of two ToF (Time of Flight) ACSMs with standard vaporisers, due to be deployed as part of the $PM_{2.5}$ MEP, the decision was made to harmonise the vaporiser types across the Network and thereby mitigate fragmentation anomalies in the organic mass fraction and improve source apportionment. The ToF-ACSM is very similar to the Q-ACSM except it uses a time-of-flight detector with the additional advantages of increased mass resolution and lower detection limits. In 2023, all the capture vaporisers were replaced with standard vaporisers (London Marylebone Road and London Honor Oak Park in April 2023, and Chilbolton Observatory in December 2023). Table 5 summarises the configuration of three Network ACSMs in 2025.

Table 5 - Configuration of Network ACSM instruments in 2025.

Site	Installation year	Vaporiser	Lens size fraction
Chilbolton Observatory	2022	Standard	$PM_{2.5}$
London Honor Oak Park	2018	Standard	$PM_{2.5}$
London Marylebone Road	2020	Standard	PM_1

2.5.4 Elemental analysis

The Cooper Environmental Xact® 625i XRF analyser (Figure 5) continuously and simultaneously measures the ambient mass concentration of 40 elements: Ag, Al, As, Ba, Bi, Br, Ca, Cd, Ce, Cl, Co, Cr, Cu, Fe, Ga, Ge, Hg, In, K, La, Mn, Mo, Ni, P, Pb, Pd, Pt, S, Sb, Se, Si, Sn, Sr, Te, Ti, Tl, V, Y, Zn, and Zr. The instrument collects PM samples on filter tape, which are then analysed by non-destructive XRF. The reel-to-reel filter tape sampling and subsequent analysis is engineered in a way that enables near real-time and continuous monitoring of the elemental composition of PM.

The instrument draws air at a flow rate of 16.7 L min^{-1} through a size selective inlet and across a filter tape. The sample that collects on the filter tape is automatically moved into the analysis area and analysed while the next sample is being collected. Measurements of one hour time resolution are achieved by conducting continuous sampling and analysis simultaneously. The sampling is only interrupted during tape advances and during internal QA/QC checks at midnight daily.

At both sites, the instrument uses a switching valve, which alternates between sampling PM_{10} and $PM_{2.5}$ on an hourly basis. The switching valve starts randomly on either PM_{10} or $PM_{2.5}$ after an intervention, such as a tape change. An analysis of the start times and the PM_{10} / $PM_{2.5}$ allocation has confirmed that no bias results from this approach.

Detailed information about the instrumentation can be found in Furger *et al*., 2017[16] and Tremper *et al*., 2018[17].

The XRF instrument installed at London Honor Oak Park was incorporated into the PCN Network in February 2022.The instrument at London Marylebone Road was installed in March 2022 and was fully operational from April 2022.

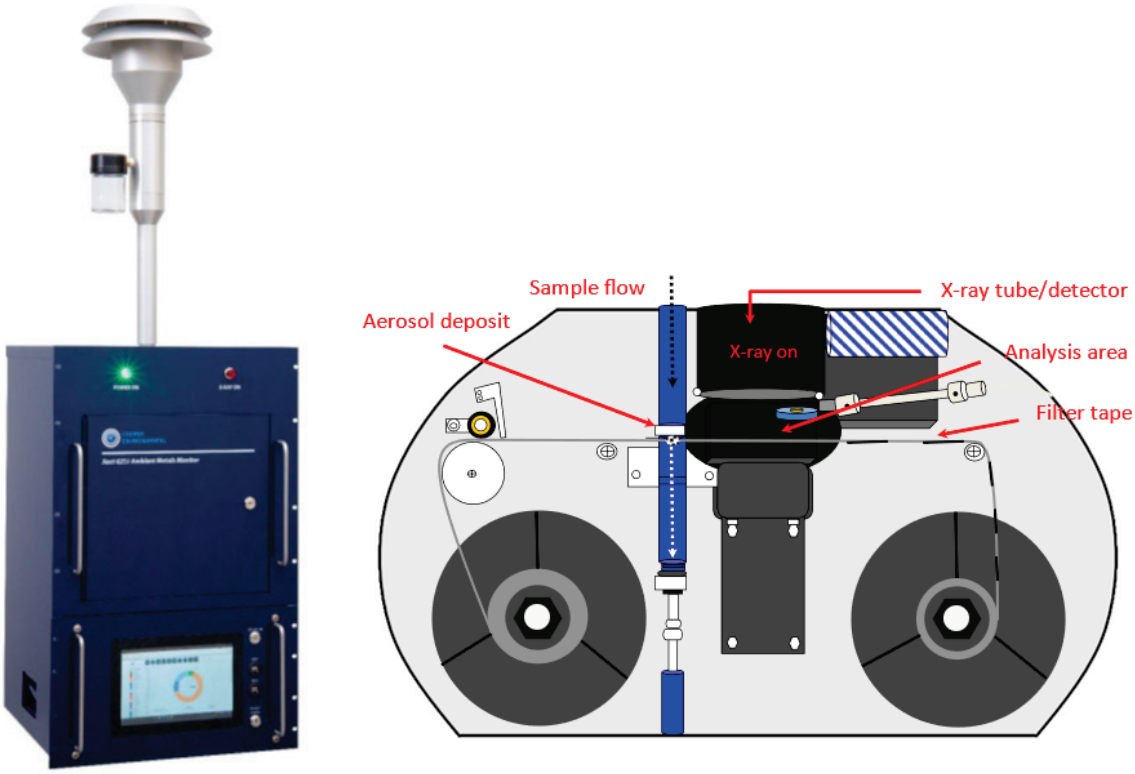

Figure 5 - Xact 625i instrument (left) and schematic of the sampling system (right). Images courtesy of Cooper Environmental Services.

2.5.5 OC/EC

OC and EC samples were collected on filters at four sites: Auchencorth Moss and Chilbolton Observatory (rural background); London Honor Oak Park (urban background); and London Marylebone Road (urban traffic). Ultrapure quartz filters (Pallflex Tissuquartz 2500QAT-UP) were used for sampling. In 2025, sampling of $PM_{2.5}$ continued at all four sites using Digitel DPA14 samplers (Figure 6).

OC/EC analysis of collected filters was carried out in the laboratory using a Sunset Laboratory Inc. thermal/optical carbon analysers with and without autoloader configurations (Figure 7). A 1.41 cm^2 or 1.50 cm^2 (depending on analyser configuration) punch is taken from each filter and analysed. The procedure involves heating the sample to remove PM from the filter, conversion of any carbonaceous material to methane, followed by detection by flame ionisation. In a helium atmosphere, the sample is gradually heated to 650 °C to remove organic carbon collected on the filter. During this first phase, organic compounds in the sample are pyrolytically converted to EC. Measuring the transmission of a laser beam through the filter continuously monitors this pyrolytic conversion and allows a correction to be made for it. EC is detected in the same way after heating to 850 °C in the presence of oxygen and helium. The analysis protocol used is termed EUSAAR2, as specified in EN 16909:2017[18]. The protocol also specifies that a transmittance correction must be used to determine mass concentrations of OC and EC. Data are reported as the mass of carbon per volume of air (µg m^{-3}).

Figure 6 - Digitel DPA14 sampler, photograph courtesy of Digitel AG.

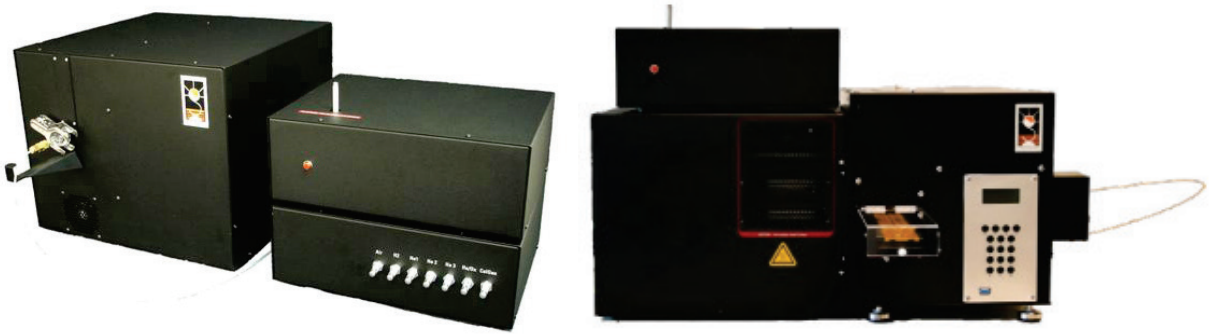

Figure 7 - Sunset Laboratory Inc. thermal/optical carbon analyser without autoloader (left – Model 4L) and with autoloader (right – Model 5L), photographs courtesy of Sunset Laboratory Inc.

2.5.6 BC and UVPM

BC is a measure of mass concentration of airborne soot-like carbon, based on the optical absorption of light at a specific wavelength (880 nm) by particulates collected on a filter. It is often assumed that BC and EC, a measure of soot-like carbon determined by thermo-optical techniques, are the same; however, in practice the measured mass concentration of the EC fraction of TC (total carbon) depends strongly on the method chosen. The term “equivalent black carbon (eBC)” is formally recommended for data which simply converts an aerosol absorption coefficient to a mass concentration.

Aethalometers measure BC on filter samples based on the transmission of light through the sample. In 2025, the BC Network used the Aerosol Magee Scientific AE33 instrument (Figure 8) across all sites.

This 7-wavelength AE33 instrument operates at 950 nm, 880 nm, 660 nm, 590 nm, 520 nm, 470 nm, and 370 nm, and samples $PM_{2.5}$ using an inlet flow of 5 L min^{-1}. The sample is collected onto a Teflon tape (M8060 type), and the optical attenuation is measured at a time resolution of 1 min. Two spots with different sample flows (approximately 1.5 L min^{-1} and 3.5 L min^{-1}) together with the reference spot (without flow), are used to calculate the attenuation. The rate of change of the attenuation of light, together with flow rate, spot area, and volume of the sample are mathematically converted to the compensated particle light absorption and a BC mass concentration. A mass absorption cross-section of 7.77 m^2 g^{-1} was used at 880 nm and one of 18.47 m^2 g^{-1} at 370 nm, as described in Drinovec *et al.*[19]. The results from the 880 nm channel (BC) give the quantitative mass concentration of 'black' carbon, and those from 370 nm channel (UV) indicate the presence of aromatic organic compounds such as those found in wood smoke, biomass-burning smoke, and tobacco smoke.

At all sites, ambient air is drawn into the sampling system through a standard rain cap mounted on the end of a vertical tube. Size selection of the sampled aerosol is made by a $PM_{2.5}$ cyclone placed close to the inlet of the Aethalometer. All the tubing upstream of the cyclone is constructed from stainless steel.

In this report, the term BC concentration refers to the mass concentration of particulate matter measured at the 880 nm wavelength (*i.e.*, within the infrared range). UVPM is calculated by subtracting the BC mass concentration from the UV mass concentration (determined from the 330 nm channel). UVPM can, in principle, be used as an indicator of organic compounds present in the sample, *e.g.* from wood or solid fuel emissions.

Figure 8 - Aerosol Magee Scientific AE33 Aethalometer.

3 Data quality

3.1 QA/QC procedures

3.1.1 General

NPL operates under a quality management system certified for scientific research and development and the provision of internal services by Lloyd's Register Quality Assurance (LRQA) according to ISO 9001:2015[20]. NPL is accredited by the UK Accreditation Service (UKAS) to ISO 17025:2017[21] for the general requirements for the competence of testing and calibration laboratories for OC/EC measurements (UKAS accredited testing laboratory No. 0002), and CPC calibration (UKAS accredited calibration laboratory No. 0478).

A summary of general QA/QC procedures used during the measurement and ratification process is given below:

- a Technical Lead (supported by expert consultants) is appointed for each instrument type to manage data collection and ratification;
- LSOs are periodically trained and audited on an ongoing basis to carry out routine maintenance and report issues. All LSO maintenance activities are recorded;
- each instrument type has an appointed ESU who is responsible for routine servicing and emergency repairs;
- an annual audit of all sites, LSOs, and instruments (including flow checks) is conducted by an independent NPL audit team;
- calibrations and checks are carried out at regular intervals throughout the year;
- data collection is performed manually for Digitel samplers by NPL and automated by the MONNET data handling system at ERG for all other instruments. All data are stored securely and backed up;
- the quarterly Network reports include data capture values from the verified data of the previous quarter;
- automatic and manual data validation is followed by rigorous ratification procedures;
- data quality circle meetings are held at least annually to review and validate the data. Other measurements made in this monitoring programme and in other EA monitoring programmes are also used to check the validity of the measurements.

The key additional measurement-specific QA/QC procedures are summarised in the following sections.

3.1.2 Particle number concentration

- The manufacturer's software is set up to automatically perform measurements every 15 min. This data is used to calculate hourly averages.
- NPL is accredited by UKAS to ISO 17025[21] to perform the calibration of CPCs directly against the UK primary reference electrometer. The primary calibration of CPC instruments is by comparison with a Faraday cup aerosol electrometer (FCAE) which NPL have ISO 17025[21] UKAS accreditation to calibrate. The reference FCAE and the test CPC simultaneously measure the particle number concentration of a test sample being produced by a well-characterised aerosol generator. The results obtained are corrected for any multiple charges on the test particles. The calibration factors are then applied during ratification to give the best estimate of the particle number concentrations.
- The CPC instruments undergo annual servicing: replacing the saturator wick, cleaning the critical orifice, and replacing any discoloured or damaged tubing. The CPC firmware is also checked at this stage and updated to the latest version if required.

3.1.3 Particle size distribution

- The LSO confirms that the radioactive source is present and makes a radiation measurement monthly.
- The manufacturer's software is set up to automatically repeat 140 s scans every 3 min. This is then used to calculate 15 min averages by ERG software.
- The CPC part of the SMPS is calibrated at NPL (see section 3.1.2).
- For the SMPS calibration process carried out by NPL, an aerosol containing a single size of polystyrene latex nanospheres is used to check the sizing accuracy. This aerosol is generated using a nebuliser and conditioned with a diffusion dryer.
- The SMPS instruments undergo annual servicing of the CPC component: replacing the saturator wick, cleaning the critical orifice, and replacing any discoloured or damaged tubing. The CPC firmware is also checked at this stage and updated to the latest version if required.
- The DMA column is sent to the manufacturer for cleaning and maintenance if a shift in particle size distribution outside of acceptance criteria of the NPL DMA calibration is observed.

3.1.4 Aerosol mass and chemical composition

- The LSO attends the instruments every fortnight to perform checks on the instrument and software. These include flow rate checks, pinhole and inlet cleaning, and instrument tuning using ACTRIS (Aerosol, Clouds, and Trace Gases Research Infrastructure) standard operating procedures (SOPs) developed for the ACSM[22].
- Calibrations are scheduled to be performed annually by trained technical users. Particles of ammonium sulfate and ammonium nitrate are generated from solution and then size-selected by passing through the DMA of the SMPS. Particles are then counted by the CPC (which is calibrated annually at NPL following the method in section 3.1.2) to produce a particle stream of known mass concentration before entering the ACSM. The stream is diluted with different ratios of particle-free air to produce a calibration curve.
- Data processing is performed by the proprietary software. Data are scaled and corrected for pressure, flow and temperature using ACSM ACTRIS SOPs[22]. Sensibility checks are performed by mass closure comparison to co-located PM mass measurements.

3.1.5 Elemental analysis

- During daily data checking, the results from the internal standards and automated overnight standards are checked for deviations.
- The LSO attends the instruments every fortnight to perform checks on the instrument and software. These include inlet cleaning and tape changes (as required).
- Flow rate checks and calibration checks are performed every quarter by trained technical users. For the calibration checks, five thin film standards covering different analysis conditions of the instrument are used to verify the instrument operates within its parameters.
- Annual services are carried out by trained engineers from the ESU.
- A full calibration of the instrument is performed after any change of the X-ray tube.
- Date processing is performed using ERG owned software. Data are scaled and corrected for flow. Sensibility checks are performed by comparison to co-located PM and chemical speciation instrument measurements.

3.1.6 OC/EC

- The Digitel DPA14 sampler is compliant with EN 12341:2023[23]. The four flow calibrations and flow checks carried out during the year are used to calculate and apply a flow correction to the data.
- Sampled filters received at NPL Teddington are recorded, handled, stored, and analysed following NPL's UKAS accredited in-house procedure for OC/EC samples.
- NPL's analysis procedure describes a method for the accurate measurement of the collected TC on ambient air monitoring filters, subdivided into OC and EC. As part of this procedure, field blank filters are analysed to evaluate the contamination due to the transport of the filters to the sites and back to the laboratory.

3.1.7 BC and UVPM

- Measurements of BC, UVPM, flow rate, tape life and data from the other five Aethalometer channels are remotely downloaded using the ERG's data handling system (MONNET). A range of checks are undertaken at this point to ensure measurements are within the threshold value range; the flow data are also checked to ensure it is 5 L min-1 (± 10 %).
- Issues raised during manual data checking are noted in the database. This information is retained and passed to NPL to inform the ratification process. Occasionally, issues raised during data checking require an intervention from either the LSO or ESU. In this case, a visit request is sent to either the LSO or ESU.
- The validated 1 min measurements are averaged to 15 min means in accordance with measurements made using gaseous and particulate monitors in the AURN. A valid 15 min measurement is only calculated where at least ten valid 1 min measurements exist in that 15 min period. Hourly averages are calculated if there are at least three valid 15 min averages in that period.

3.2 Measurement uncertainty

3.2.1 Particle number concentration

The expanded (k = 2) uncertainty of these measurements is currently 3.5 %, in accordance with NPL's ISO 17025 UKAS accreditation. This value is based on the results of the Consultative Committee for Amount of Substance: Metrology in Chemistry and Biology International Comparison CCQM-K150[24].

3.2.2 Particle size distribution

The expanded uncertainty of these size measurements is 4.0 %. The main component of this measurement uncertainty, as determined by NPL, is due to the uncertainty in the mobility diameter of polystyrene latex beads used in the calibration.

3.2.3 Aerosol mass and chemical composition

The uncertainty in the ACSM measurements is obtained by comparison of the sum of measured mass concentrations with a regulatory measurement of time-resolved mass concentration of particulate matter, by a Tapered Element Oscillating Microbalance Filter Dynamics Measurement System (TEOM FDMS), Beta Attenuation Monitor (BAM) or Fine Dust Analysis System (FIDAS) aerosol spectrometer. The correlation between measurements obtained by ACSM and particle mass measurements is taken into account in this process.

According to the results of the European ACTRIS interlaboratory comparison campaign[25] in 2013, the relative expanded uncertainties of the measured mass concentration from hourly ACSM measurements are equal to 9 % for the sum of the five measurands in non-refractory sub-micrometre aerosols. Relative uncertainties for individual measurands are 15 % for nitrate, 19 % for organics, 28 % for sulfate and 36 % for ammonium.

3.2.4 Elemental analysis

The XRF calculates and reports an uncertainty with each hourly mass concentration measurement. These calculated uncertainties vary depending on the mass concentration and element being measured, with the relative uncertainty of each hourly measurement typically being larger at lower mass concentrations.

The dominant uncertainty contribution is typically from the spectral deconvolution process applied by the instrument (*i.e.*, the process of resolving the signal from the detector into individual peaks that can be quantified).

As examples of the magnitude of the estimated uncertainties reported by the XRF, the average relative uncertainties from an hourly measurement of iron (one of the most abundant elements) and zinc (an element of lower abundance, but still above the limit of detection in almost all measurements) in 2025 are shown in Table 6.

Table 6 - Average relative expanded uncertainties of highest and lowest abundance elements from hourly XRF measurements in 2025.

	Average relative expanded uncertainties / %			
	London Marylebone Road		**London Honor Oak Park**	
	$PM_{2.5}$	**PM_{10}**	**$PM_{2.5}$**	**PM_{10}**
Fe	13.2	13.0	14.0	13.3
Zn	14.3	16.2	19.0	17.0

3.2.5 OC/EC

The uncertainty in the measured TC mass concentrations is a combination of the analytical uncertainty and the uncertainty in the measured sample volume. The expanded analytical relative uncertainty for TC has been found to be 6 %. EN 12341:2023[23] requires the consistency of the average volumetric flow rate for $PM_{2.5}$ and PM_{10} samplers to be ≤ 2 % over the sampling period. The uncertainty of the measurement of OC and EC is therefore dominated by the analytical uncertainty.

3.2.6 BC and UVPM

A standardised method for the determination of the uncertainty in BC mass concentration has not been formulated yet. This is however one of the deliverables in the European Partnership of Metrology project for the standardisation of BC aerosol metrics, STANBC[26]. NPL's current uncertainty budget estimates the expanded uncertainty for the annual mass concentration of BC measured using the AE33 Aethalometer to be 9 %, with the dominant contribution arising from the uncertainty in the measurement of the flow rate. Uncertainties related to the default parameters used in the Aethalometer algorithm are not yet taken into account.

The Aethalometer measurement of BC does not depend on the absolute calibrated response of the detectors but relies instead upon their ability to determine very small relative changes in optical transmission. The repeatability of the Aethalometer when sampling zero air has been assessed to be < 0.2 % relative to typical Network concentrations over a period of a year, and therefore it is a negligible contribution to the overall uncertainty.

The uncertainty in the annual mass concentration of UVPM is expected to be of the same magnitude as that in the annual mass concentration of BC, as both are dominated by the uncertainty in the flow rate.

3.3 Scheduled instrument service and calibration

3.3.1 CPC

NPL holds ISO 17025[21] accreditation for CPC calibration. The Network CPCs are serviced (replacing the saturator wick, cleaning the critical orifice, and replacing any discoloured or damaged tubing) and calibrated at NPL on an annual basis. Details of the calibration and servicing are provided in section 3.1.2.

3.3.2 SMPS

The SMPS instruments have been serviced (CPC component serviced by replacing the saturator wick, cleaning the critical orifice, and replacing any discoloured or damaged tubing) and calibrated at NPL on an annual basis. Details of the calibration are provided in section 3.1.3.

3.3.3 ACSM

The ACSMs are managed by ERG staff who perform monthly flow checks and *ad hoc* instrument tuning, pinhole cleaning, and inlet cleaning. Repairs are carried out by the ERG operator following manufacturer (Aerodyne) advice and procedures. The instruments are calibrated at least once annually using laboratory ammonium sulfate and ammonium nitrate standards.

3.3.4 XRF

The XRF instruments are managed by ERG and ACOEM UK Ltd. ERG carry out tape changes and *ad hoc* checks, as well as routine flow checks and three-monthly calibration checks. Annual services are carried out by ACOEM UK Ltd. These services can include a full instrument calibration if the X-ray tube has been changed. ACOEM UK Ltd also carries out *ad hoc* callouts and repairs.

3.3.5 Digitel samplers and OC/EC analyser

In 2025, the Digitel DPA14 samplers were serviced by the Environment Agency's Ambient Air Monitoring (AAM) Team. These 6-monthly services include replacing old or worn parts, cleaning, sensor and flow checks and calibrations, leak tests, and time and date checks.

The Sunset Laboratory Inc. L5 thermal/optical carbon analyser is serviced annually by a Sunset Laboratory Inc. service engineer, as per manufacturer's guidelines. The service involves replacing worn parts, and a full test and calibration. NPL run a daily calibration check prior to sample analysis using a laboratory blank filter and a filter spiked with a traceable standard solution.

3.3.6 Aethalometers

The AE33 Aethalometers were serviced by ACOEM UK Ltd. These 6-monthly service visits include replacing old or worn parts, cleaning cyclones/optics, flow calibrations, leak tests and tape mechanism check. Service visits are either scheduled or carried out during a callout visit.

3.4 Data Capture

3.4.1 Overview

Data capture is calculated as the percentage of time for which valid measurements exist across the intended measurement period (*e.g.*, excluding downtime for planned calibrations).

The tables below show the annual data capture for 2025 for each instrument at each site. In the cases where an instrument measures more than one analyte, an average has been calculated for each site. All values are stated to the nearest whole percentage.

3.4.2 Particle number concentration

No significant losses were observed outside of normal maintenance schedules.

Table 7 - Data capture for particle number concentration measurements.

Site	Data capture / %
Chilbolton Observatory	88
London Honor Oak Park	82
London Marylebone Road	85
Average	**85**

3.4.3 Particle size distribution

No significant losses were observed outside of normal maintenance schedules.

Table 8 - Data capture for particle size distribution measurements.

Site	Data capture / %
Chilbolton Observatory	73
Horley	89
London Honor Oak Park	80
London Marylebone Road	88
Average	**83**

3.4.4 Aerosol mass and chemical composition

Data loss at London Honor Oak Park in 2025 occurred mainly due to computer connection issues and software crashes. Further data loss resulted from the detector in the mass spectrometer reaching its maximum secondary electron multiplier (SEM) capacity and a backing pump failure at the end of December. A new replacement ACSM was installed on site in January 2026. The Chilbolton ACSM suffered from multiple part failures in July 2025. Firstly, one of the mass spectrometer electronic boards failed. On replacing this it was found that the second filament in the vaporiser region had also failed and two new filaments were procured and installed. Finally, the backing pump required a diaphragm overhaul. Measurements were restarted in December 2025.

Table 9 - Data capture for aerosol mass and chemical composition measurements.

Site	Data capture / %
Chilbolton Observatory	53
London Honor Oak Park	86
London Marylebone Road	97
Average	**79**

3.4.5 Elemental analysis

Minor non-scheduled data losses occurred at both sites in 2025 due to the tape running out outside of scheduled tape changes and unexpected errors, such as X-ray tube failure, USB port failure for the licence key, tape wheel loosening and power cuts.

Table 10 - Data capture for elemental measurements.

Site	Data capture / %
London Honor Oak Park	93
London Marylebone Road	72
Average	**82**

3.4.6 OC/EC

All the samplers functioned without any major issues in 2025. Data loss occurred at Chilbolton Observatory due to temperature and pressure sensor errors.

Table 11 - Data capture for OC/EC measurements.

Site	Data capture / %
Auchencorth Moss	96
Chilbolton Observatory	89
London Honor Oak Park	98
London Marylebone Road	100
Average	**96**

3.4.7 BC and UVPM

The majority of the Aethalometers operated without any major issues in 2025. Causes of data capture less than 90 % are detailed below.

- **Auchencorth Moss:** short-term intermittent communication issues during the whole year and internal instrument memory issue in February 2025.
- **Ballymena Ballykeel:** the instrument was removed from site in December 2024 and reinstalled in January 2025 after repair. The site was not operational in March 2025 due to planned maintenance of the cabin roof.
- **Belfast Centre:** short-term intermittent communication issues during the whole year.
- **Birmingham Ladywood:** short-term intermittent communication issues during the whole year.
- **Bradford Shipley:** short-term intermittent communication issues during the whole year. Instrument collected for repair in December 2025.
- **Cardiff Centre:** the site was not operational from February to April 2025 due to planned maintenance of the cabin roof.
- **Chilbolton Observatory:** short-term intermittent communication issues during the whole year.
- **London Honor Oak Park:** the inlet tubing was accidentally disconnected from June to August 2025.

Table 12 - Data capture for BC measurements.

Site Name	Data captured / %
Auchencorth Moss	84
Ballymena Ballykeel	85 (79*)
Barnsley Gawber	95
Belfast Centre	89
Birmingham A4540 Roadside	93
Birmingham Ladywood	88
Blackburn Audley Park	96
Bradford Shipley Airedale Road	85
Cardiff Centre	98 (82*)
Chilbolton Observatory	89
Derby Stockbrook	97
Detling	96
Glasgow High Street	96
Glasgow Townhead	92
Glazebury	96
Kilmakee Leisure Centre	94
Ladybower	99
London Honor Oak Park	81
London Marylebone Road	99
London North Kensington	93
London Teddington Bushy Park	94
Newcastle Centre	99
Shrewsbury Underdale	98
St Osyth	97
Strabane 2	92
Wicken Fen	95
Average	**93 (92*)**

* Downtime due to planned site maintenance activities has been excluded from the data capture calculation (data capture including this downtime is included in brackets).

4 Network data

4.1 Particle number concentration

4.1.1 2025 time series

Time series of CPC and SMPS hourly particle number concentrations (between approximately 10 nm and 2.5 µm in diameter) measured at Network sites during 2025 are shown in Figure 9 to Figure 12.

4.1.2 2025 diurnal, weekly, and monthly profiles

The diurnal, weekly, and monthly profiles for particle number concentrations from both CPCs and SMPSs at Network sites in 2025 (where available) are shown in Figure 13 to Figure 19.

4.1.3 Long-term trends

Figure 20 and Figure 21 show long-term annual trends for CPC measurements at all sites since 2005. The 2017 data are omitted due to data loss from delays in installing new CPCs in that year and flow issues with the CPC drier systems after installation. There was insufficient data capture to generate a datapoint for Chilbolton Observatory in 2023.

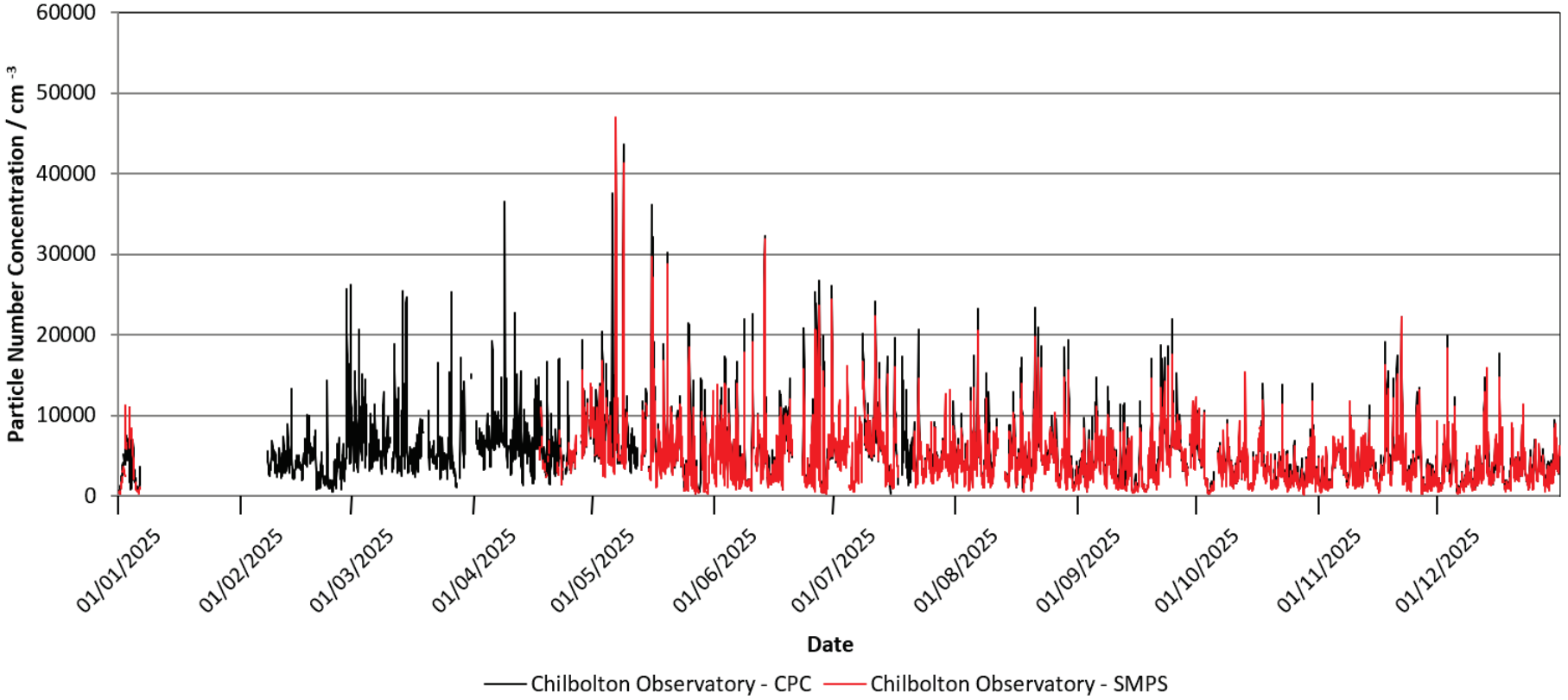

Figure 9 - Hourly particle number concentrations from both CPC and SMPS instruments at Chilbolton Observatory in 2025.

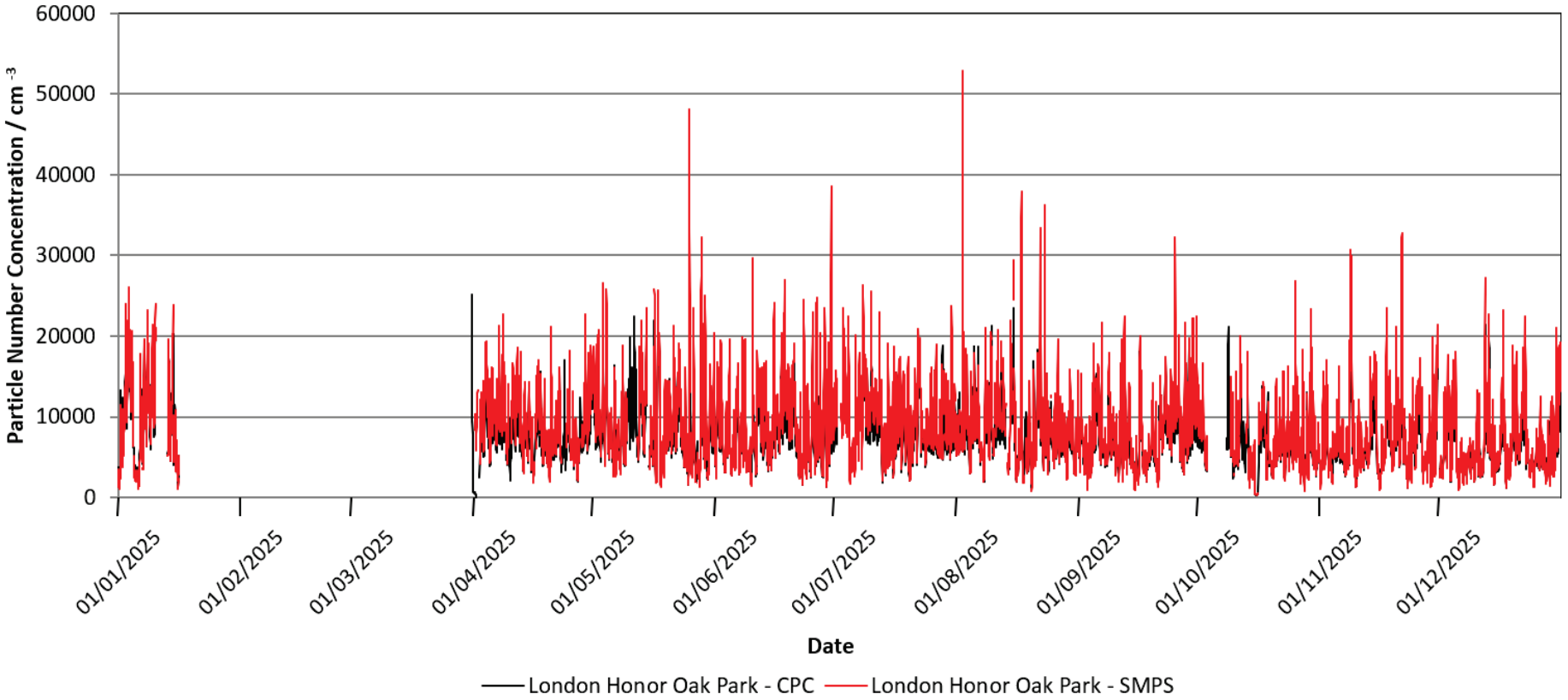

Figure 10 - Hourly particle number concentrations from both CPC and SMPS instruments at London Honor Oak Park in 2025.

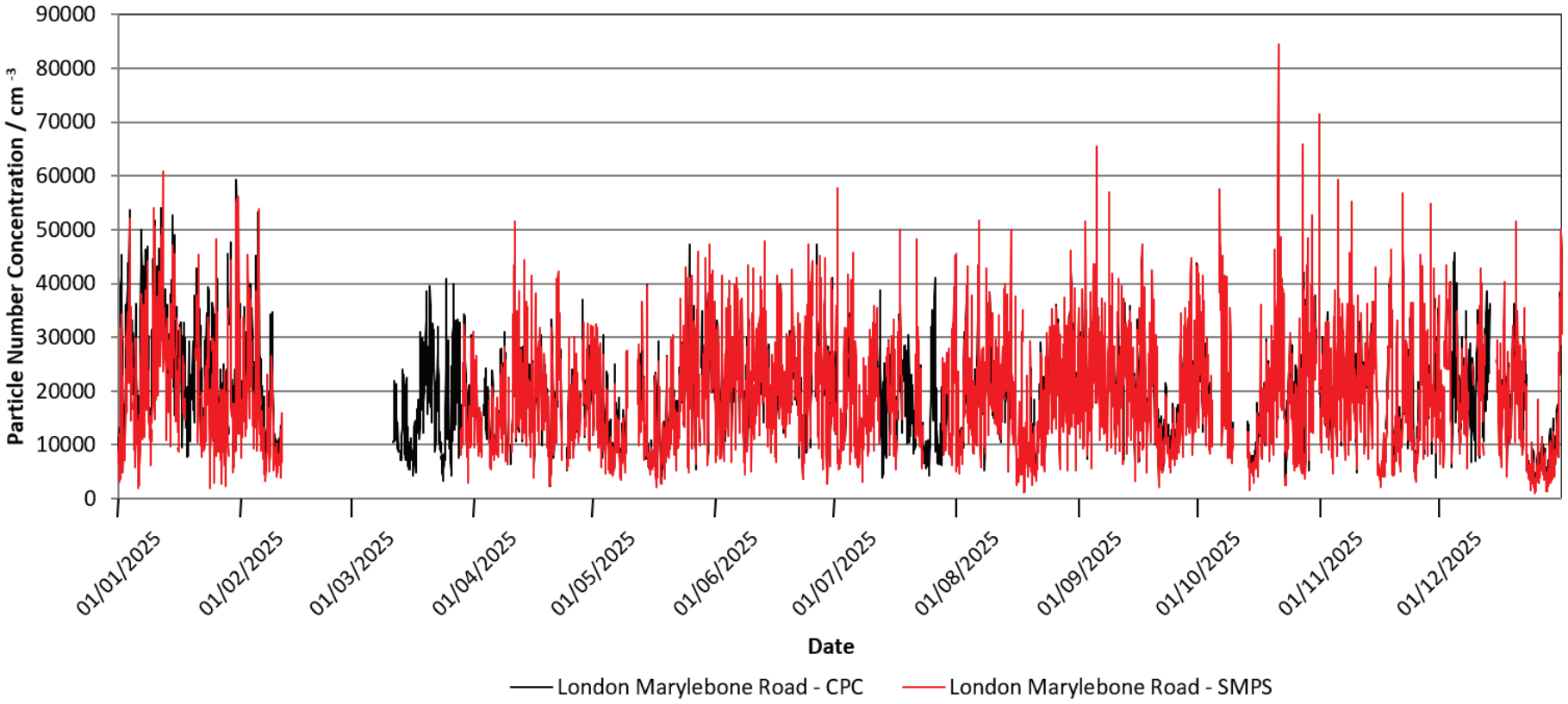

Figure 11 - Hourly particle number concentrations from both CPC and SMPS instruments at London Marylebone Road in 2025.

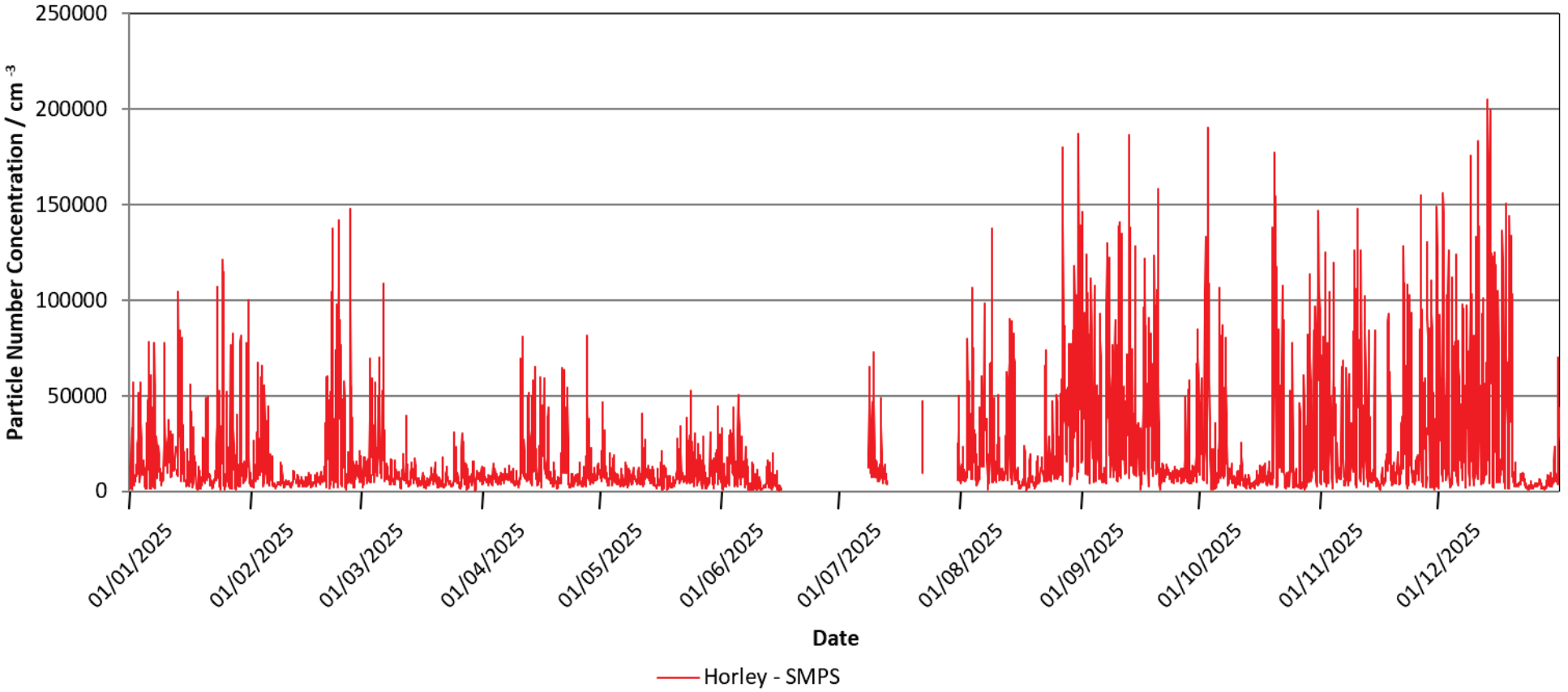

Figure 12 - Hourly particle number concentrations from SMPS instrument at Horley in 2025.

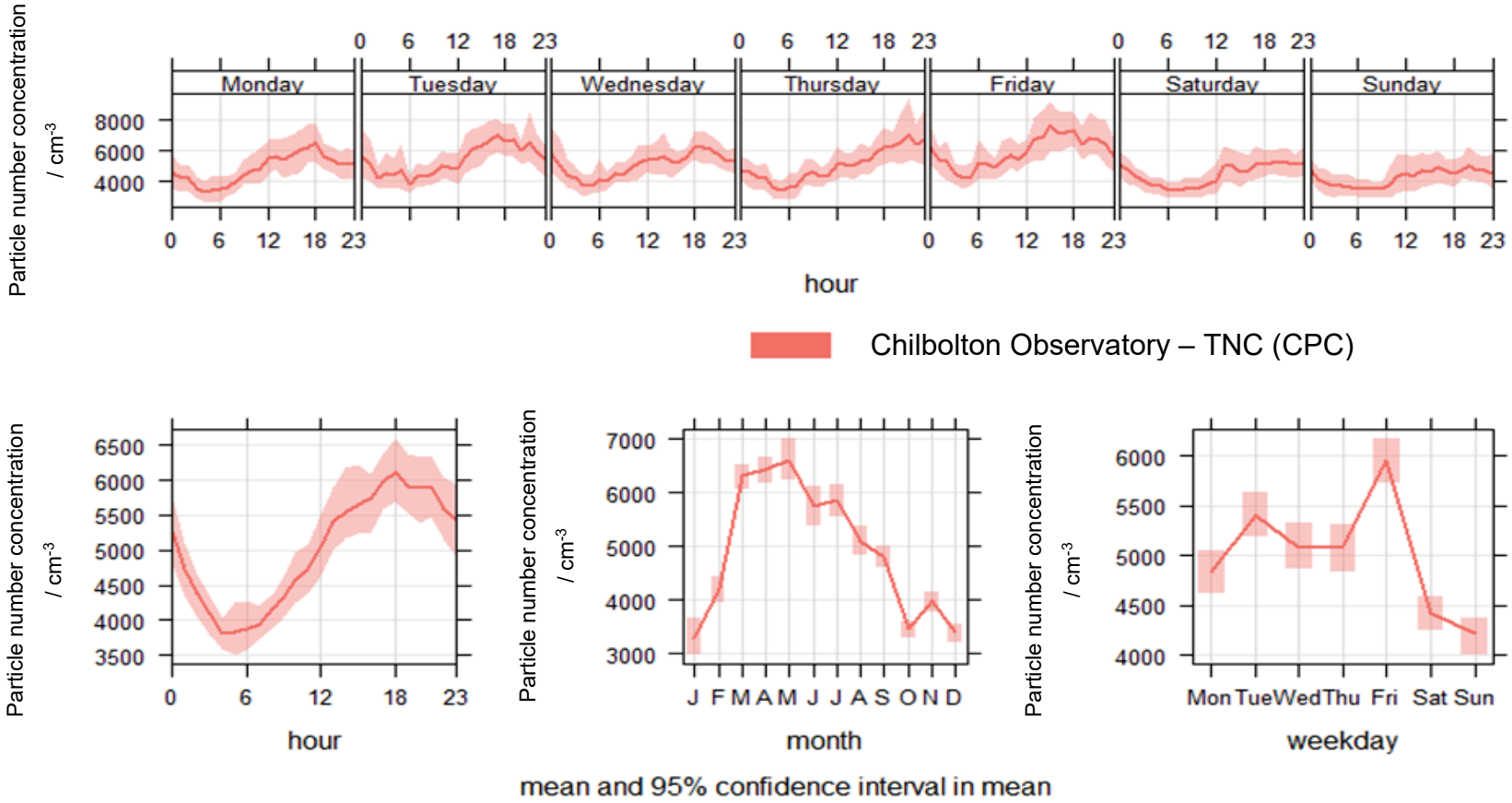

Figure 13 - Diurnal, weekly and monthly variations in CPC total particle number concentrations in 2025 at Chilbolton Observatory. The solid lines represent the mean total particle number concentration, and the shaded areas represent the 95 % confidence interval in the mean. Note that any line joining non-consecutive months in the monthly plot is automatically produced by the software used to generate the plot and is not intended to represent the particle number concentration of the 'missing' month(s).

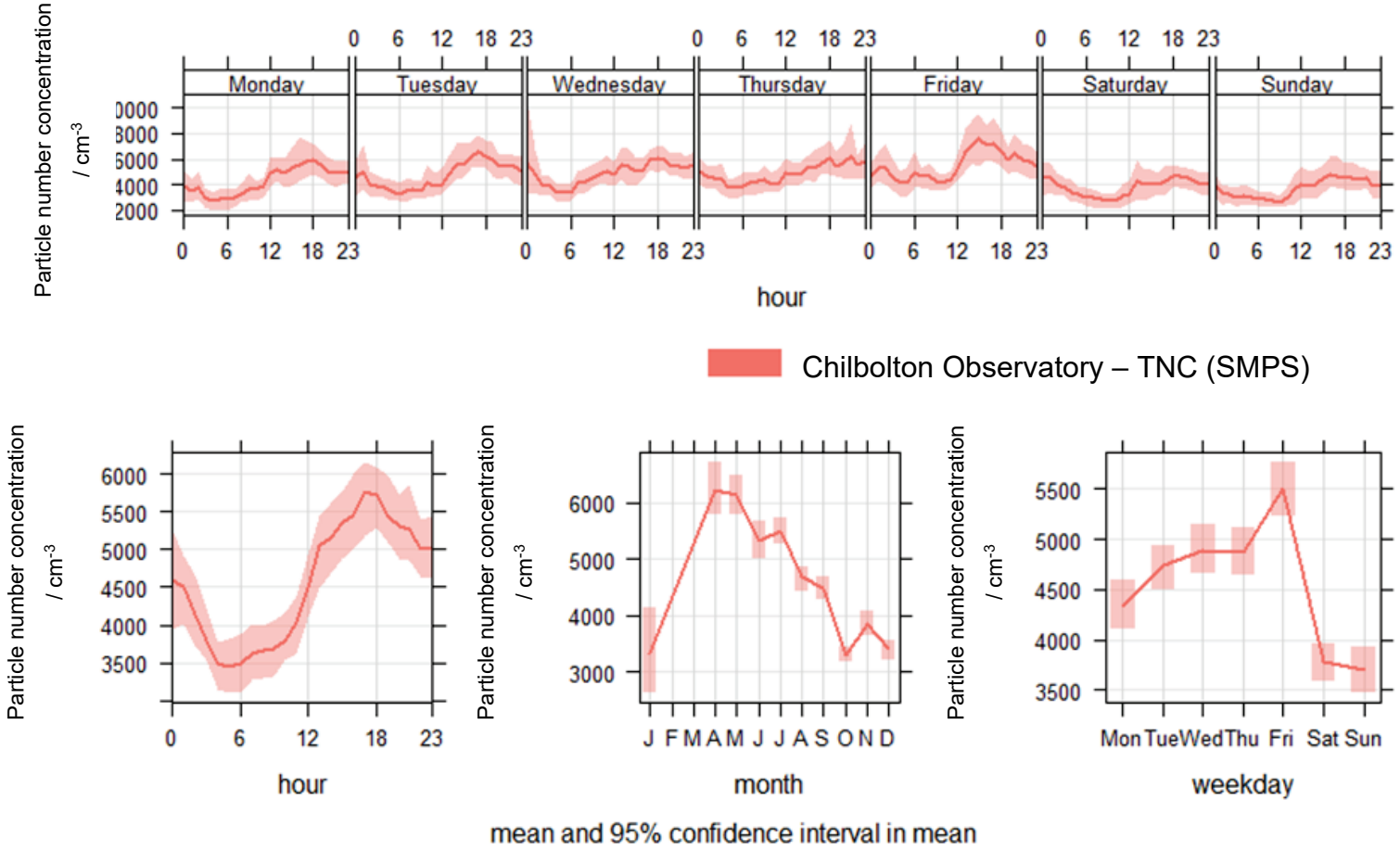

Figure 14 - Diurnal, weekly and monthly variations in SMPS total particle number concentrations in 2025 at Chilbolton Observatory. The solid lines represent the mean total particle number concentration, and the shaded areas represent the 95 % confidence interval in the mean. Note that any line joining non-consecutive months in the monthly plot is automatically produced by the software used to generate the plot and is not intended to represent the particle number concentration of the 'missing' month(s).

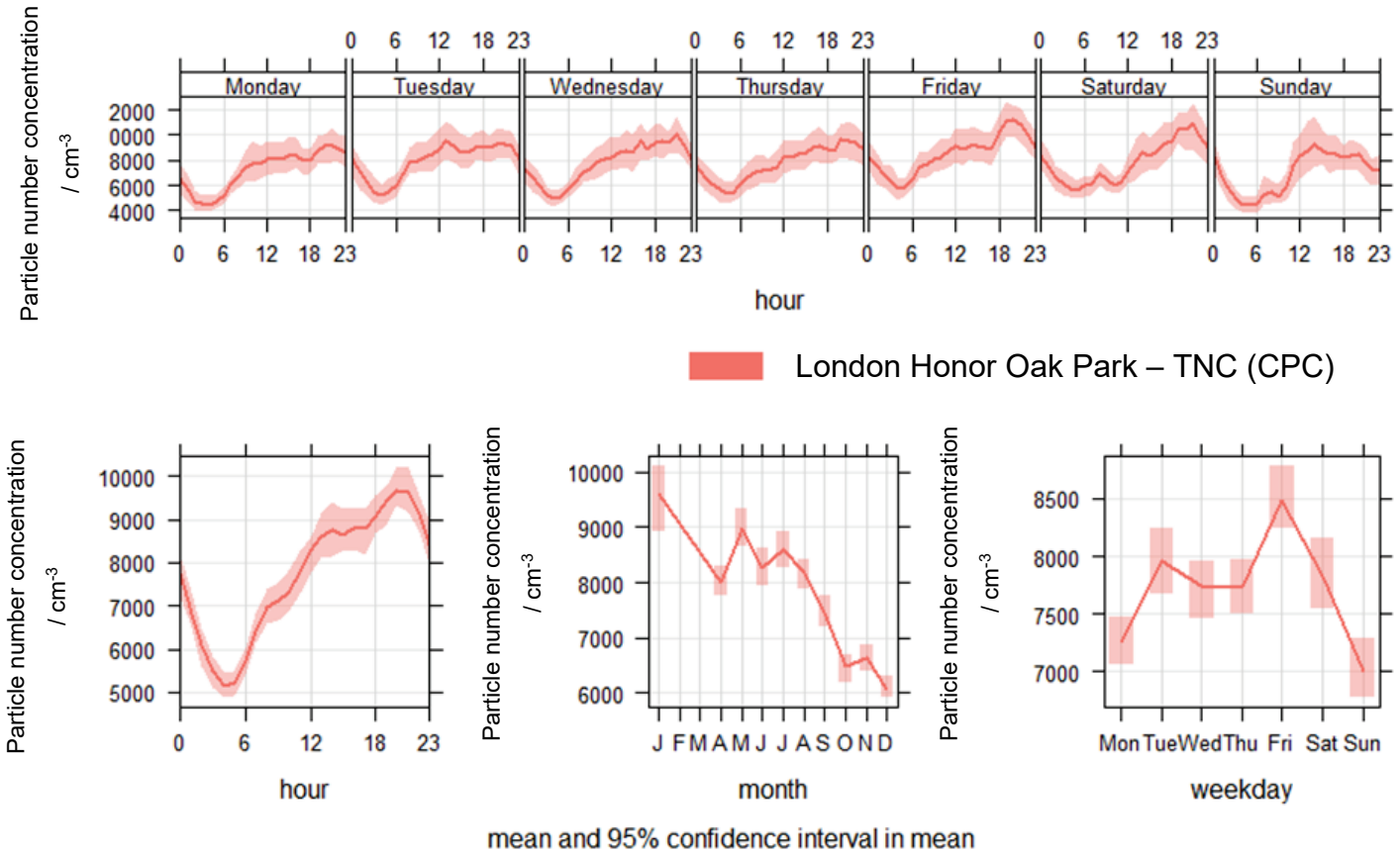

Figure 15 - Diurnal, weekly and monthly variations in CPC total particle number concentrations in 2025 at London Honor Oak Park. The solid lines represent the mean total particle number concentration, and the shaded areas represent the 95 % confidence interval in the mean. Note that any line joining non-consecutive months in the monthly plot is automatically produced by the software used to generate the plot and is not intended to represent the particle number concentration of the 'missing' month(s).

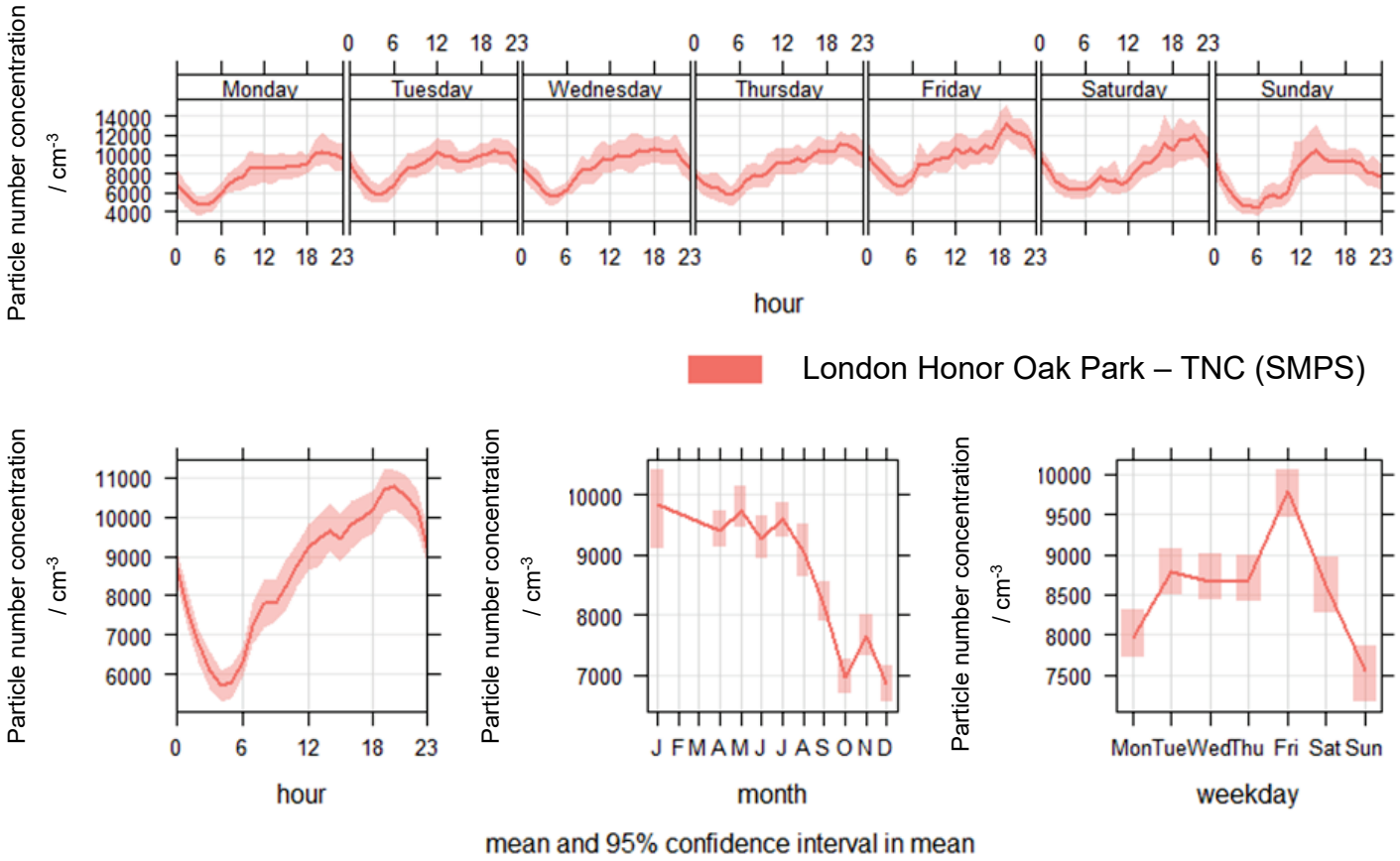

Figure 16 - Diurnal, weekly and monthly variations in SMPS total particle number concentrations in 2025 at London Honor Oak Park. The solid lines represent the mean total particle number concentration, and the shaded areas represent the 95 % confidence interval in the mean. Note that any line joining non-consecutive months in the monthly plot is automatically produced by the software used to generate the plot and is not intended to represent the particle number concentration of the 'missing' month(s).

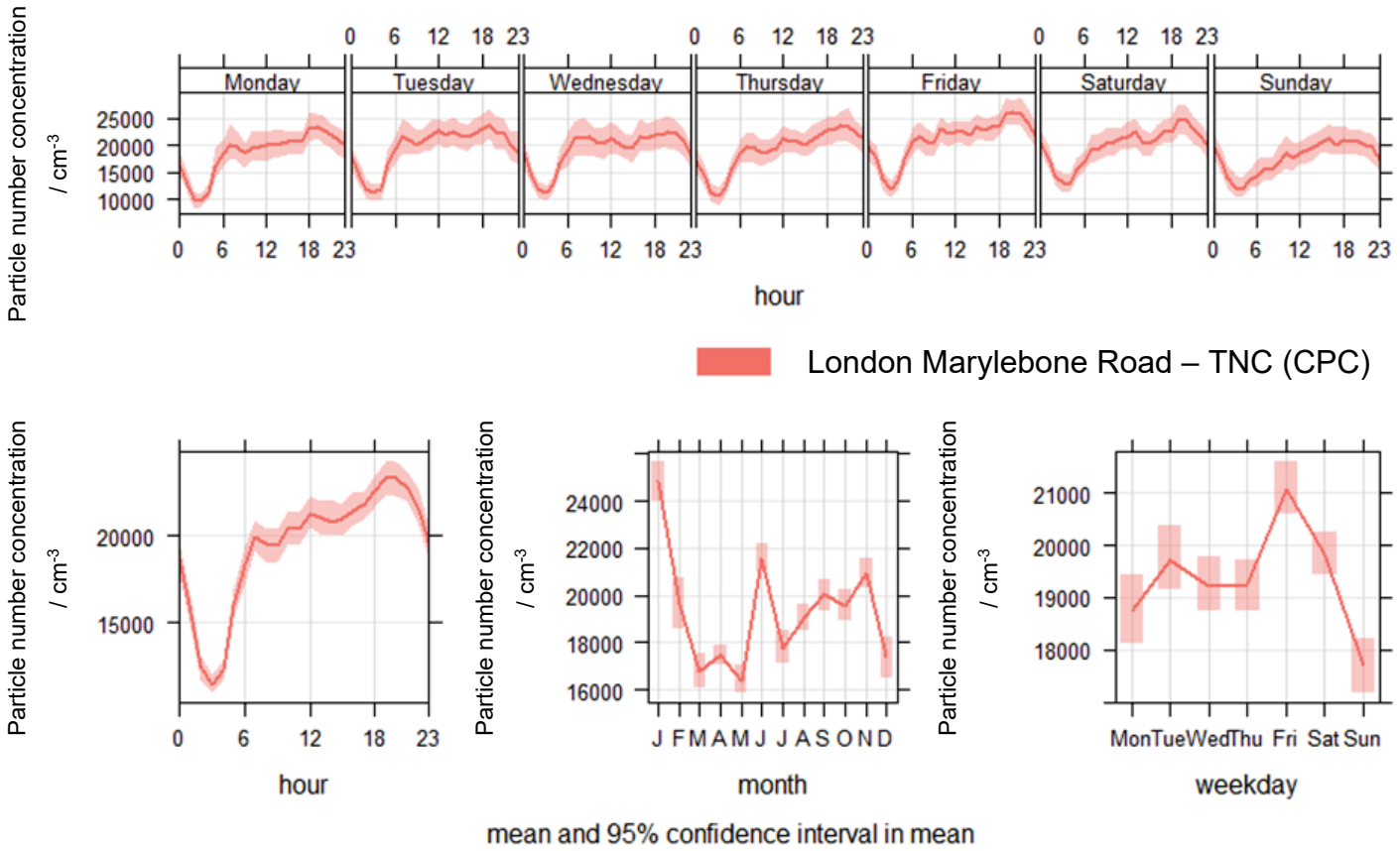

Figure 17 - Diurnal, weekly and monthly variations in CPC total particle number concentrations in 2025 at London Marylebone Road. The solid lines represent the mean total particle number concentration, and the shaded areas represent the 95 % confidence interval in the mean.

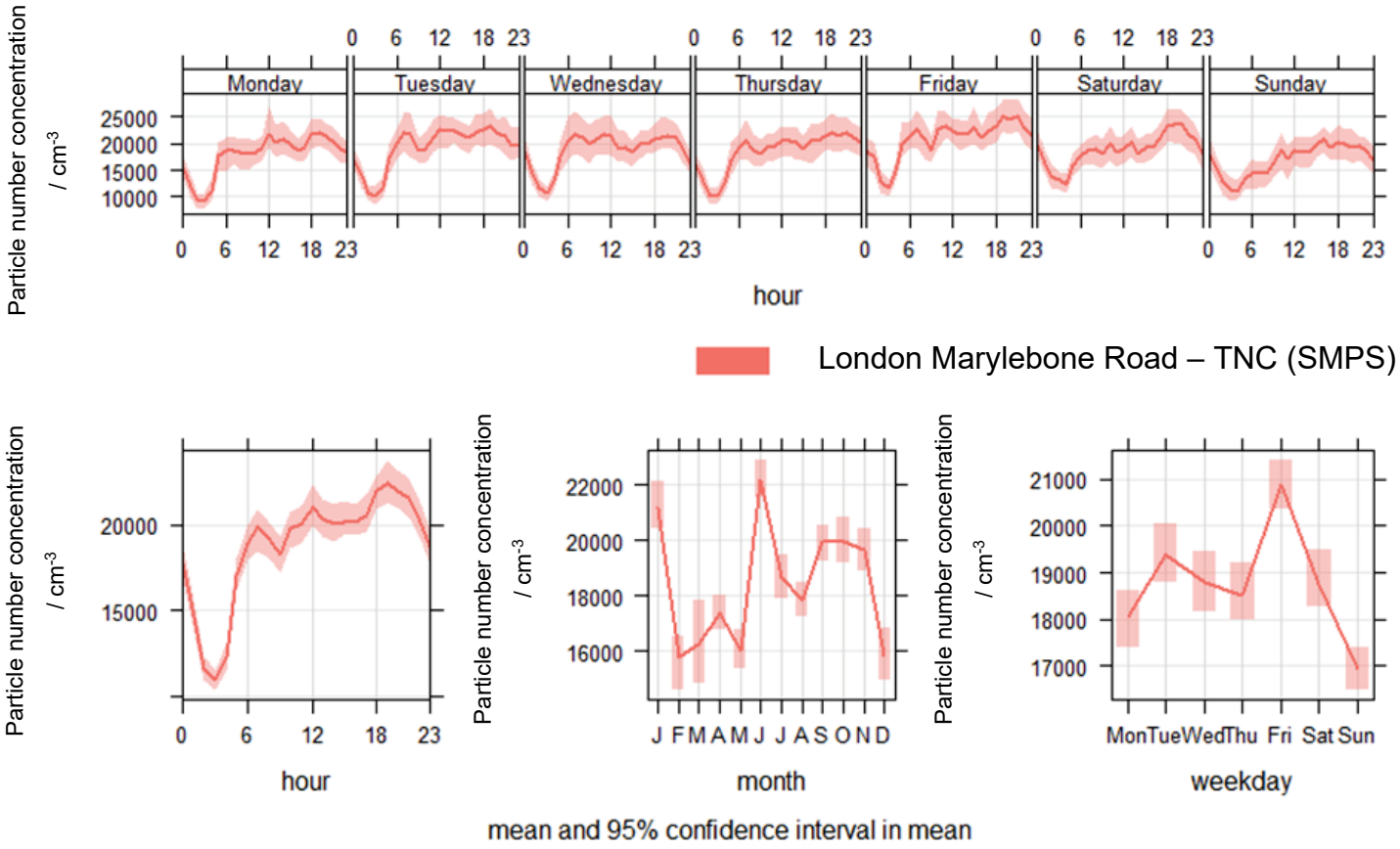

Figure 18 - Diurnal, weekly and monthly variations in SMPS total particle number concentrations in 2025 at London Marylebone Road. The solid lines represent the mean total particle number concentration, and the shaded areas represent the 95 % confidence interval in the mean.

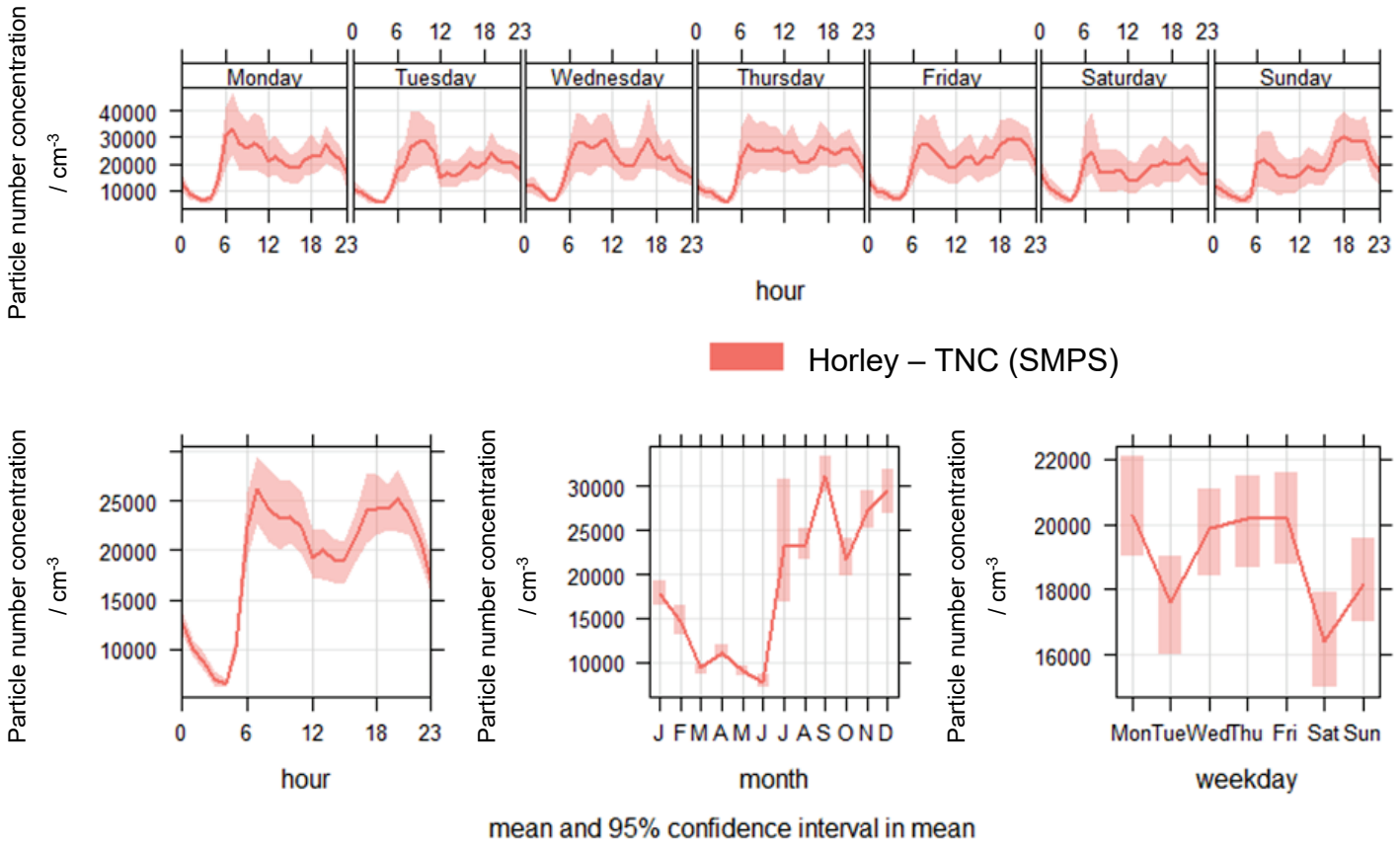

Figure 19 - Diurnal, weekly and monthly variations in SMPS total particle number concentrations in 2025 at Horley. The solid lines represent the mean particle number concentration, and the shaded areas represent the 95 % confidence interval in the mean.

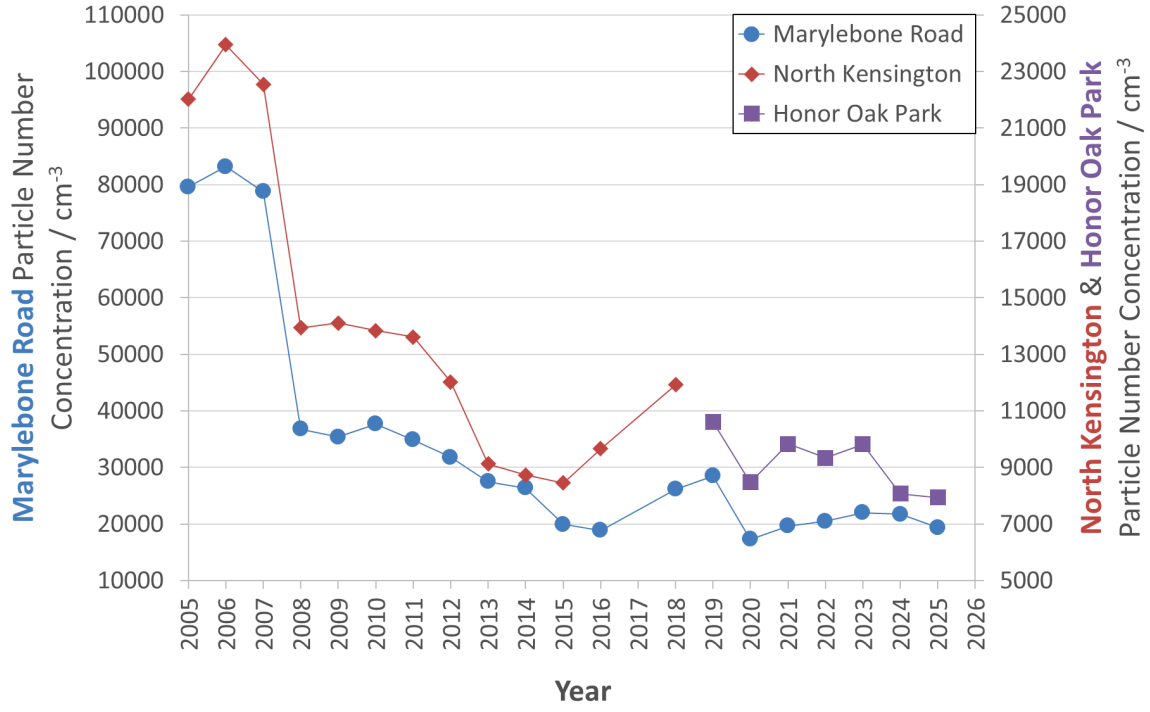

Figure 20 - Long-term CPC particle number concentrations annual trends at all London sites. Data from 2017 omitted due to insufficient data capture. The London North Kensington site moved to London Honor Oak Park in November 2018.

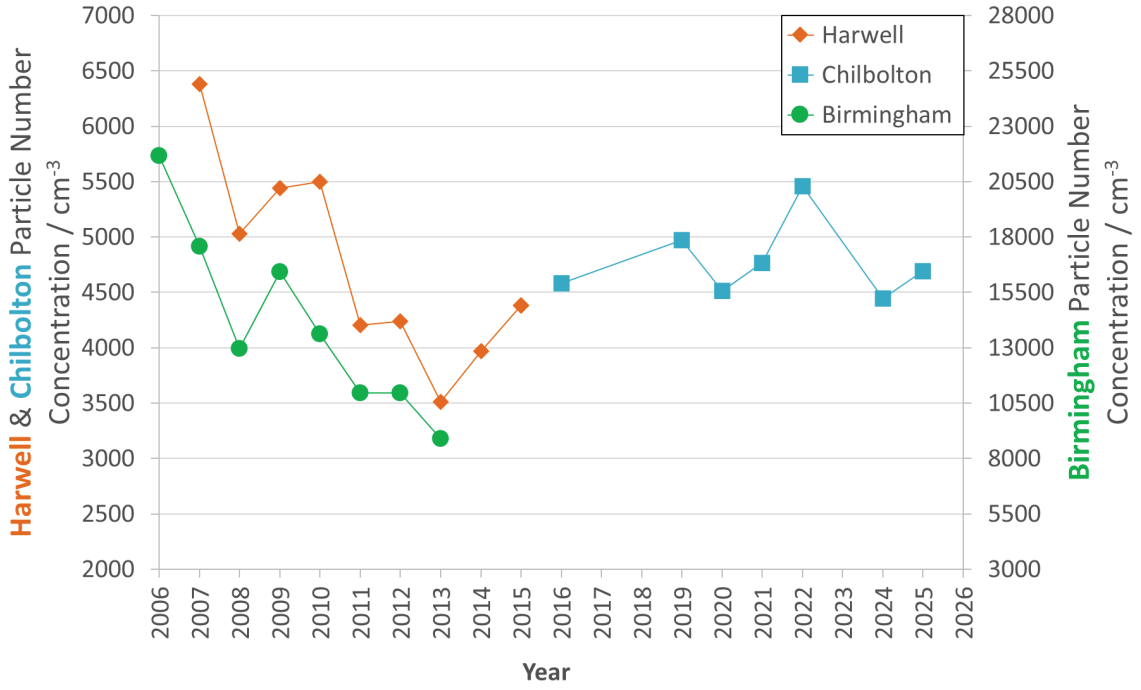

Figure 21 - Long-term CPC particle number concentrations annual trends at all sites outside London. The Harwell site moved to Chilbolton Observatory in 2016. Data from Chilbolton Observatory in 2023 omitted due to insufficient data capture.

4.2 Particle size distribution

4.2.1 2025 time series

Time series of monthly particle size distributions measured at Network sites during 2025 are shown in Figure 22 to Figure 25. The plots show both the variation in particle number concentration and the shape of the particle size distribution across 2025 at each site.

4.2.2 Long-term trends

Time series of annual particle size distributions measured at Network sites from 2020 to 2025 are shown in Figure 26 to Figure 29. The plots show both the variation in particle number concentration and particle size distribution. The plot for Chilbolton Observatory does not include data for 2023 due to low data capture.

The introduction of the newer TSI model of SMPS at the sites in 2023 showed a broadening of the particle size distribution, which has been seen again in the 2025 data. The shift of the peak to larger mobility diameters at London Honor Oak Park and London Marylebone Road in 2023 and 2024 is seen again in the 2025 data and is also displayed at the Chilbolton Observatory monitoring site in 2024 and 2025. The fact that this peak shift is seen across all three sites and has continued again from 2024 to 2025 supports the hypothesis that this is most likely an artefact of the change in instrument rather than a shift in the particle size distribution of the ambient aerosol. This is further discussed in an NPL Report[3].

The particle size distribution at Horley is driven by its proximity to Gatwick airport and is, therefore, different to the other sites on the Network. The peak of the size distributions at Horley being sub-20 nm and the increased normalised concentration is in line with what is known of airport emissions.

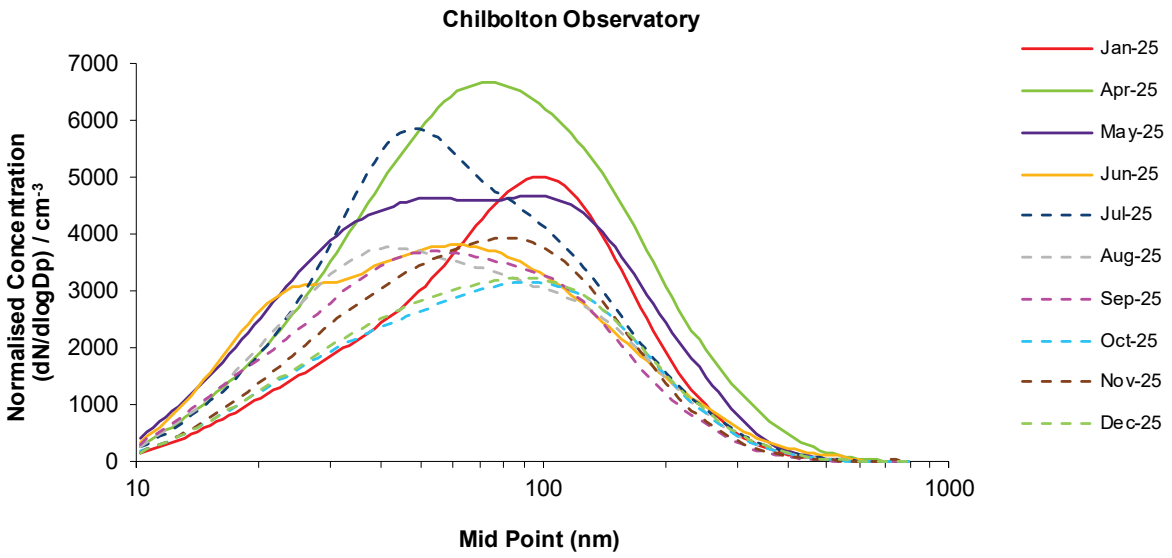

Figure 22 - Monthly averaged particle size distributions at Chilbolton Observatory during 2025.

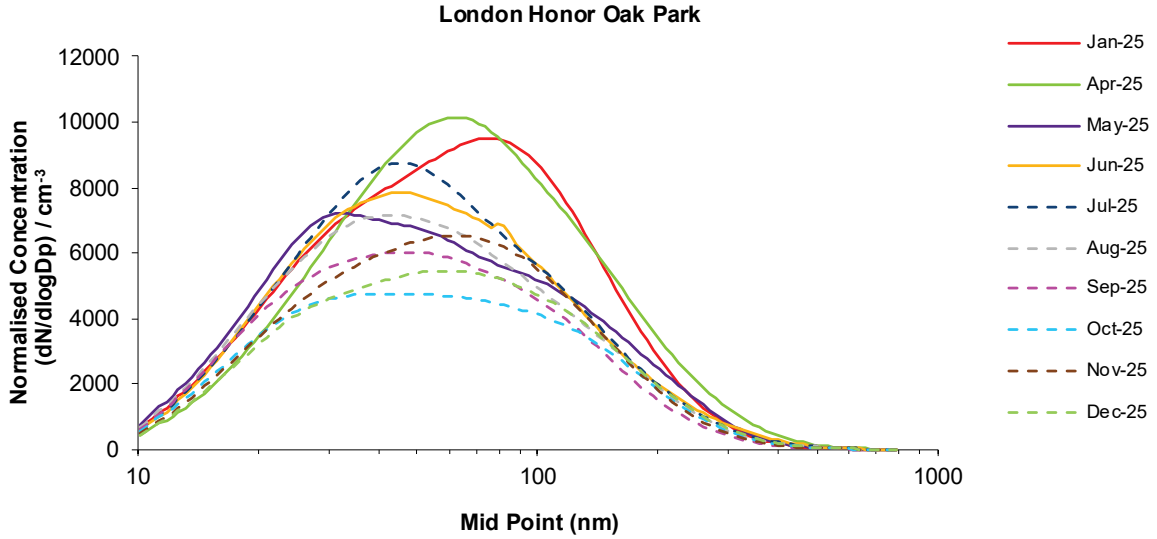

Figure 23 - Monthly averaged particle size distributions at London Honor Oak Park during 2025.

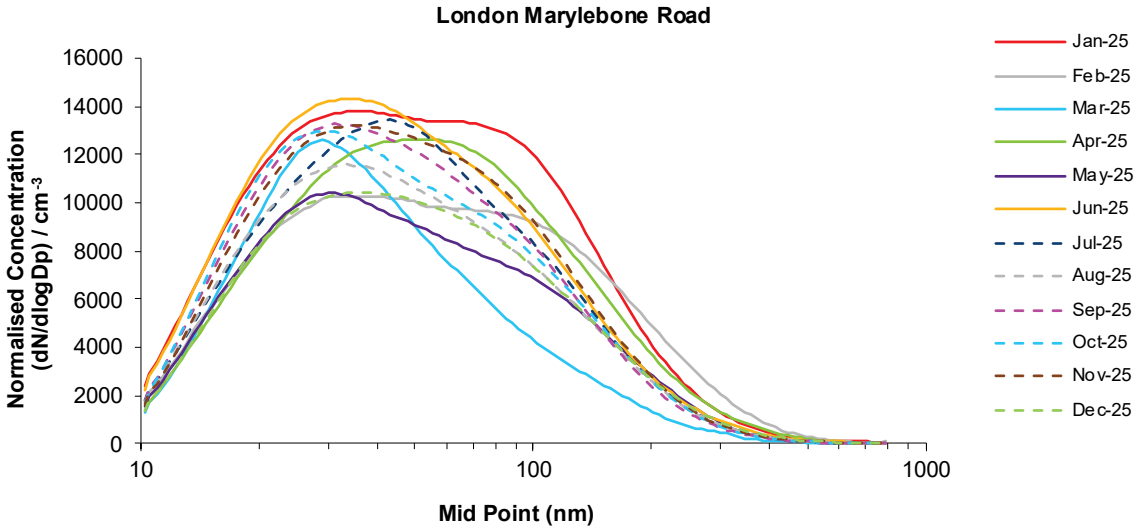

Figure 24 - Monthly averaged particle size distributions at London Marylebone Road during 2025.

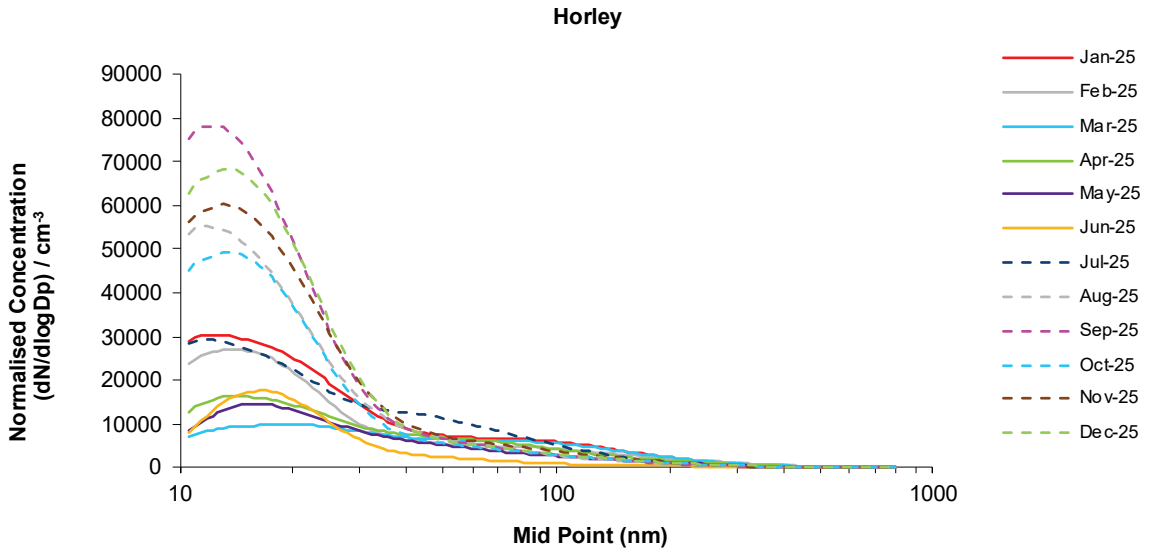

Figure 25 - Monthly averaged particle size distributions at Horley during 2025.

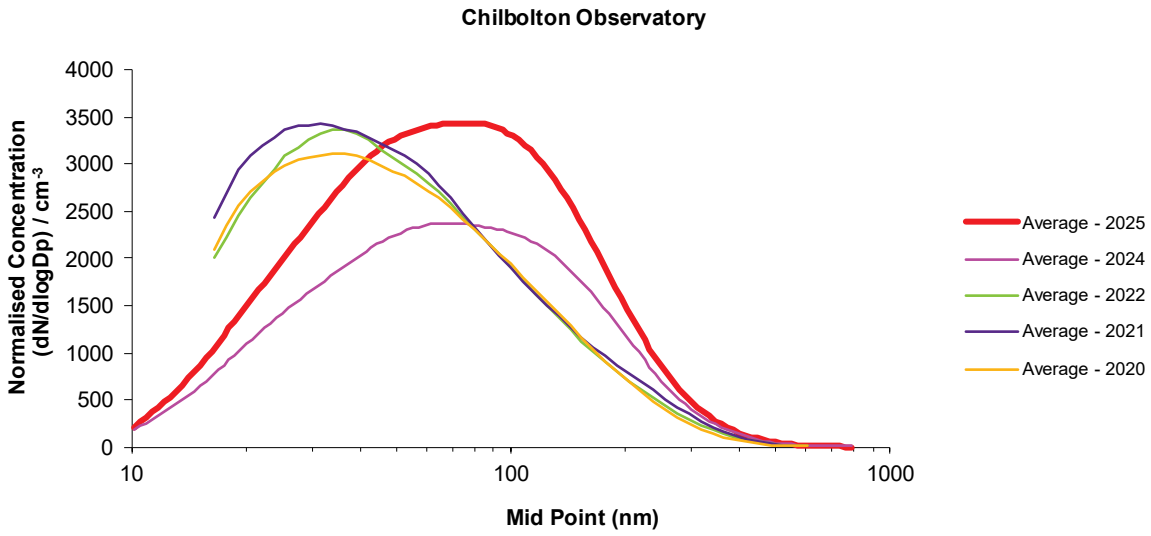

Figure 26 - Comparison of 2020 to 2025 annual average particle size distributions at Chilbolton Observatory. Data for Chilbolton Observatory in 2023 are not included due to low data capture. A thicker line has been used to distinguish the 2025 annual average.

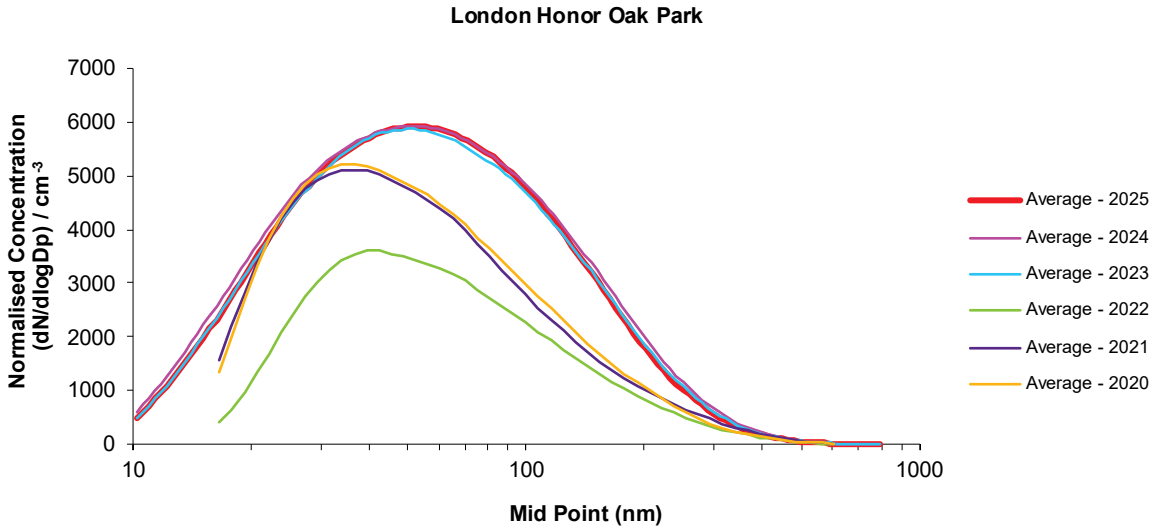

Figure 27 - Comparison of 2020 to 2025 annual average particle size distributions at London Honour Oak Park. Data for January and February 2023 from the old TSI 3936 SMPS at London Honor Oak Park are not included here. Note that 2023 and 2024 size distributions are partially obscured due to their similarity to the 2025 size distribution. A thicker line has been used to distinguish the 2025 annual average.

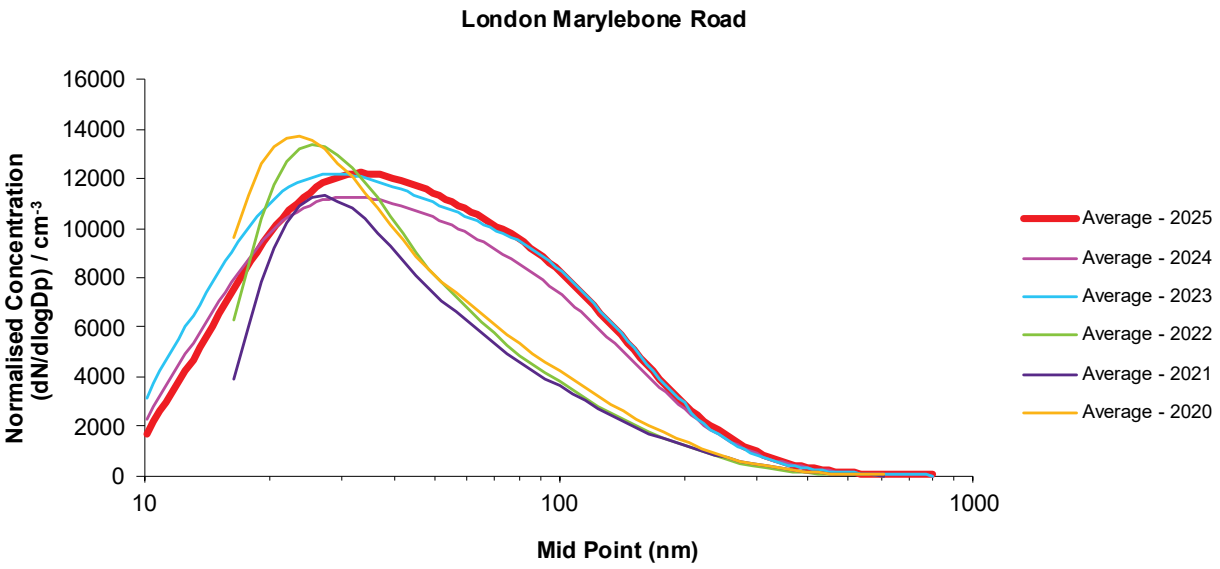

Figure 28 - Comparison of 2020 to 2025 annual average particle size distributions at London Marylebone Road. A thicker line has been used to distinguish the 2025 annual average.

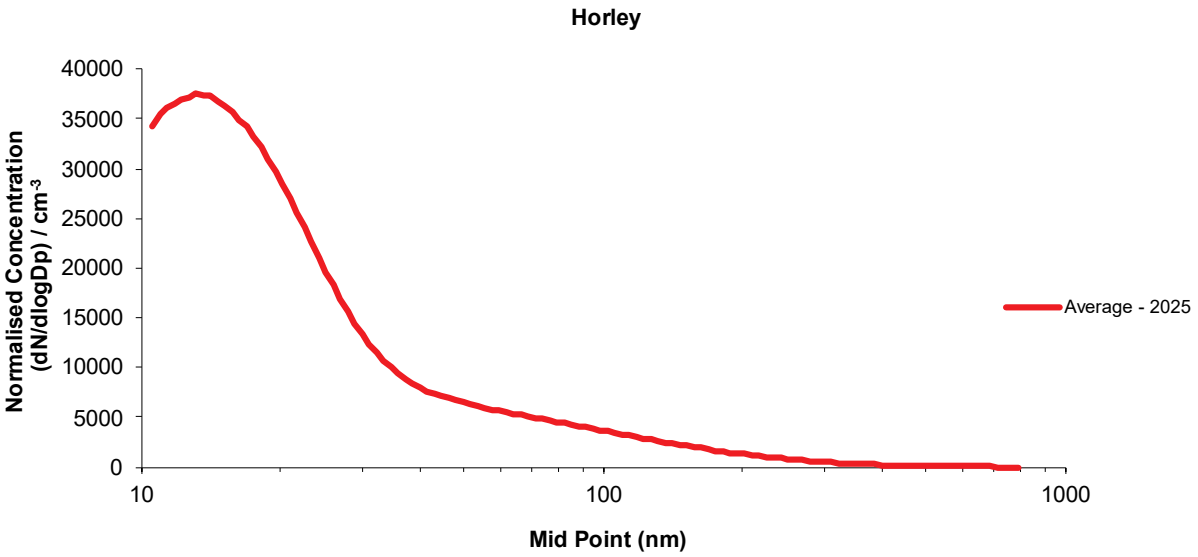

Figure 29 - Presentation of 2025 annual average particle size distribution at Horley.

4.3 Aerosol mass chemical composition

4.3.1 2024 time series

Figure 30 to Figure 32 show the time series of monthly average mass concentrations of organics, nitrate, sulfate, and ammonium at Chilbolton Observatory, London Honor Oak Park, and London Marylebone Road during 2025.

It should be noted that although the intended measurands of the ACSM analysis are ions (*e.g.*, NO_3^-) in particulate matter, the ACSM also measures elements, or neutral species (*e.g.*, NO_3). For simplicity, all the results in this report are presented as ions.

4.3.2 Long-term trends

Figure 33 to Figure 36 show the long-term trends (using annual averages) of the four components measured using the ACSM instrument at London North Kensington / London Honor Oak Park, London Marylebone Road and Chilbolton Observatory.

An ACSM instrument was installed at London North Kensington in 2013 measuring PM_1. Data from 2014 has been excluded from the plot due to low data capture that year. The ACSM was then moved to London Honor Oak Park in November 2018. Since November 2018, the instrument has measured the hourly mass concentrations of organics, nitrate, sulfate, and ammonium in $PM_{2.5}$. A new replacement $PM_{2.5}$ ACSM was installed in January 2026.

An ACSM instrument measuring the PM_1 size fraction was installed at London Marylebone Road in mid-July 2020. In April 2022 a new ACSM measuring $PM_{2.5}$ was installed at Chilbolton Observatory.

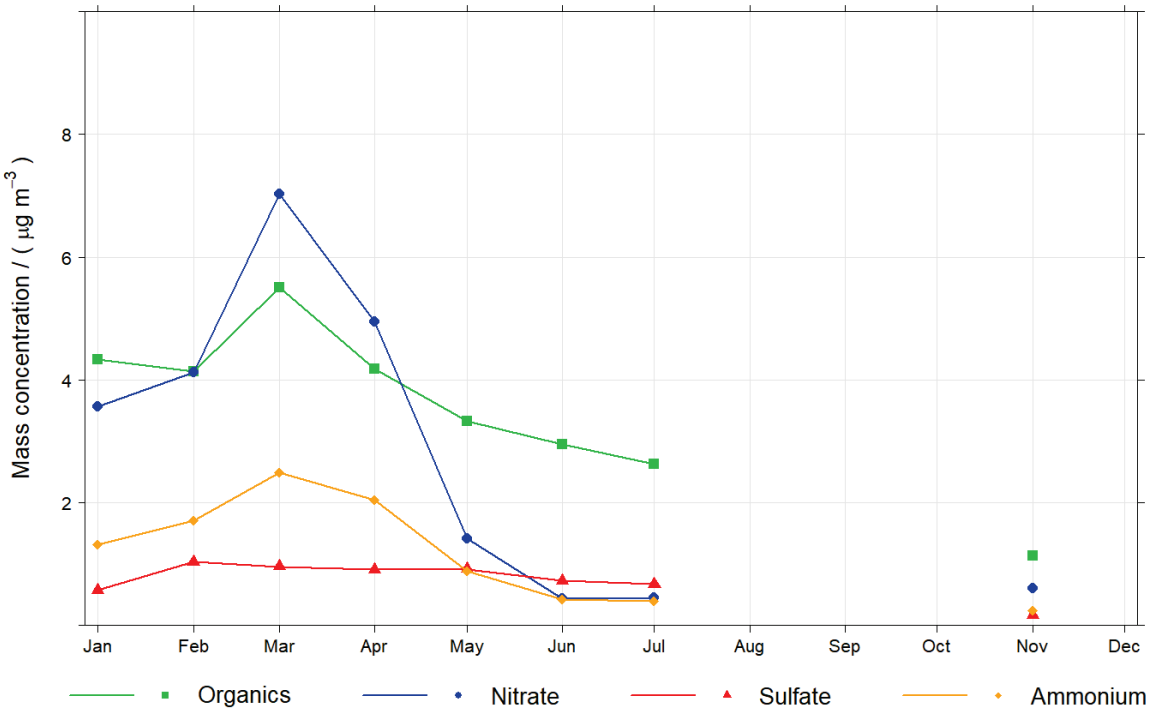

Figure 30 - Monthly average mass concentrations of organics, nitrate, sulfate, and ammonium in $PM_{2.5}$ measured by ACSM in 2025 at Chilbolton Observatory.

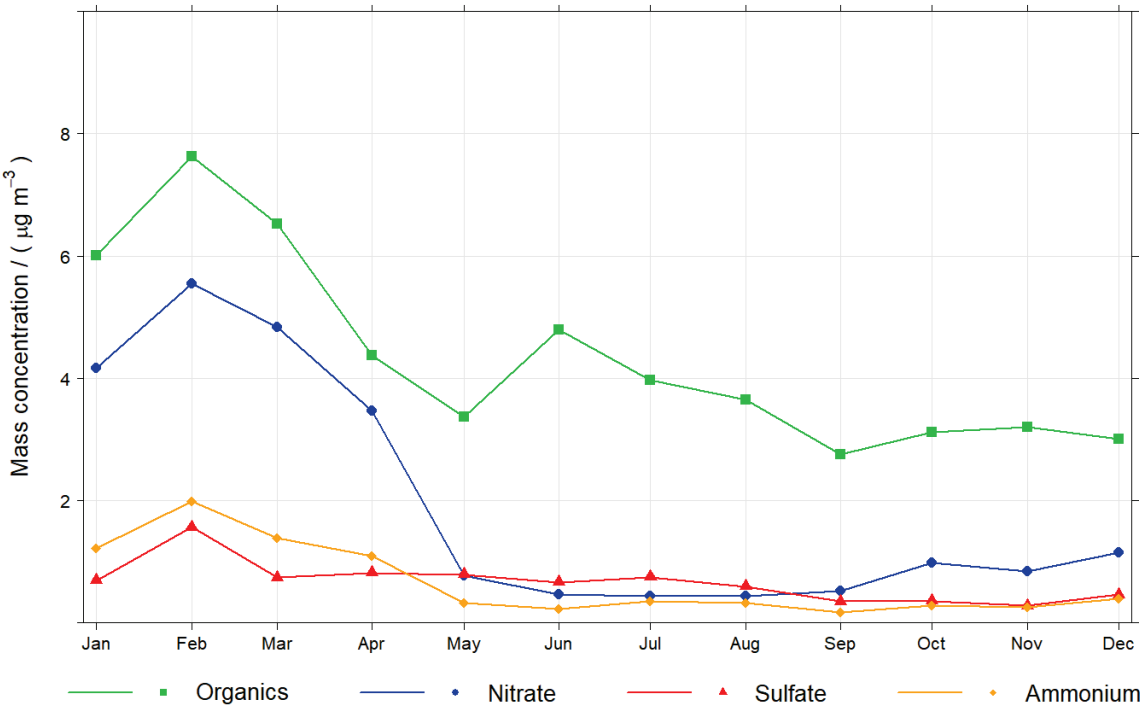

Figure 31 - Monthly average mass concentrations of organics, nitrate, sulfate, and ammonium in $PM_{2.5}$ measured by ACSM in 2025 at London Honor Oak Park.

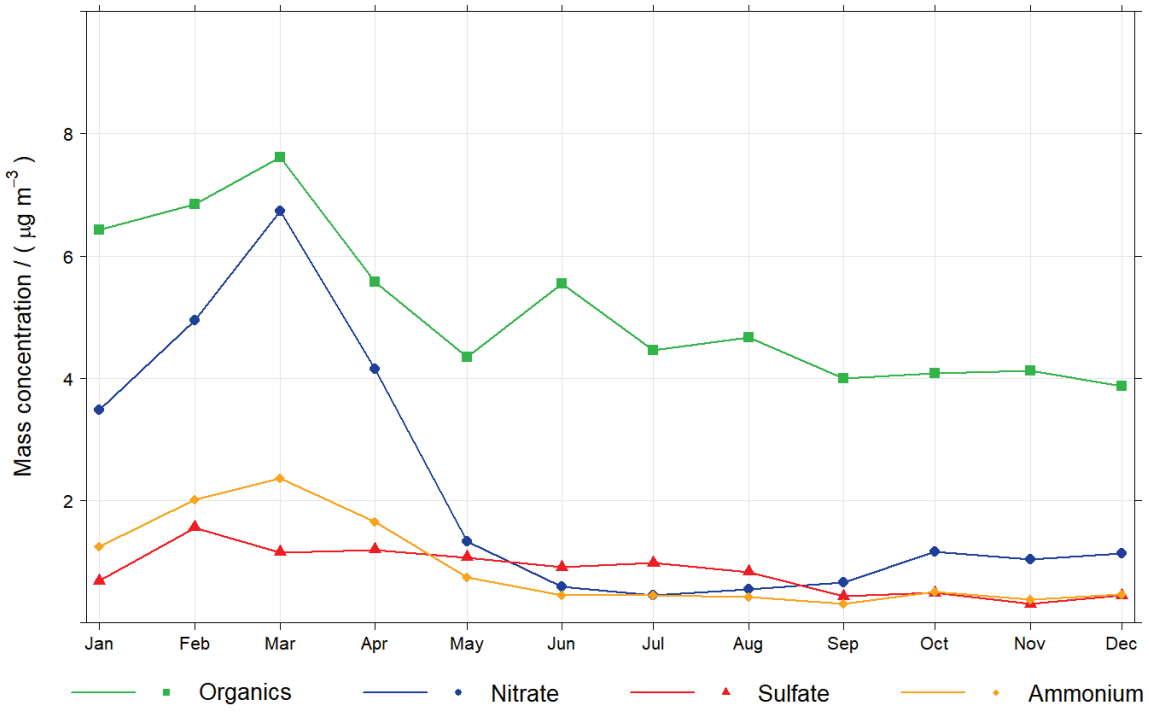

Figure 32 - Monthly average mass concentrations of organics, nitrate, sulfate, and ammonium in PM_1 measured by ACSM in 2025 at London Marylebone Road.

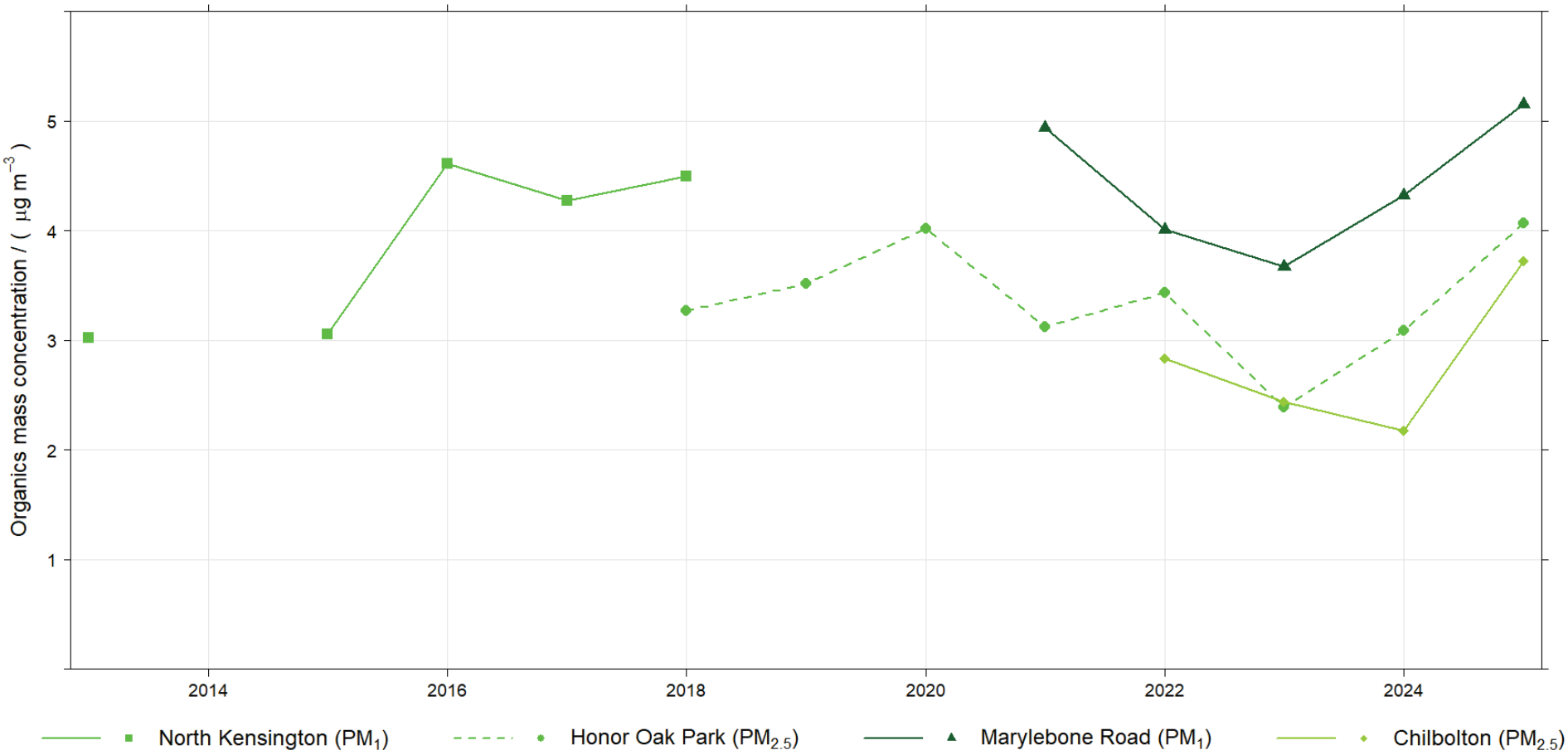

Figure 33 - Annual average mass concentration of organics at the rural background site Chilbolton Observatory, urban background site London Honor Oak Park (London North Kensington before 2019) and urban traffic site London Marylebone Road. The tick marks on the x-axis indicate the start of each year. Data from North Kensington in 2014 has been excluded due to low data capture.

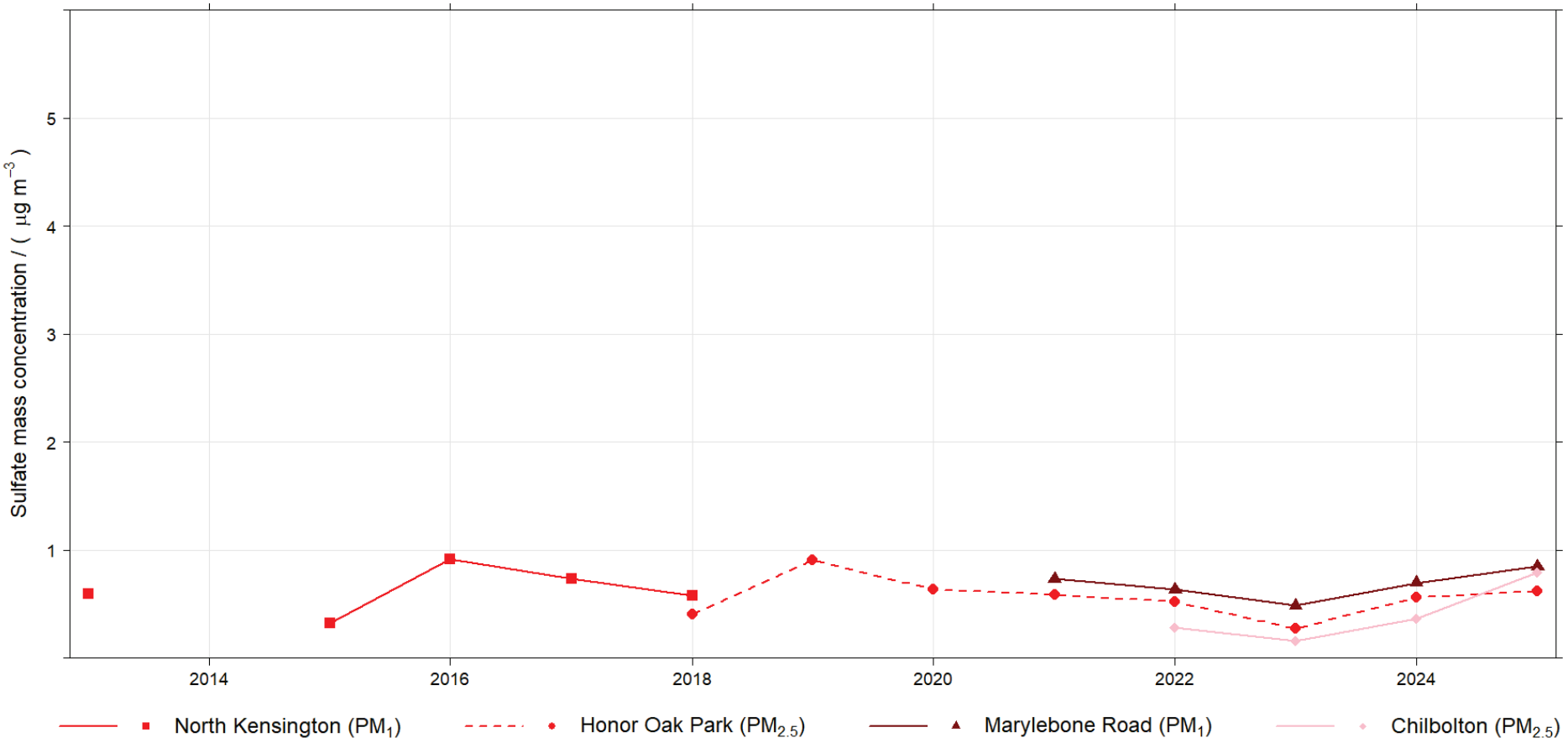

Figure 34 - Annual average mass concentration of sulfate at the rural background site Chilbolton Observatory, urban background site London Honor Oak Park (London North Kensington before 2019) and urban traffic site London Marylebone Road. The tick marks on the x-axis indicate the start of each year. Data from North Kensington in 2014 has been excluded due to low data capture.

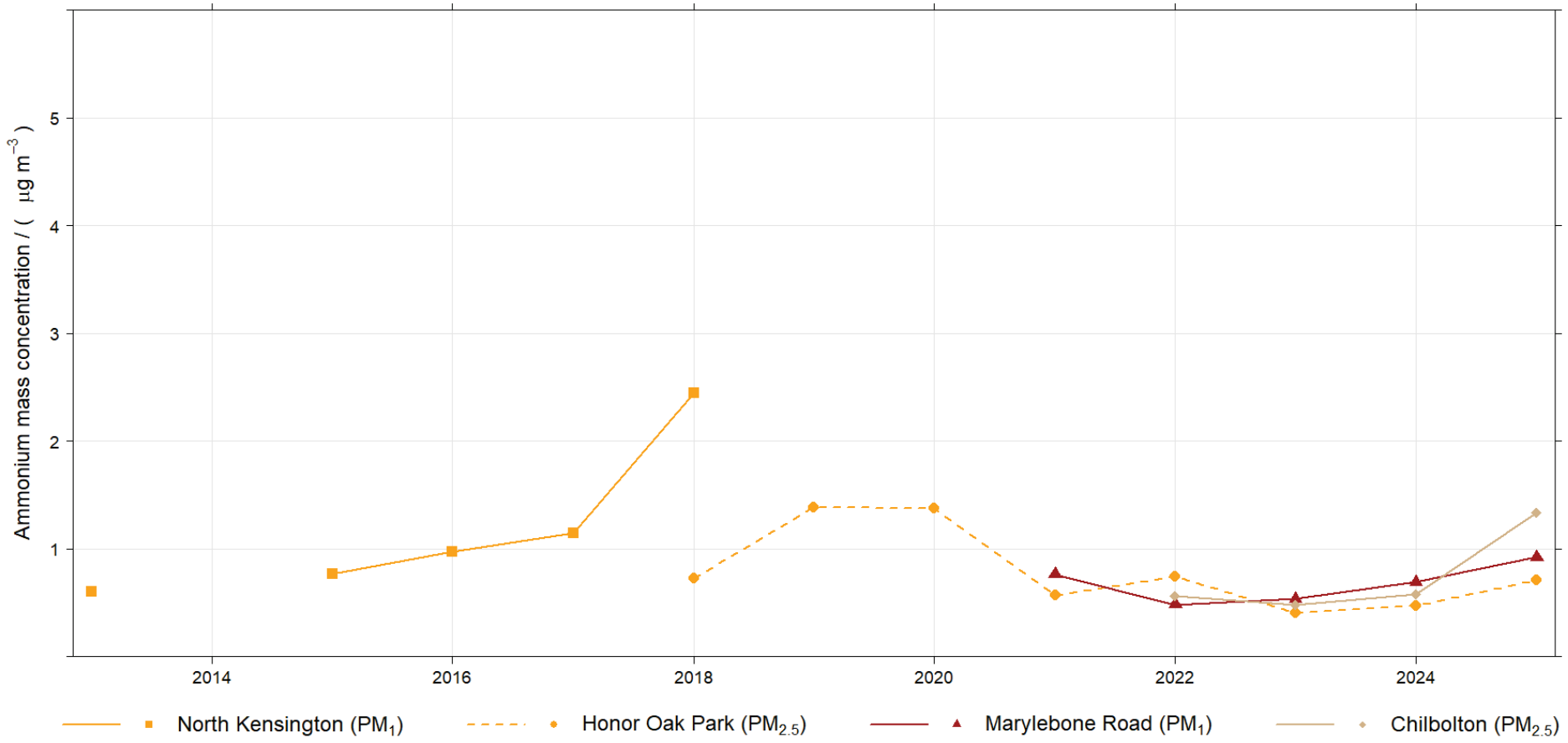

Figure 35 - Annual average mass concentration of ammonium at the rural background site Chilbolton Observatory, urban background site London Honor Oak Park (London North Kensington before 2019) and urban traffic site London Marylebone Road. The tick marks on the x-axis indicate the start of each year. Data from North Kensington in 2014 has been excluded due to low data capture.

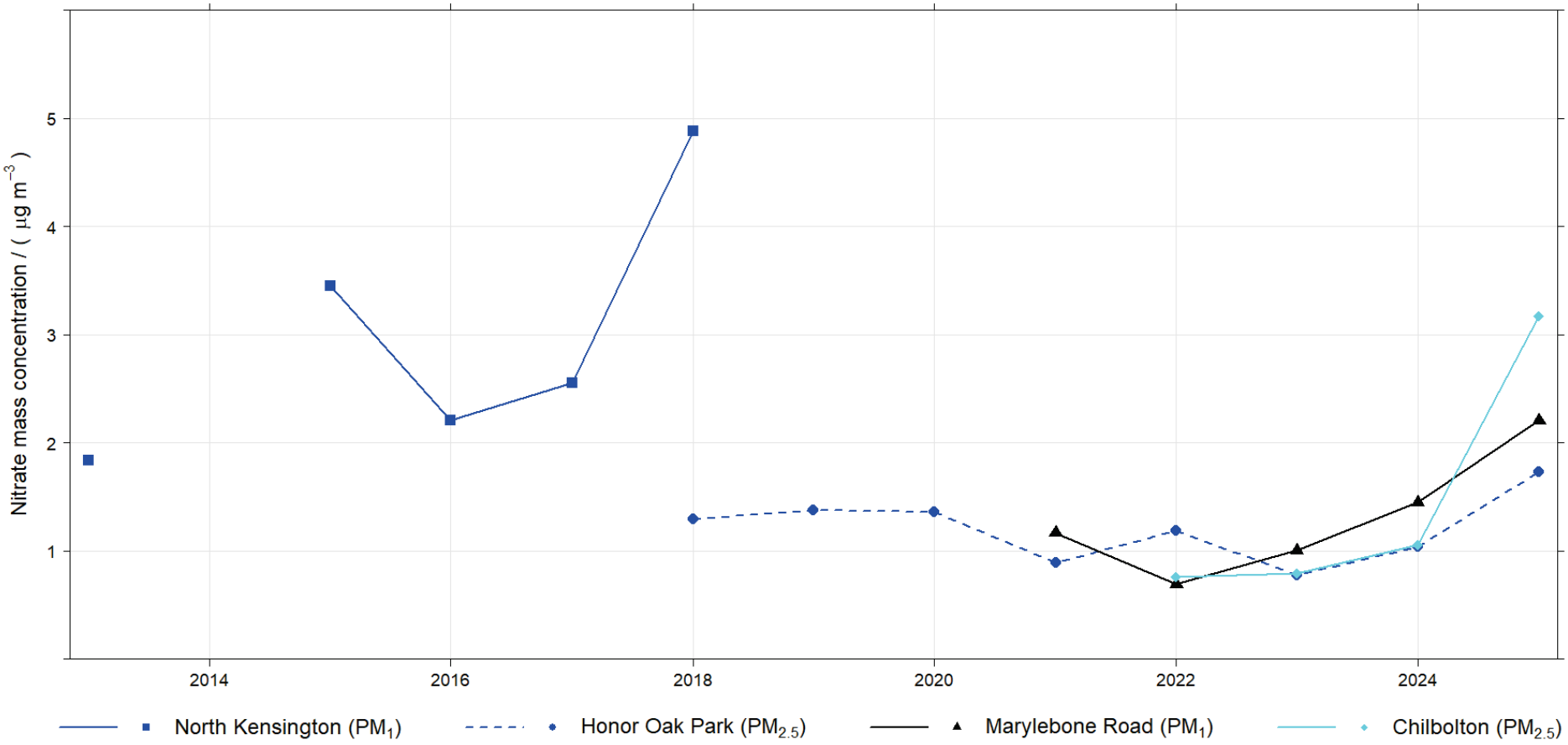

Figure 36 - Annual average mass concentration of nitrate at the rural background site Chilbolton Observatory, urban background site London Honor Oak Park (London North Kensington before 2019) and urban traffic site London Marylebone Road. The tick marks on the x-axis indicate the start of each year. Data from North Kensington in 2014 has been excluded due to low data capture.

4.4 Elemental Analysis

4.4.1 2025 time series

Figure 37 to Figure 44 show the time series of the daily concentrations of four elements (Ba, Cl, Si and Zn) at London Honor Oak Park and London Marylebone Road in 2025 for both $PM_{2.5}$ and PM_{10} fractions. These four elements were chosen from the 40 measured as examples, because they are representative tracer for important sources: brake wear (Ba), sea salt (Cl), resuspended dust (Si) and tyre wear (Zn). The full dataset for all elements measured can be found on UK AIR.

4.4.2 Long term trends

Figure 45 to Figure 52 show the annual PM_{10} mass concentration of the elements Ba, Cl, Si and Zn as a stacked bar chart of the $PM_{2.5}$ and PM_{coarse} fractions (where PM_{coarse} = $PM_{10} – PM_{2.5}$).

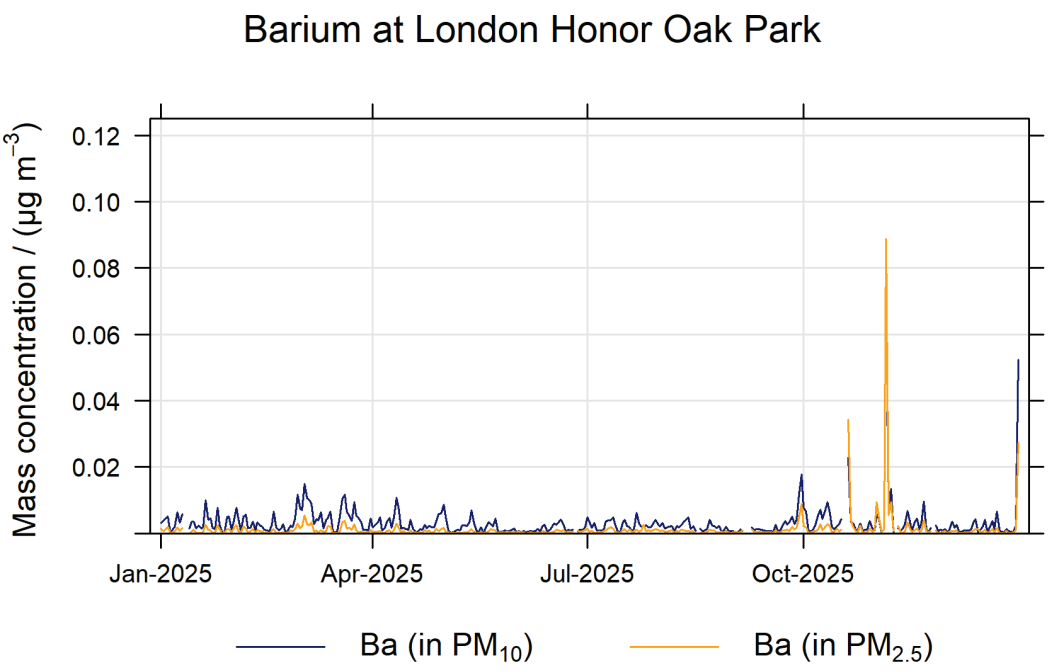

Figure 37 - Mean daily barium mass concentrations at London Honor Oak Park in 2025 based on interpolated bihourly 1 h periods of data. The tick marks on the *x*-axis indicate the start of every third month.

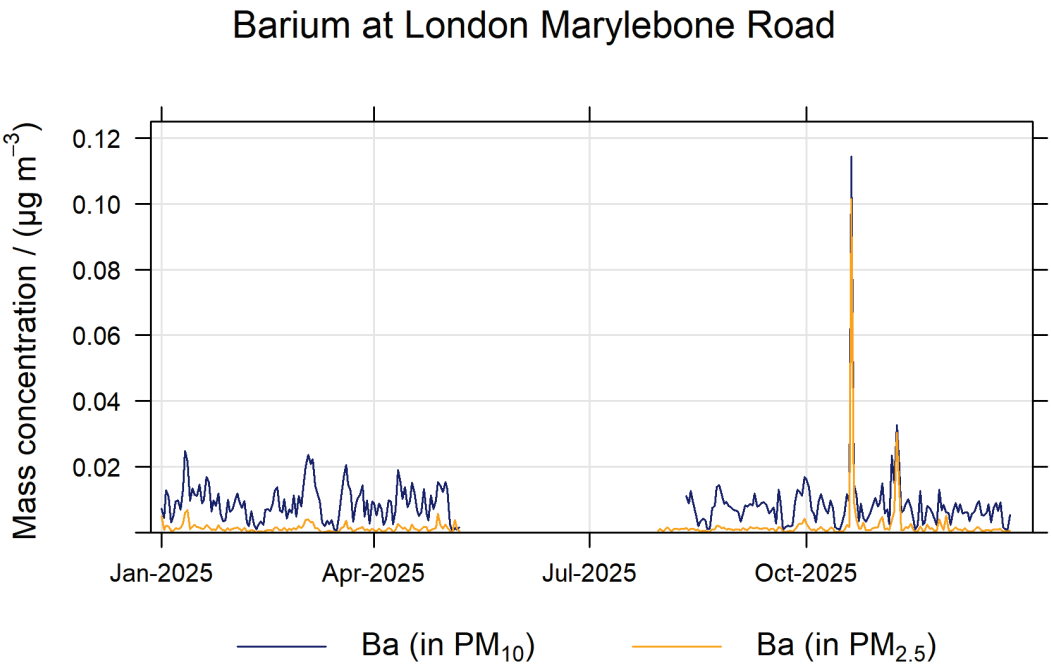

Figure 38 - Mean daily barium mass concentrations at London Marylebone Road in 2025 based on interpolated bihourly 1 h periods of data. The tick marks on the *x*-axis indicate the start of every third month.

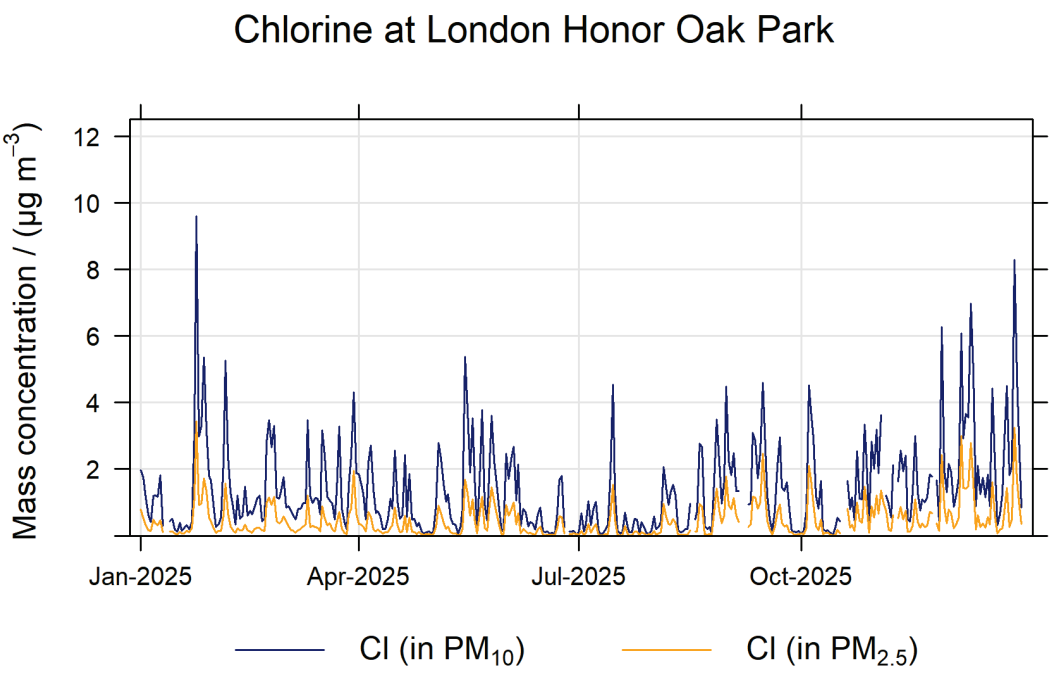

Figure 39 - Mean daily chlorine mass concentrations at London Honor Oak Park in 2025 based on interpolated bihourly 1 h periods of data. The tick marks on the *x*-axis indicate the start of every third month.

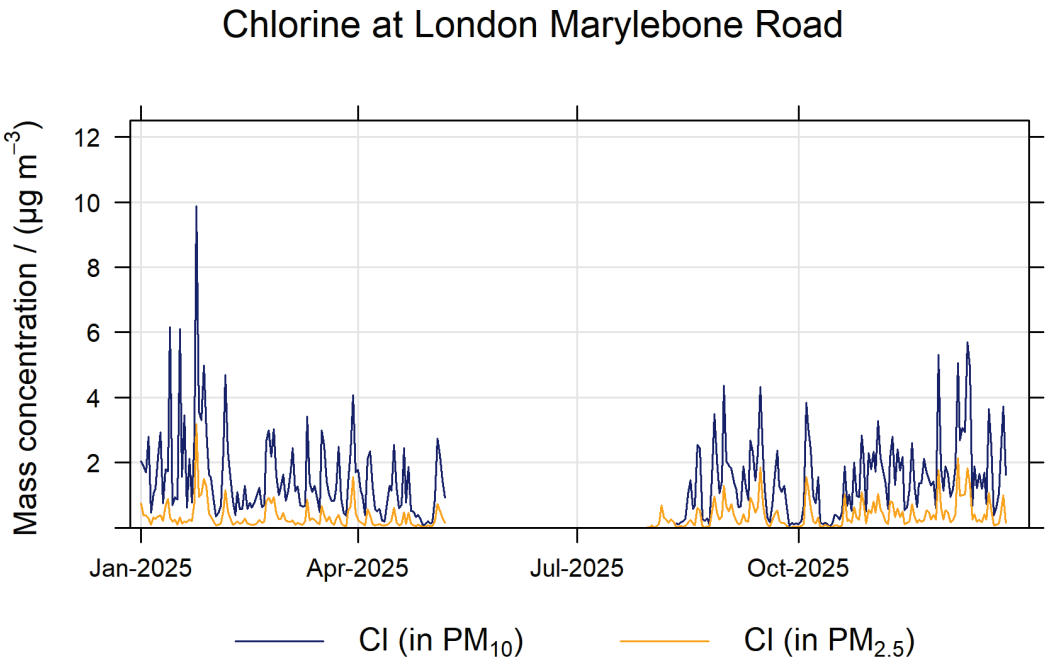

Figure 40 - Mean daily chlorine mass concentrations at London Marylebone Road in 2025 based on interpolated bihourly 1 h periods of data. The tick marks on the *x*-axis indicate the start of every third month.

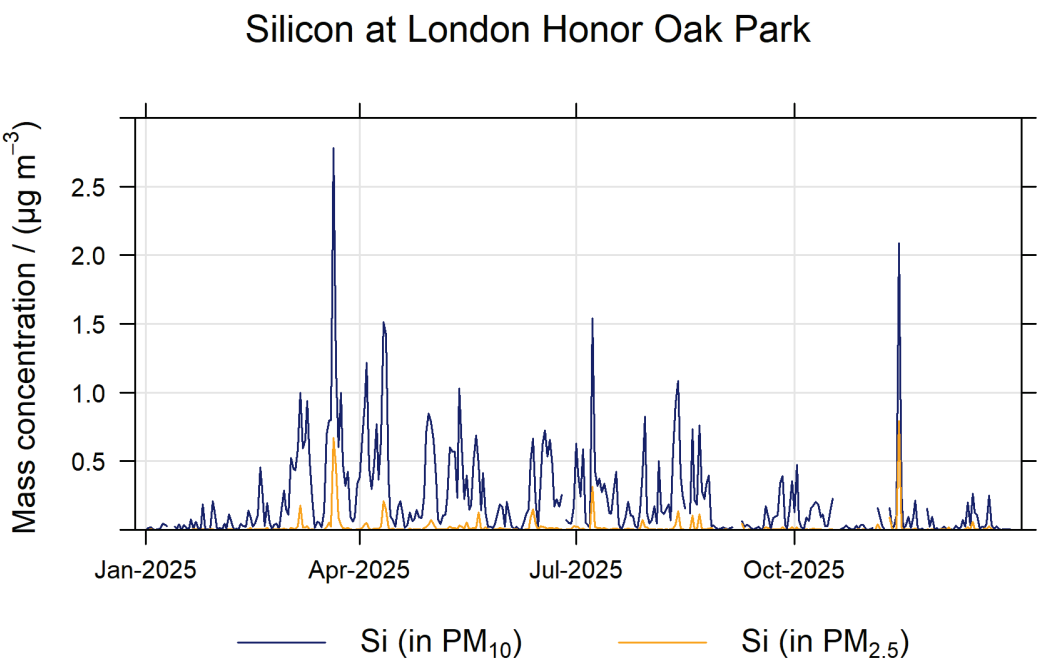

Figure 41 - Mean daily silicon mass concentrations at London Honor Oak Park in 2025 based on interpolated bihourly 1 h periods of data. The tick marks on the *x*-axis indicate the start of every third month.

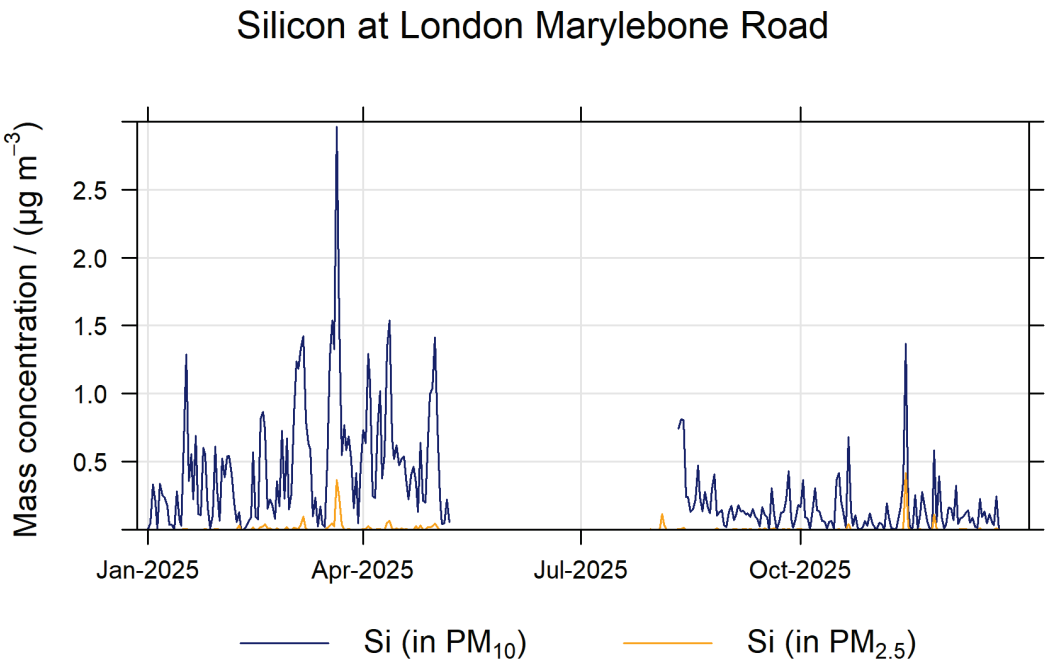

Figure 42 - Mean daily silicon mass concentrations at London Marylebone Road in 2025 based on interpolated bihourly 1 h periods of data. The tick marks on the *x*-axis indicate the start of every third month.

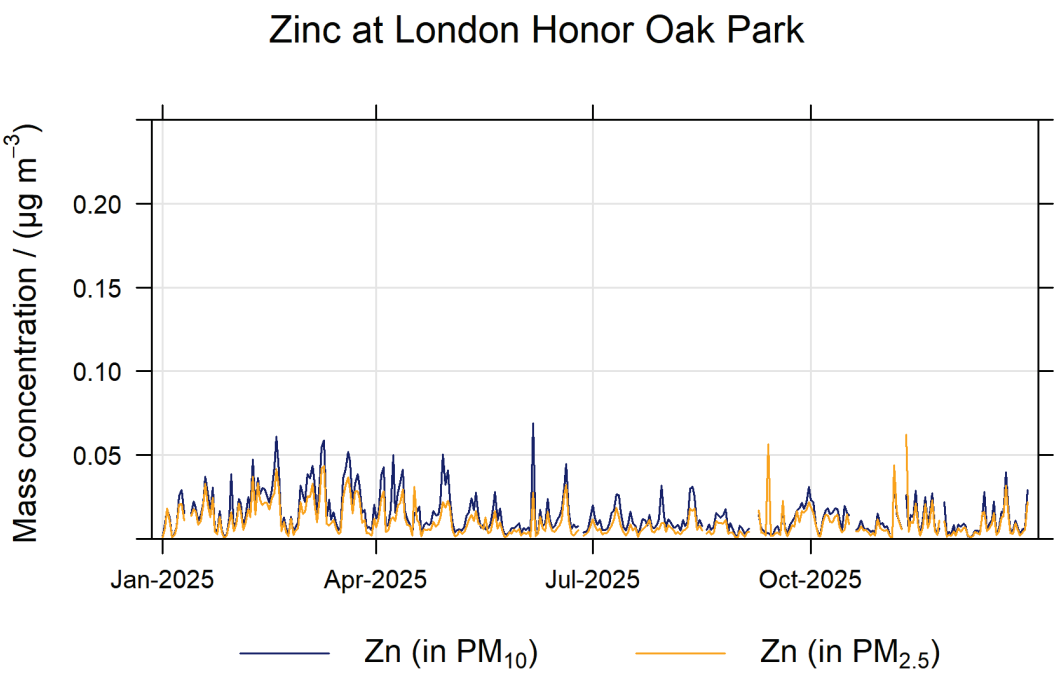

Figure 43 - Mean daily zinc concentrations at London Honor Oak in 2025 based on interpolated bihourly 1 h periods of data. The tick marks on the *x*-axis indicate the start of every third month.

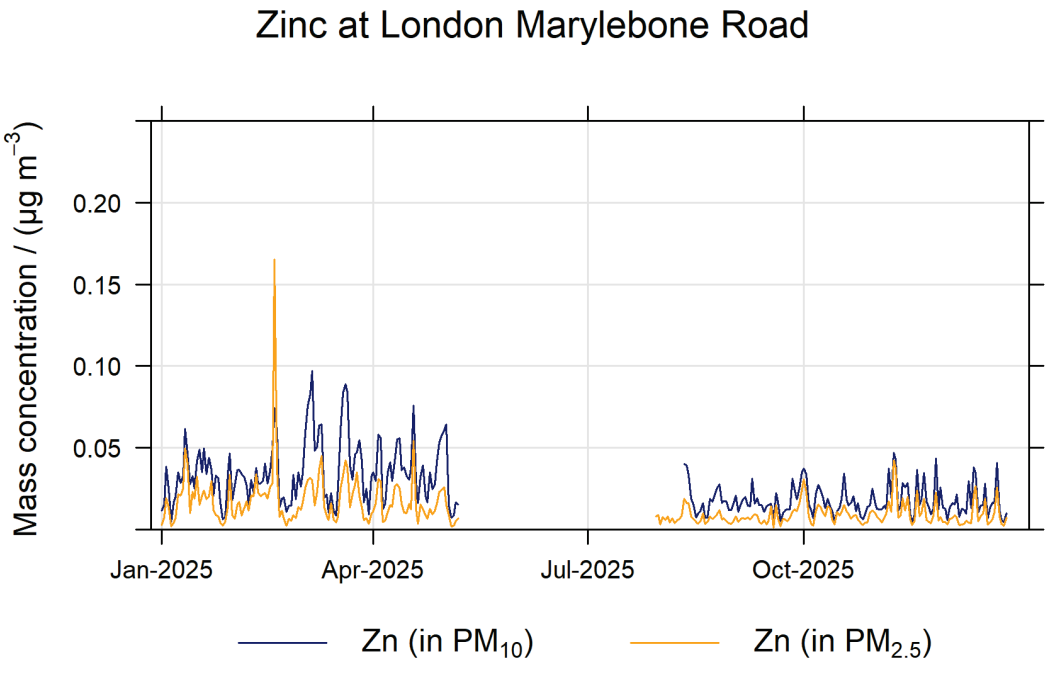

Figure 44 - Mean daily zinc concentrations at London Marylebone Road in 2025 based on interpolated bihourly 1 h periods of data. The tick marks on the *x*-axis indicate the start of every third month.

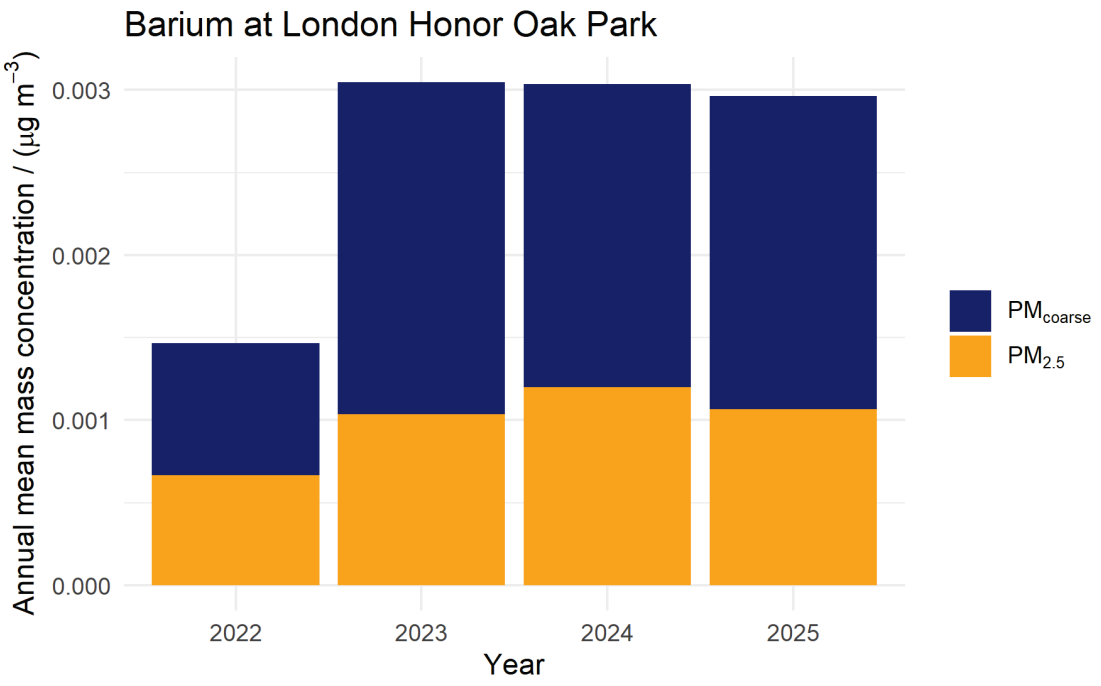

Figure 45 - Mean annual barium concentrations in PM_{10} (split into $PM_{2.5}$ and PM_{coarse}) in 2022-2025 at London Honor Oak Park based on interpolated bihourly 1 h periods of data.

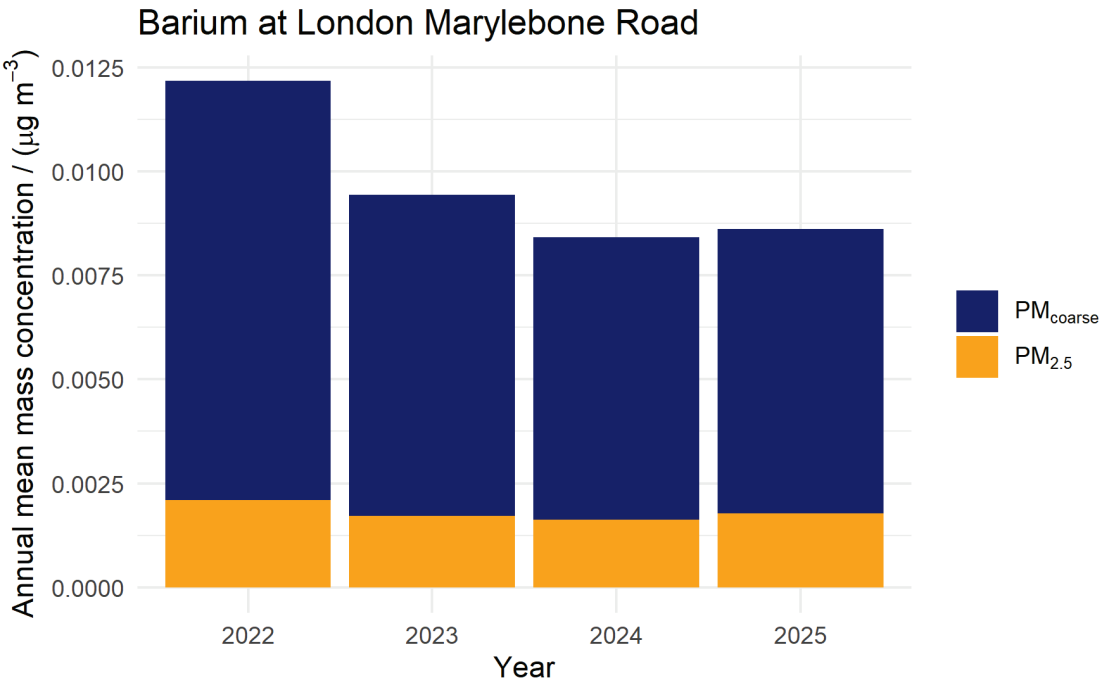

Figure 46 - Mean annual barium concentrations in PM_{10} (split into $PM_{2.5}$ and PM_{coarse}) in 2022-2025 at London Marylebone Road based on interpolated bihourly 1 h periods of data.

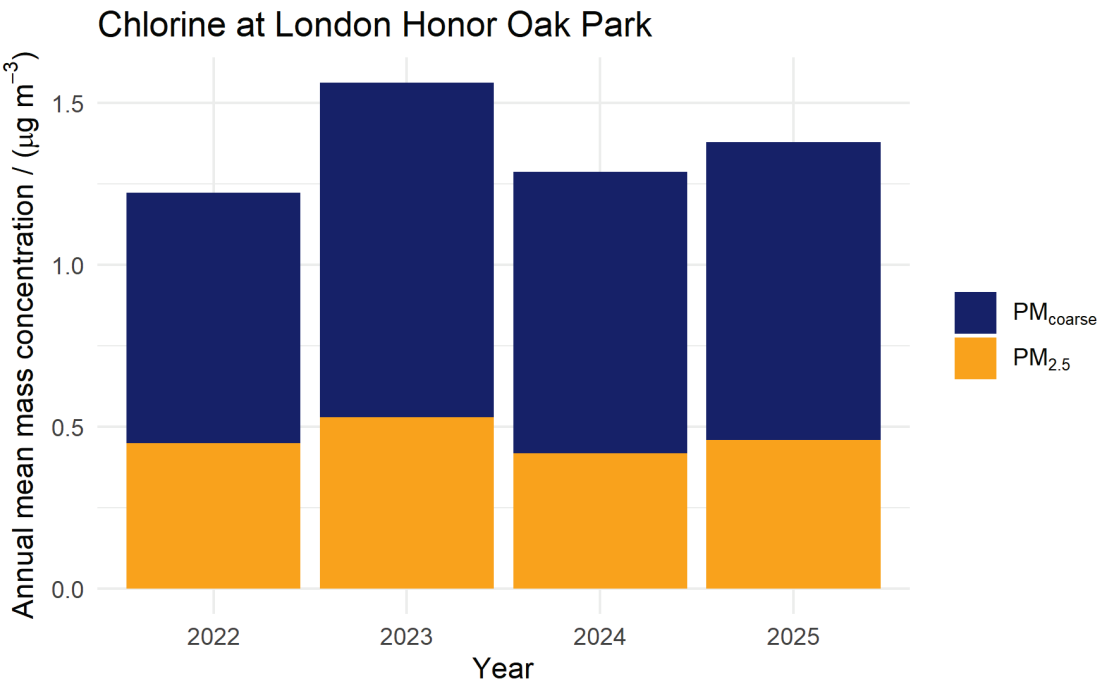

Figure 47 - Mean annual chlorine concentrations in PM_{10} (split into $PM_{2.5}$ and PM_{coarse}) in 2022-2025 at London Honor Oak Park based on interpolated bihourly 1 h periods of data.

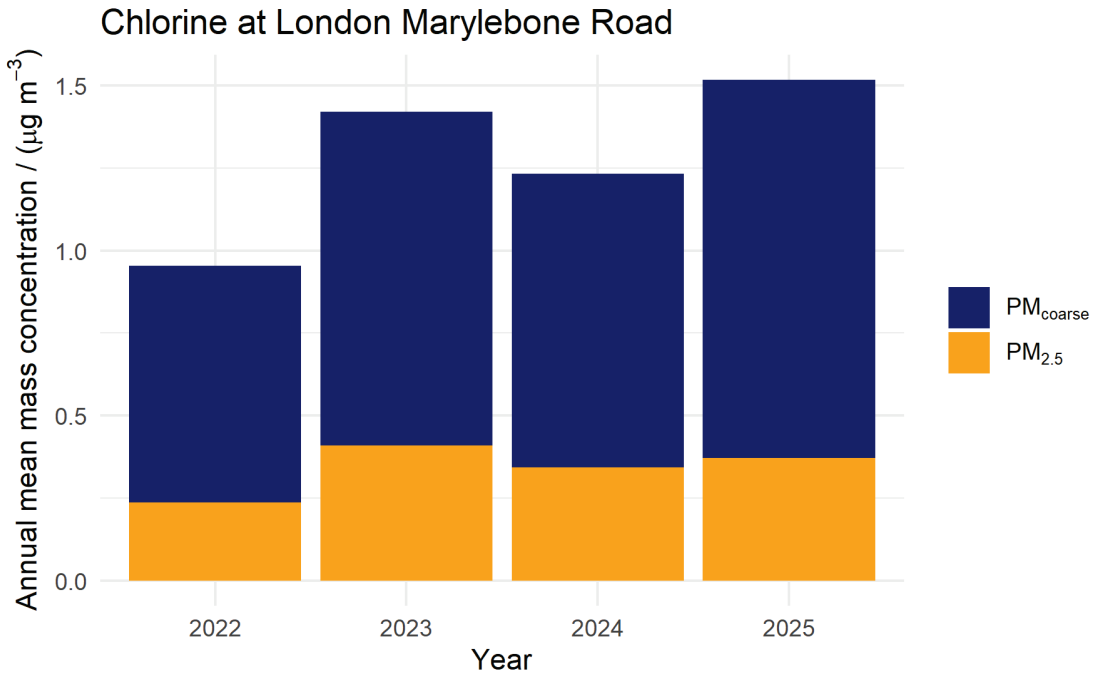

Figure 48 - Mean annual chlorine concentrations in PM_{10} (split into $PM_{2.5}$ and PM_{coarse}) in 2022-2025 at London Marylebone Road based on interpolated bihourly 1 h periods of data.

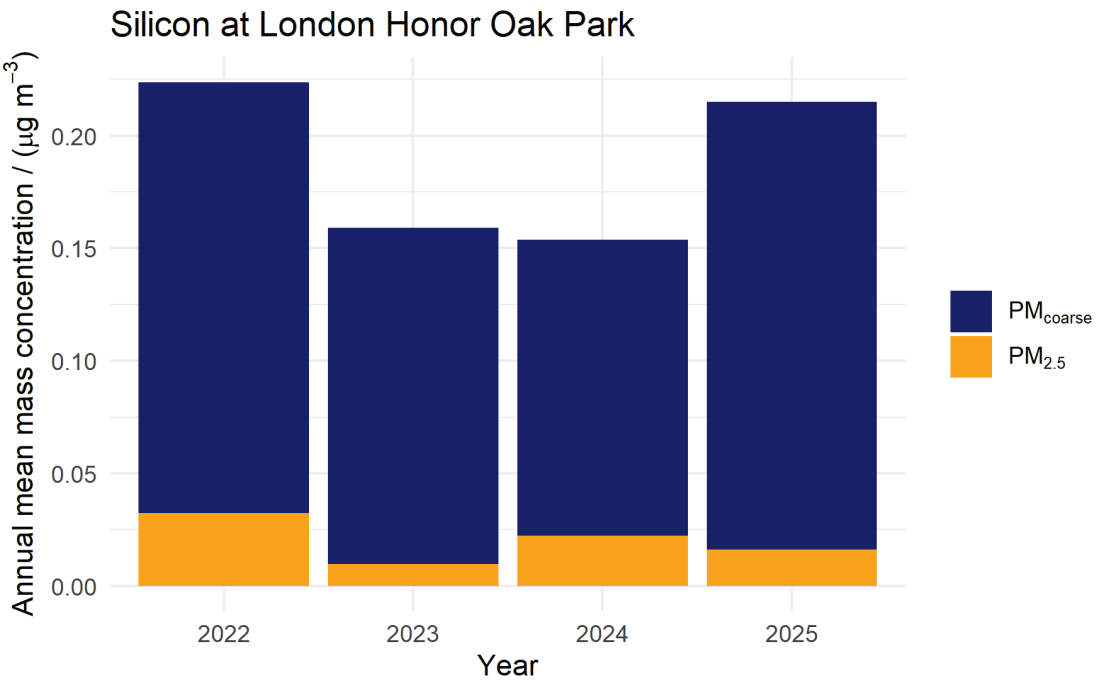

Figure 49 - Mean annual silicon concentrations in PM_{10} (split into $PM_{2.5}$ and PM_{coarse}) in 2022-2025 at London Honor Oak Park based on interpolated bihourly 1 h periods of data.

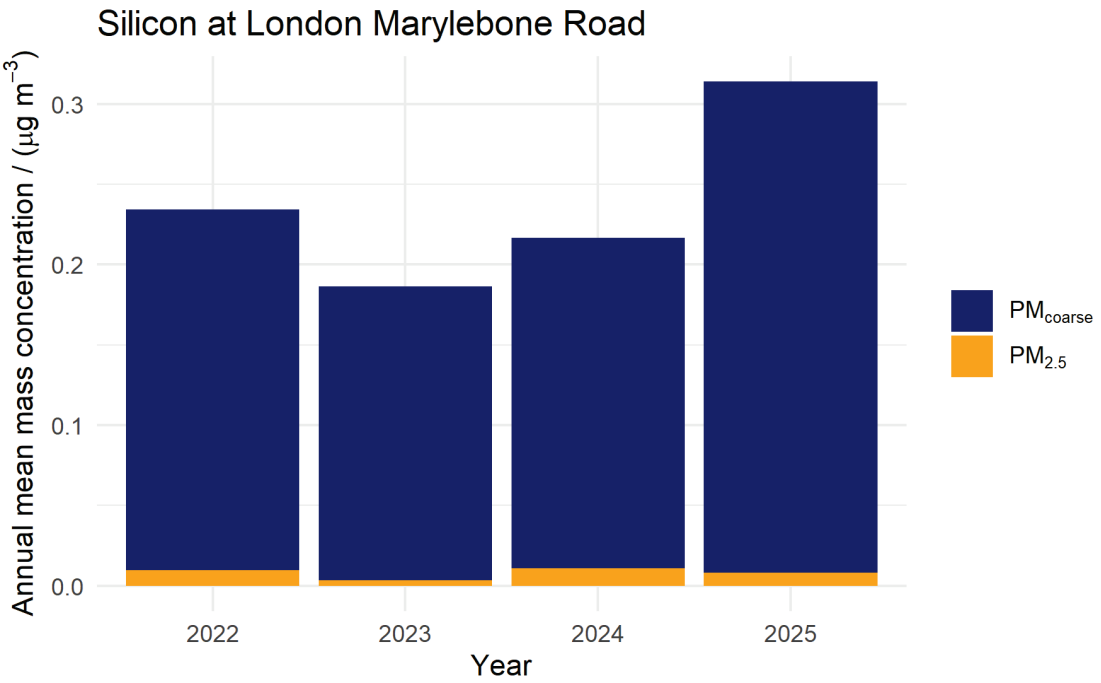

Figure 50 - Mean annual silicon concentrations in PM_{10} (split into $PM_{2.5}$ and PM_{coarse}) in 2022-2025 at London Marylebone Road based on interpolated bihourly 1 h periods of data.

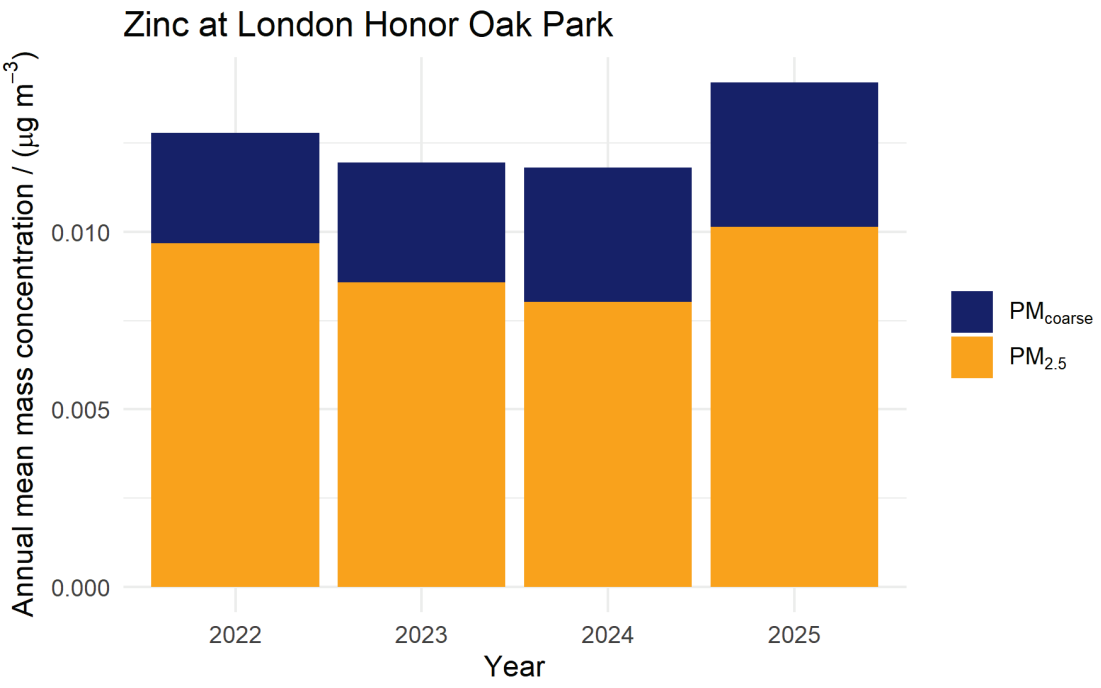

Figure 51 - Mean annual zinc concentrations in PM_{10} (split into $PM_{2.5}$ and PM_{coarse}) in 2022-2025 at London Honor Oak Park based on interpolated bihourly 1 h periods of data.

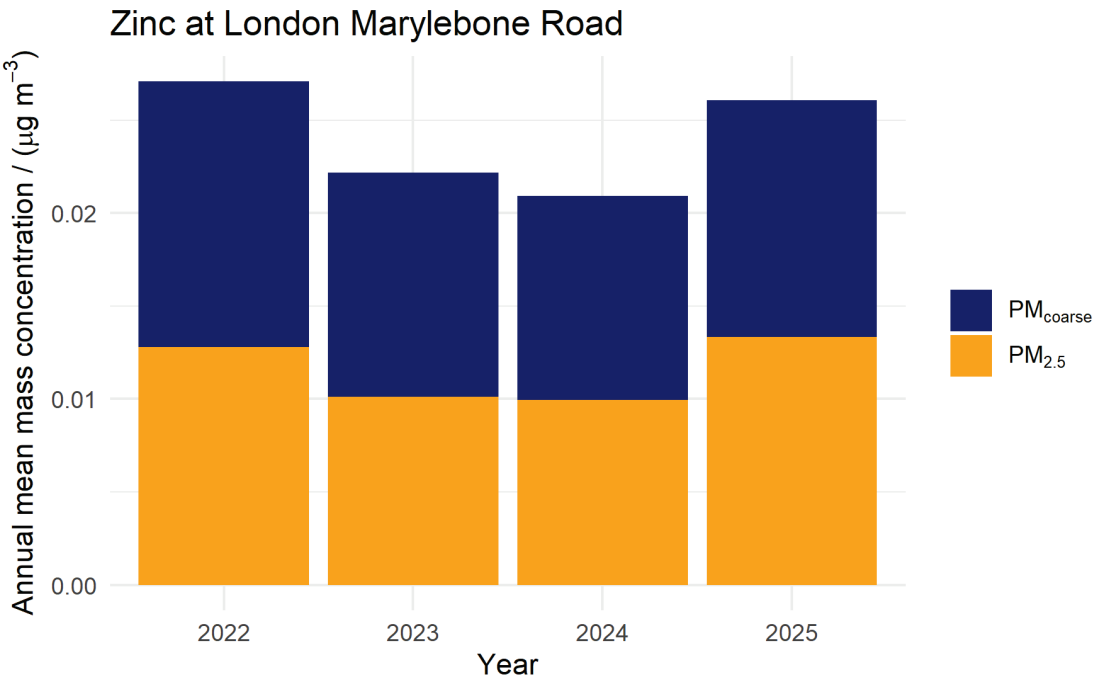

Figure 52 - Mean annual zinc concentrations in PM_{10} (split into $PM_{2.5}$ and PM_{coarse}) in 2022-2025 at London Marylebone Road based on interpolated bihourly 1 h periods of data.

4.5 OC and EC

4.5.1 Introduction

OC is present in urban environments both as primary PM emitted directly from combustion and other sources, and as secondary organic aerosol (SOA) formed through oxidation of volatile organic compounds (VOCs). SOA typically dominates the organic aerosol fraction in rural locations, particularly during the summer, driven largely by biogenic VOC emissions and their subsequent atmospheric processing. These processes contribute substantially to regional-scale high PM episodes, highlighting the importance of OC in both air quality and climate impacts. EC (often referred as soot) is usually formed by high temperature combustion processes such as combustion of fossil fuels (predominantly from heavy hydrocarbons, such as diesel) and certain biofuels. Measurements of EC at urban and roadside locations are required to improve emission inventories and to determine the impacts of vehicle emissions. As EC is chemically inert and primarily associated with combustion, it is widely used as a tracer for primary combustion emissions.

$PM_{2.5}$ sampling at Chilbolton Observatory and Auchencorth Moss is undertaken to comply with a statutory requirement under the AQSR 2010, which requires measurements of OC and EC in $PM_{2.5}$ at rural background sites.

The sampler previously stationed at Harwell (from 1 September 2011) was relocated to Chilbolton Observatory where it has been in continuous operation since 4 February 2016. The sampler at Auchencorth Moss has been operational since 17 November 2011.

4.5.2 2025 time series

The annual time series of OC, EC, and TC (the sum of OC and EC) for each site are displayed in Figure 53 to Figure 56. The plots for London Marylebone Road, London Honor Oak Park and Chilbolton Observatory comprise of daily mean data; the plot for Auchencorth Moss comprises of weekly mean data.

4.5.3 Long-term trends

Figure 57 to Figure 59 show the long-term trends in annual average mass concentrations for OC, EC, and TC measurements for the daily sampling at the two London sites (London Marylebone Road and London Honor Oak Park).

The London Marylebone Road OC, EC and TC mass concentrations show a downward trend over the period 2008 to 2020 (note that the sampler changed from PM_{10} to $PM_{2.5}$ in 2020). Since 2020, EC mass concentrations have become relatively stable, while OC and TC show an increasing trend up to 2023, followed by a decline at both sites in 2024 and similar levels in 2025.

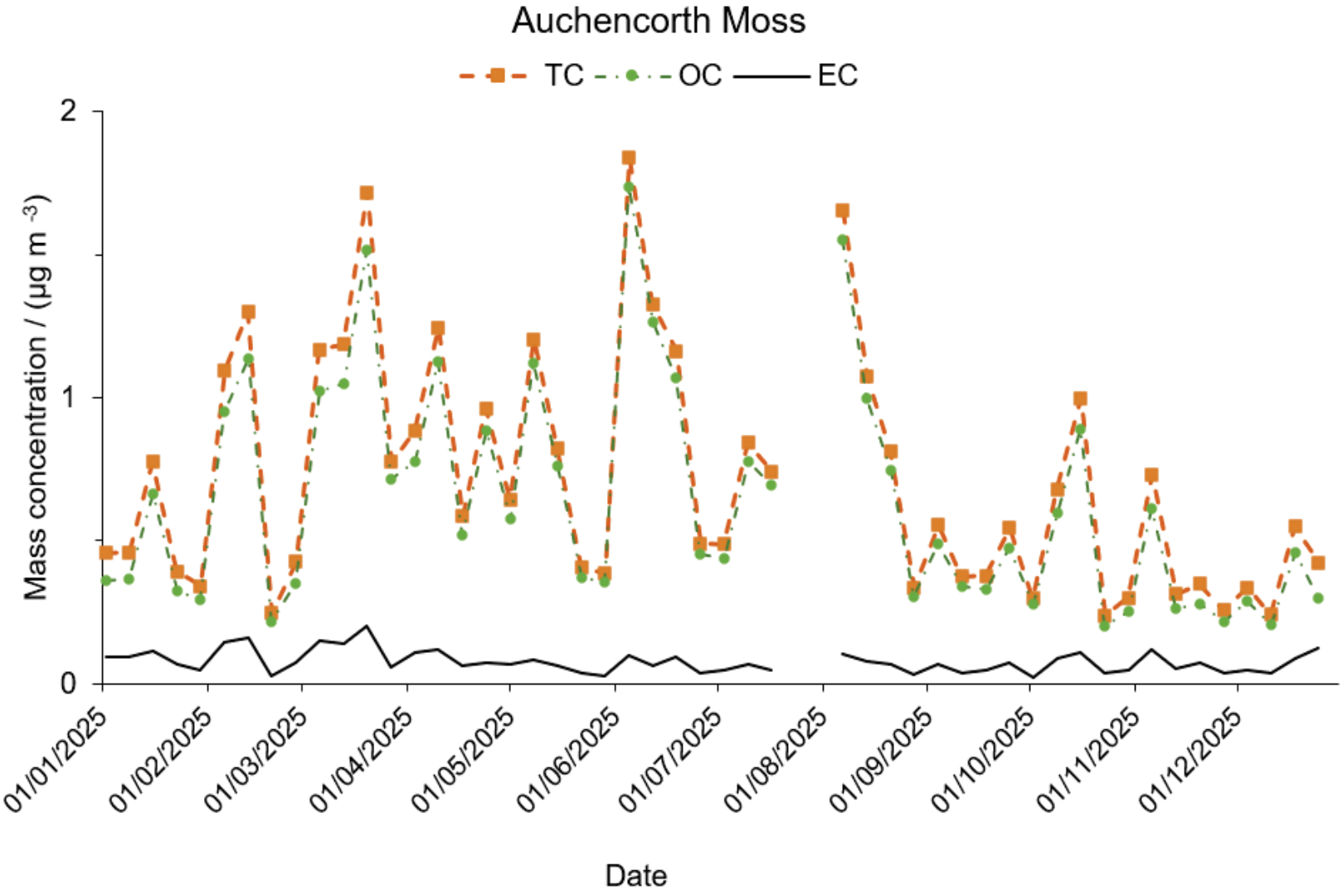

Figure 53 - Weekly OC, EC and TC mass concentrations in $PM_{2.5}$ measured at Auchencorth Moss during 2025.

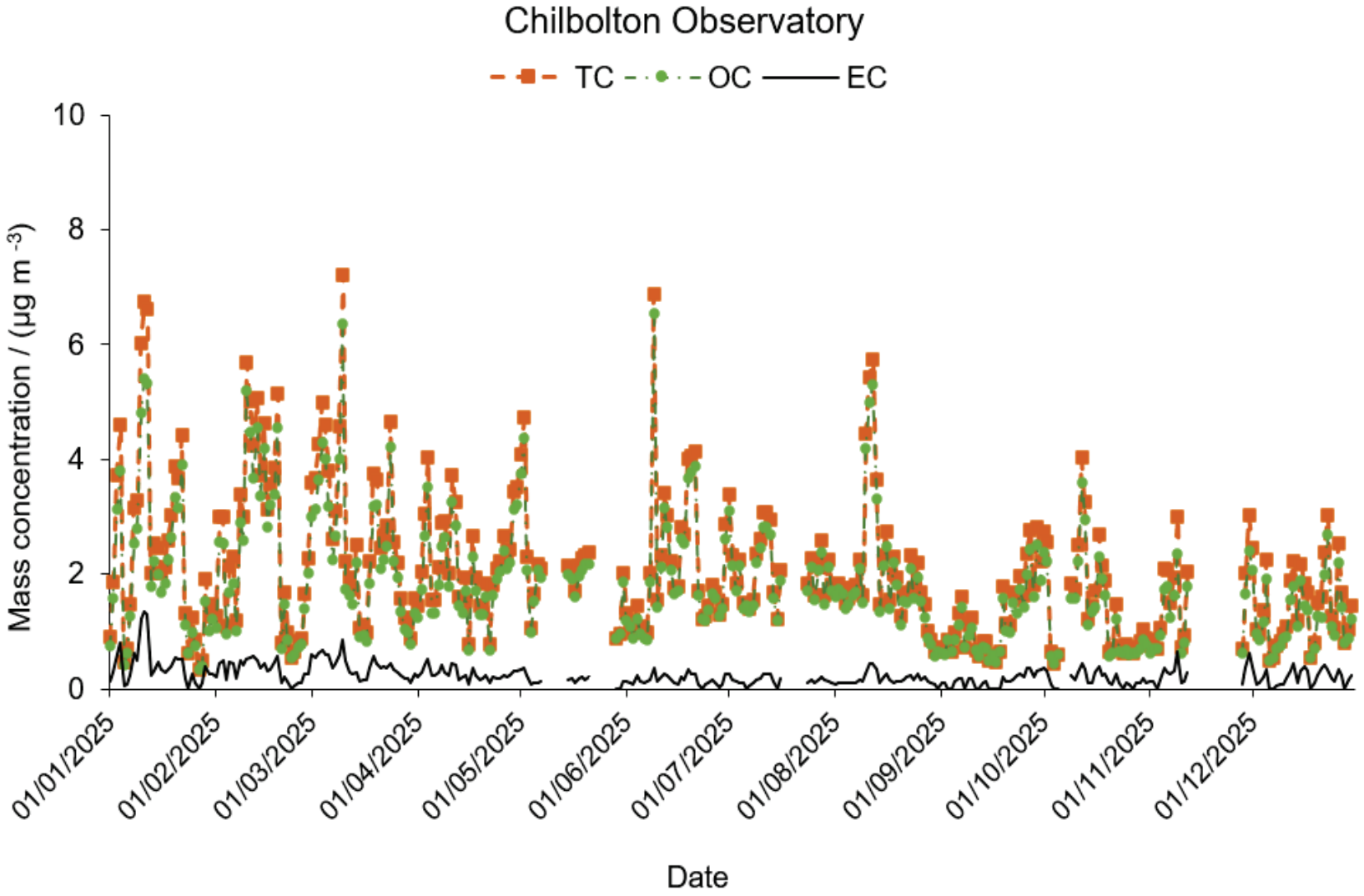

Figure 54 - Daily OC, EC and TC mass concentrations in $PM_{2.5}$ measured at Chilbolton Observatory during 2025.

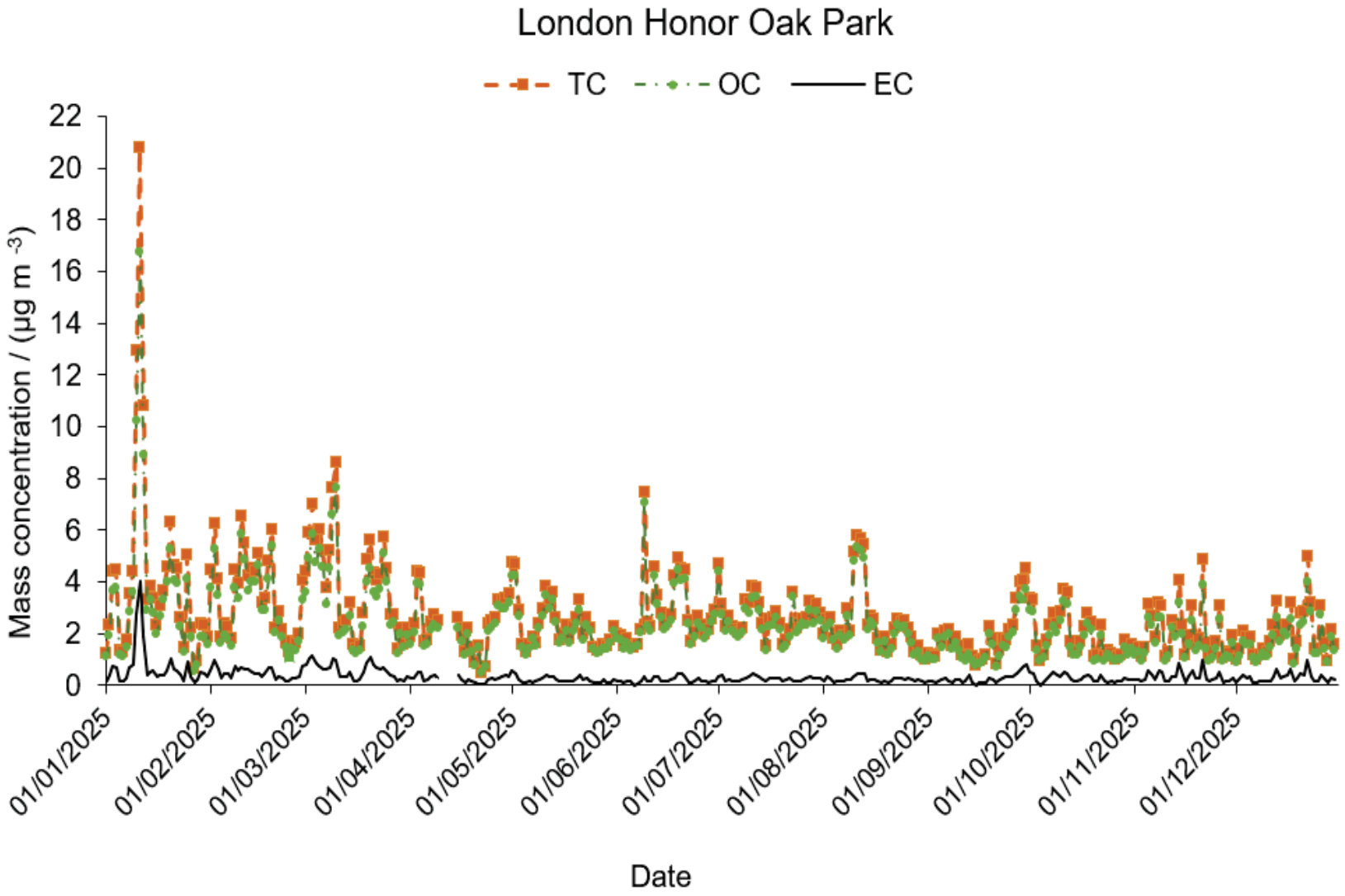

Figure 55 - Daily OC, EC, and TC mass concentrations in $PM_{2.5}$ measured at London Honor Oak Park during 2025.

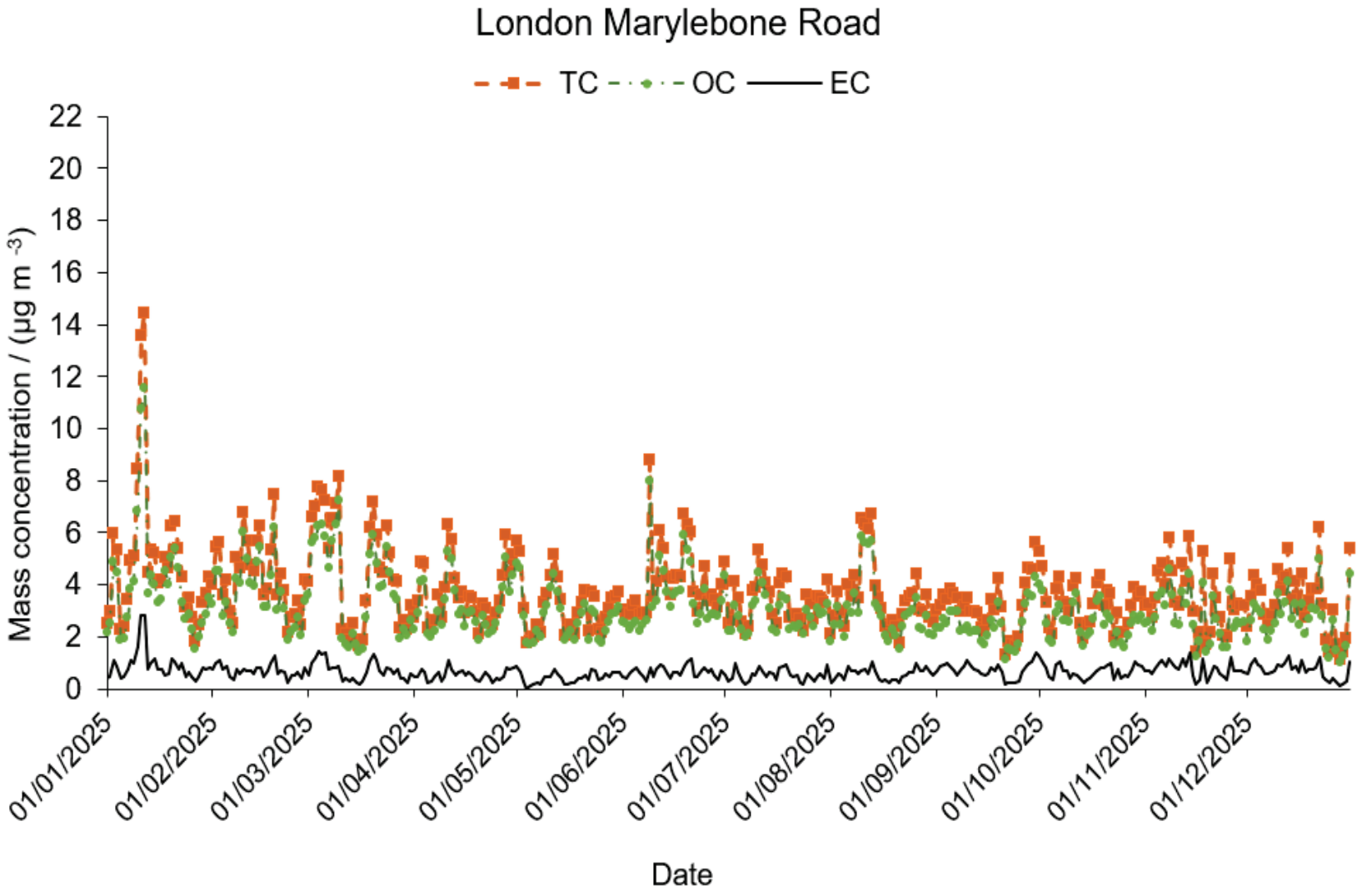

Figure 56 - Daily OC, EC, and TC mass concentrations in $PM_{2.5}$ measured at London Marylebone Road during 2025.

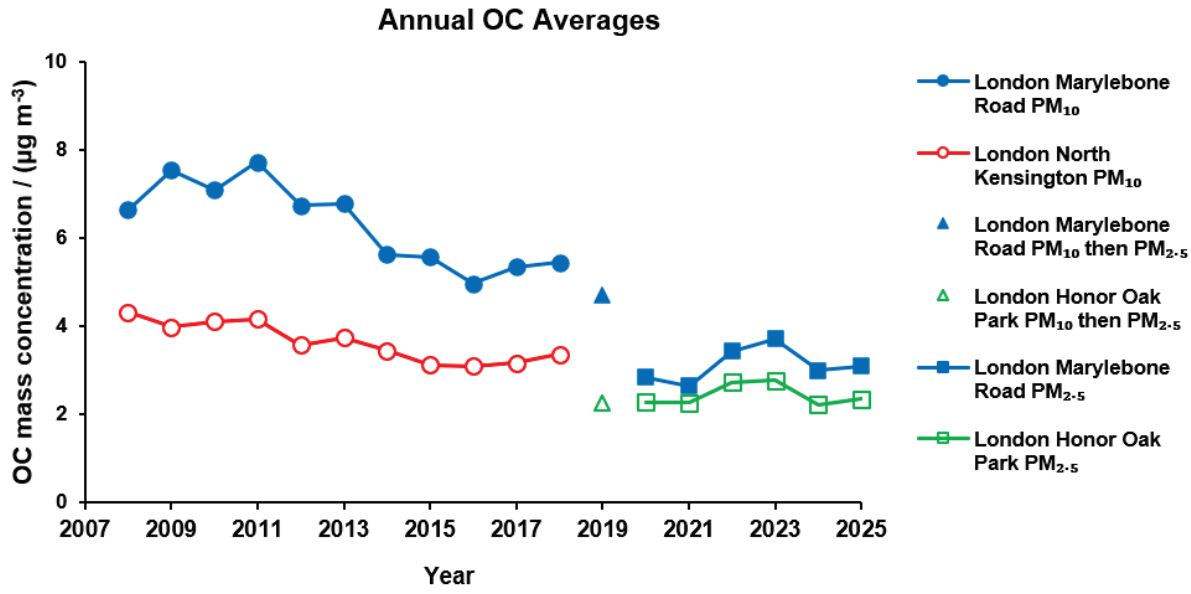

Figure 57 - Annual trends for OC measurements. PM_{10} sampling head was changed to $PM_{2.5}$ at London Honor Oak Park in February 2019 and at London Marylebone Road in October 2019, (therefore PM_{10} and $PM_{2.5}$ were both collected in 2019). Partisol samplers were replaced with Digitel samplers at London Honor Oak Park and London Marylebone Road in 2022.

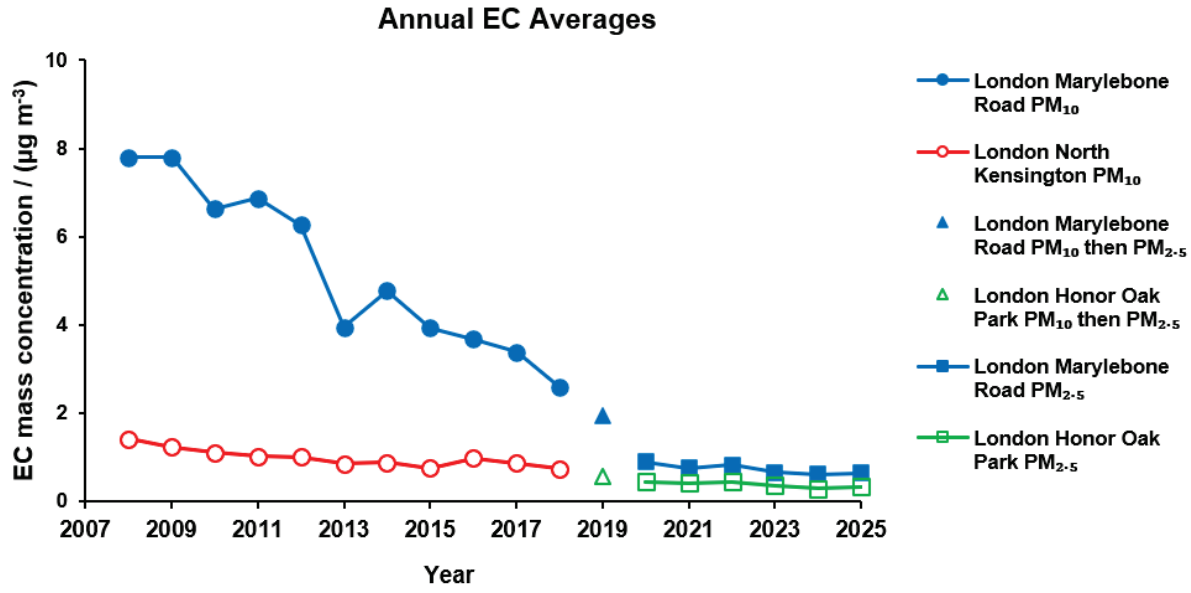

Figure 58 - Annual trends for EC measurements. PM_{10} sampling head was changed to $PM_{2.5}$ at London Honor Oak Park in February 2019 and at London Marylebone Road in October 2019, (therefore PM_{10} and $PM_{2.5}$ were both collected in 2019). Partisol samplers were replaced with Digitel samplers at London Honor Oak Park and London Marylebone Road in 2022.

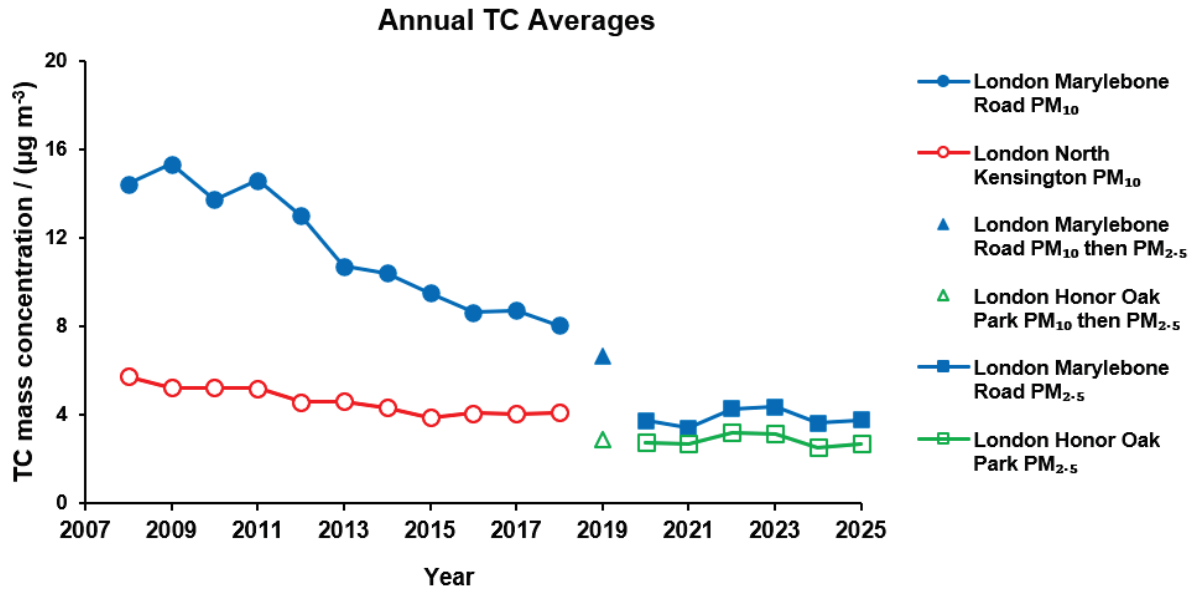

Figure 59 - Annual trends for TC measurements. PM10 sampling head was changed to PM2.5 at London Honor Oak Park in February 2019 and at London Marylebone Road in October 2019 (therefore PM_{10} and $PM_{2.5}$ were both collected in 2019). Partisol samplers were replaced with Digitel samplers at London Honor Oak Park and London Marylebone Road in 2022.

4.6 BC and UVPM

4.6.1 Introduction

BC and UVPM concentration data for 2025 are presented and discussed in the following sections. It should be noted that the Aethalometers at all sites were upgraded in November 2019 from Aerosol Magee Scientific model AE22 to model AE33. Thus, all results provided in this report should be treated with caution especially when comparing earlier years when the AE22 model was used[27].

The AE33 Aethalometer calculates mass concentration at seven wavelengths: 950 nm (infrared, IR-2), 880 nm (BC), 660 nm (Red), 590 nm (Yellow), 520 nm (Green), 470 nm (Blue), and 370 nm (UV).

4.6.2 2025 time series - BC

Figure 60 to Figure 65 show daily BC mass concentrations based on hourly results reported for 2025. The data have been split into separate figures covering different areas of the UK (defined in Section 2.2) for clarity. As seen in previous years, Northern Ireland sites generally measured increased concentrations during the colder months from October to mid-April, indicating the contribution from domestic heating.

4.6.3 2025 annual averages - BC and UVPM

The annual mean mass concentrations of BC and UVPM are presented as a bar graph, in Figure 66 and Figure 67 respectively, to aid the comparison between sites and site classifications. The highest BC mass concentrations were measured in the Northern England (Bradford Shipley Airedale Road) and at urban traffic sites.

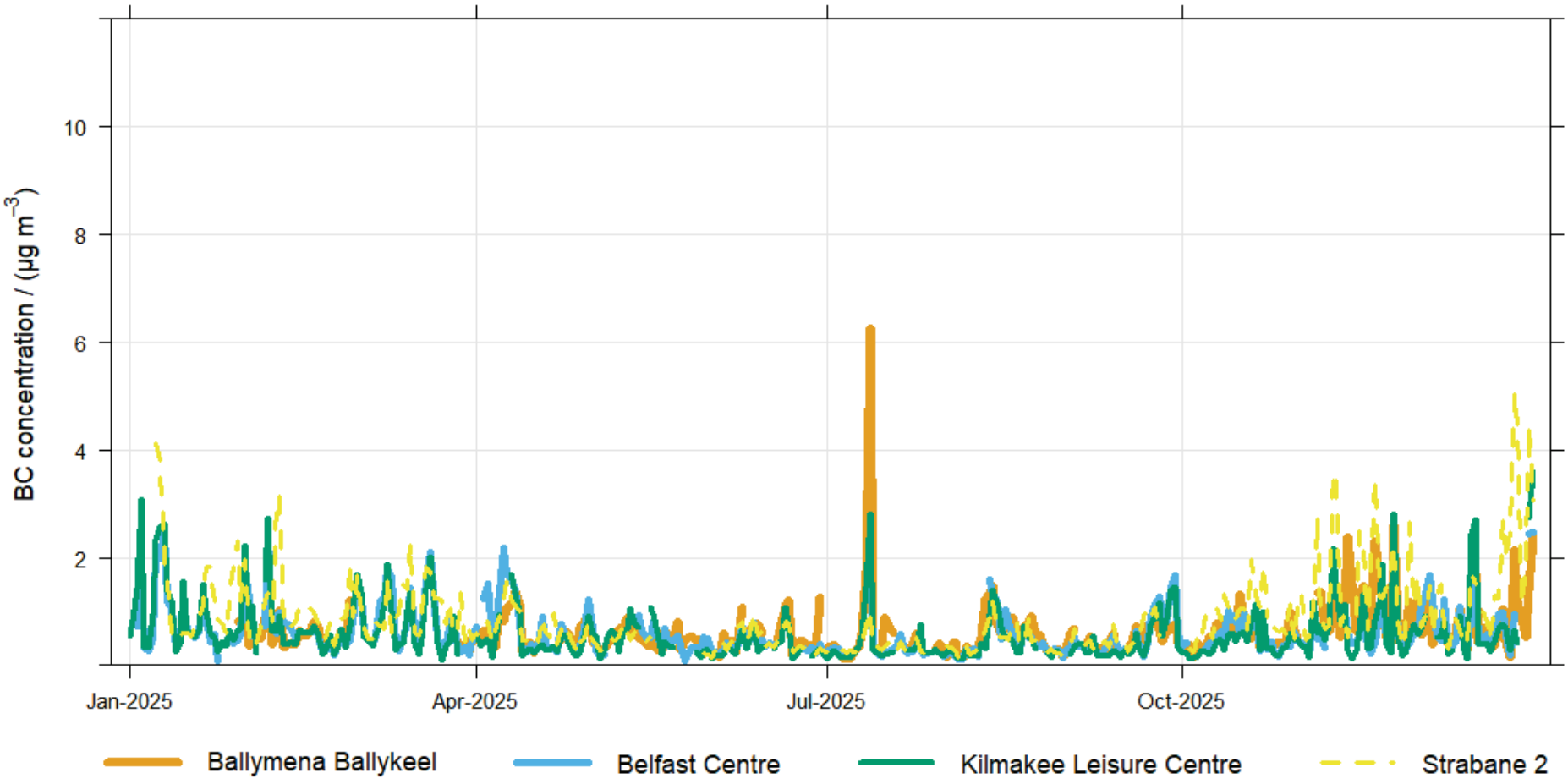

Figure 60 - BC concentrations during 2025 in Northern Ireland.

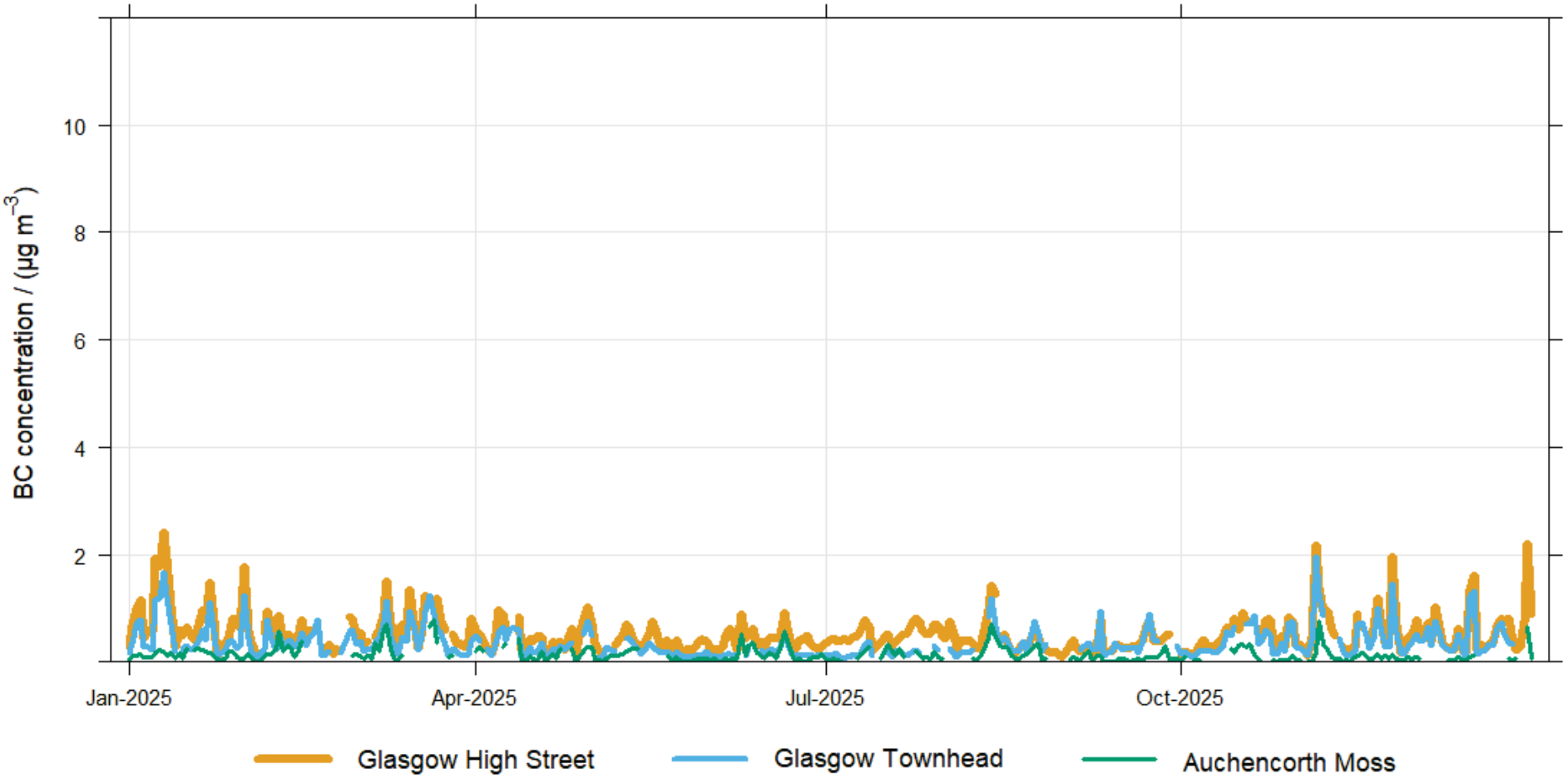

Figure 61 - BC concentrations during 2025 in Scotland.

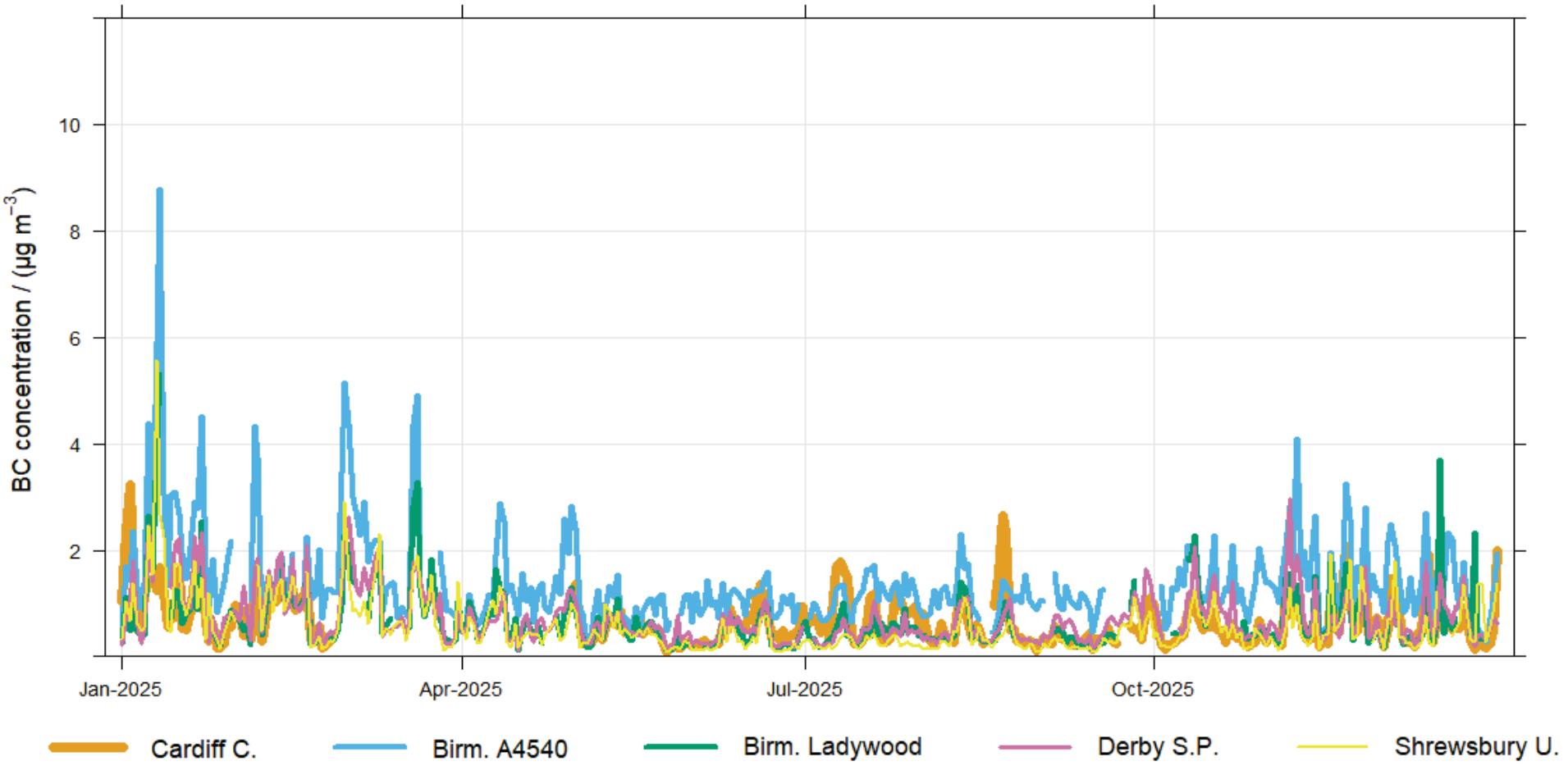

Figure 62 - BC concentrations during 2025 in Wales and the Midlands.

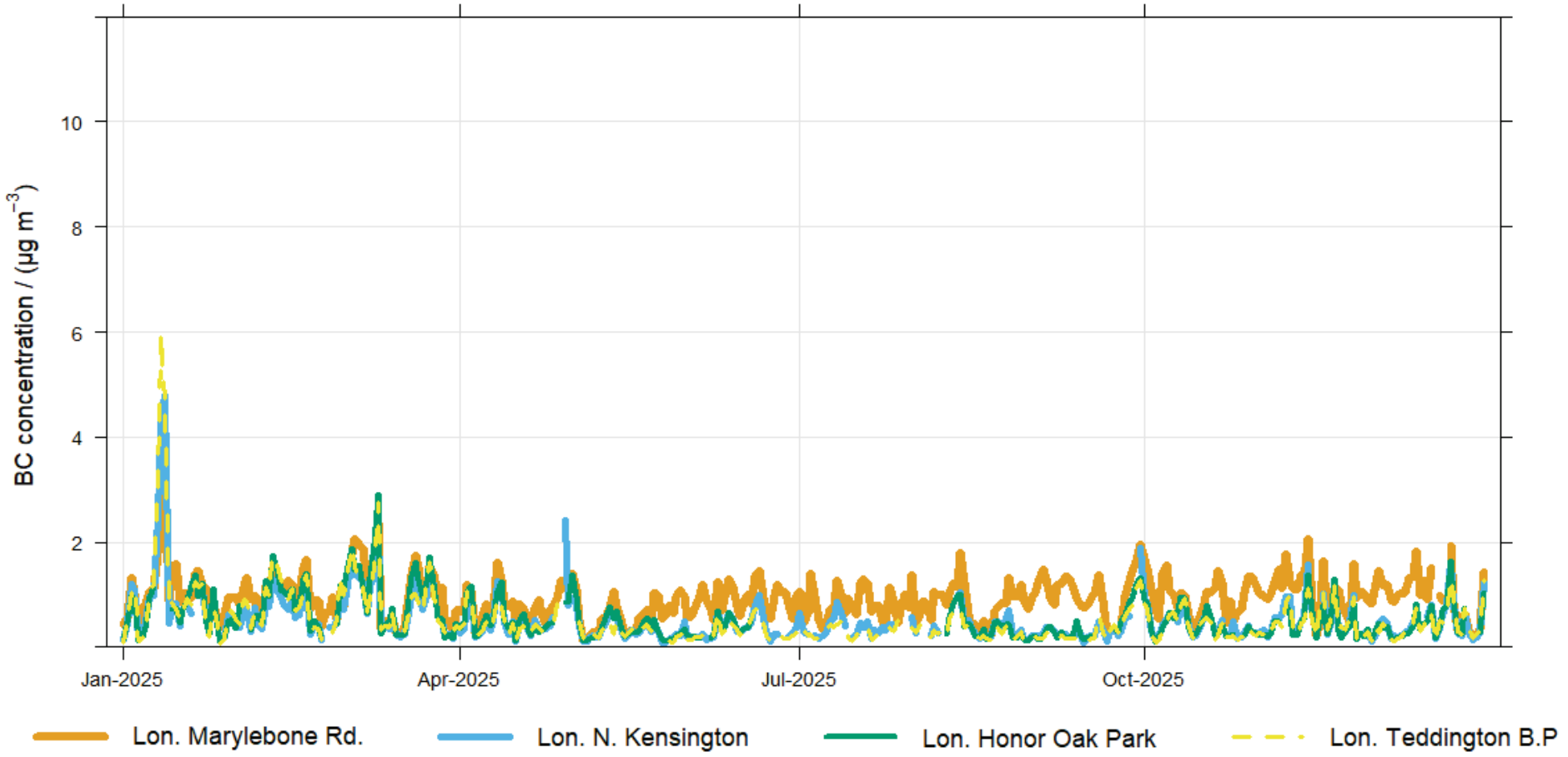

Figure 63 - BC concentrations during 2025 in London.

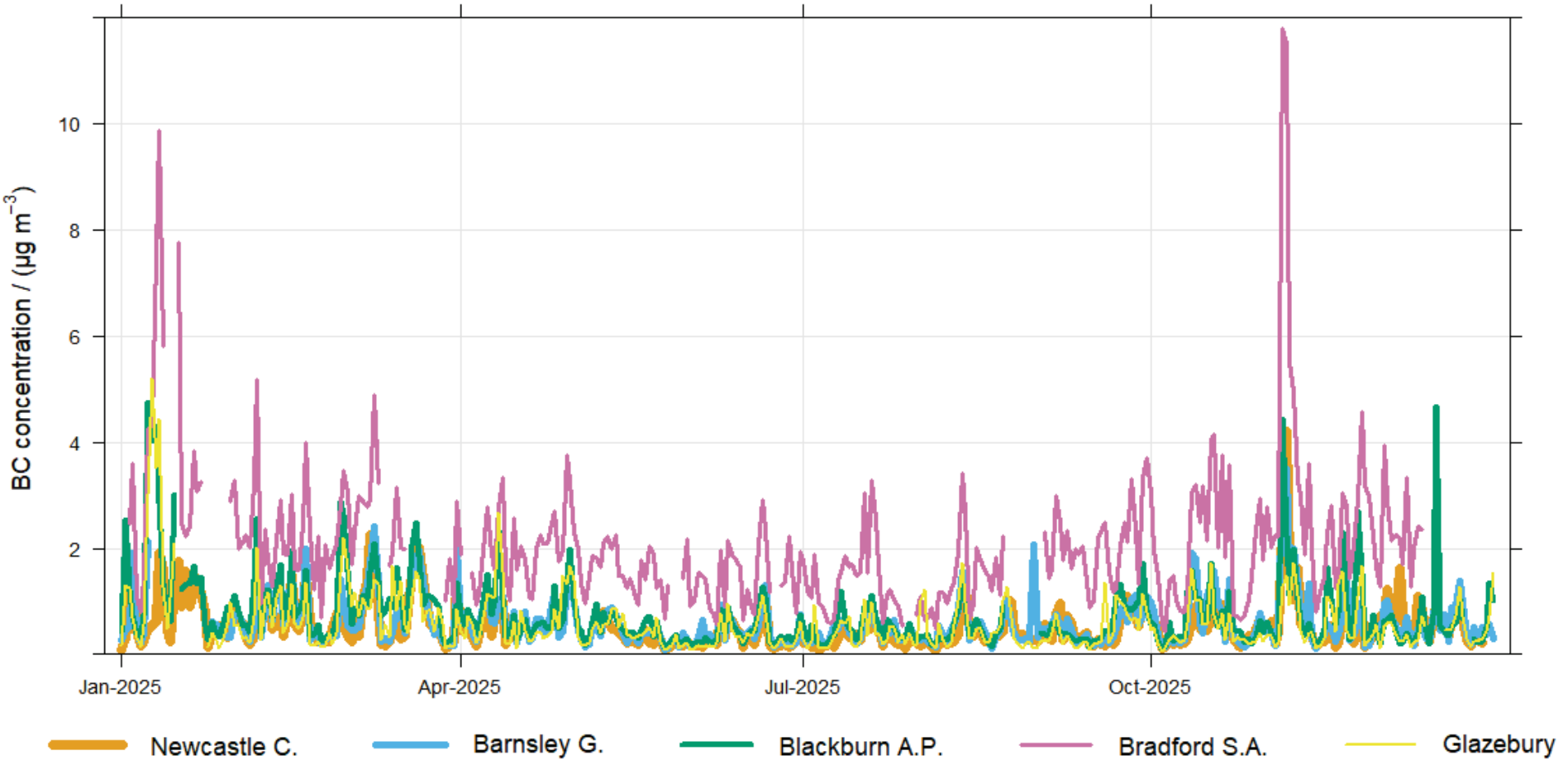

Figure 64 - BC concentrations during 2025 in Northern England.

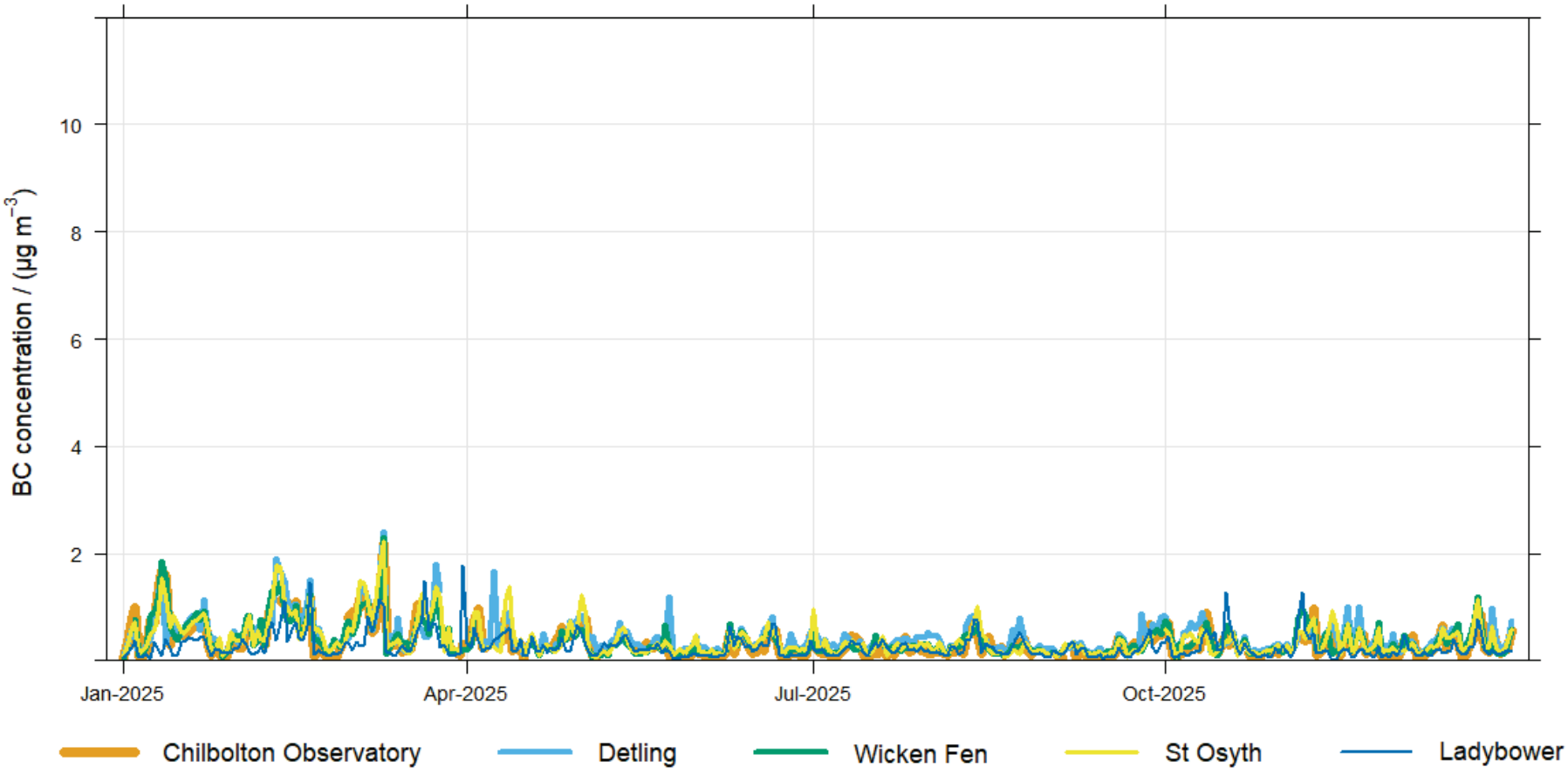

Figure 65 - BC concentrations during 2025 at rural locations (excluding Auchencorth Moss and Glazebury, which are plotted in Figure 61 and Figure 64, respectively).

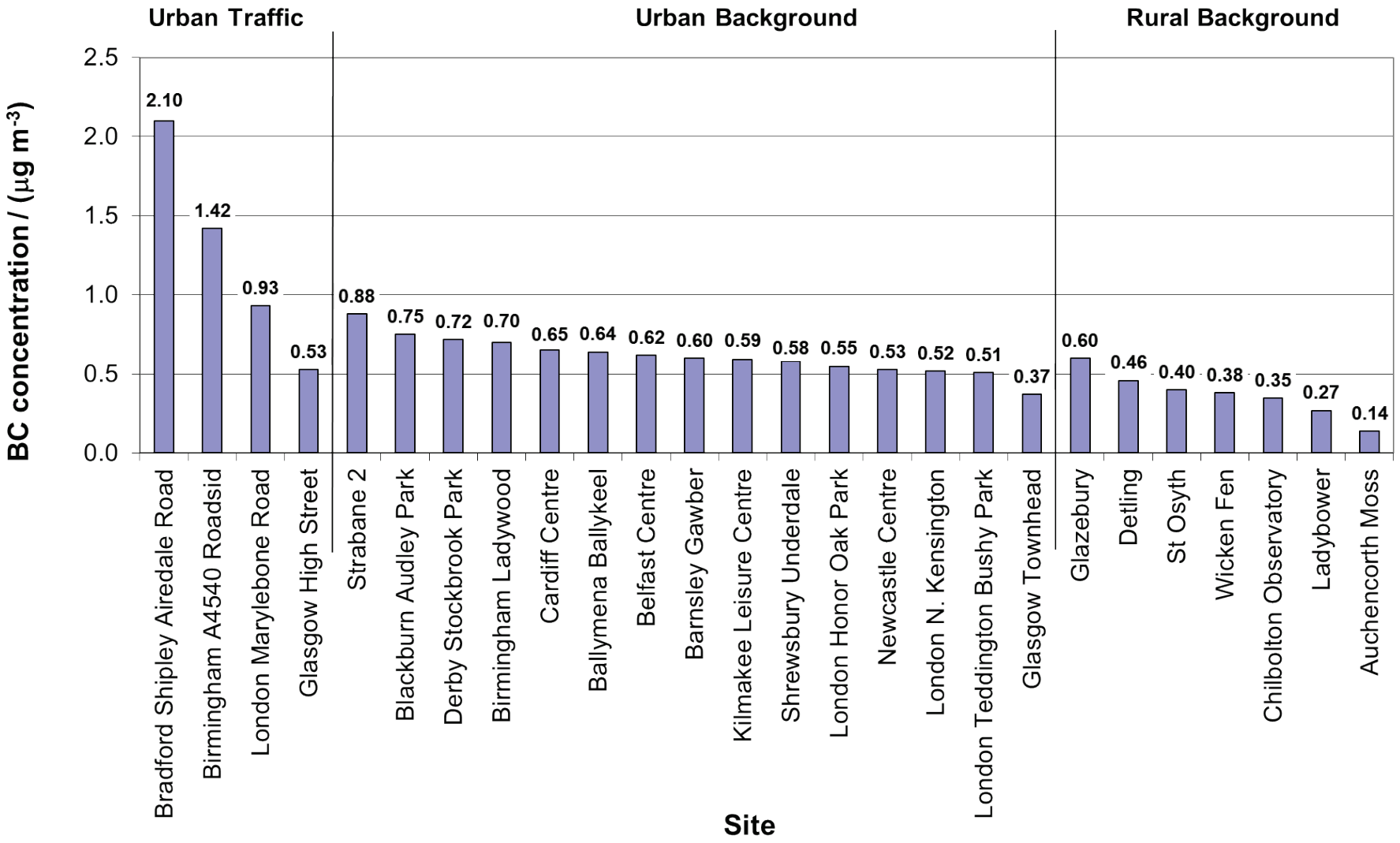

Figure 66 - Annual mean BC concentrations measured in 2025.

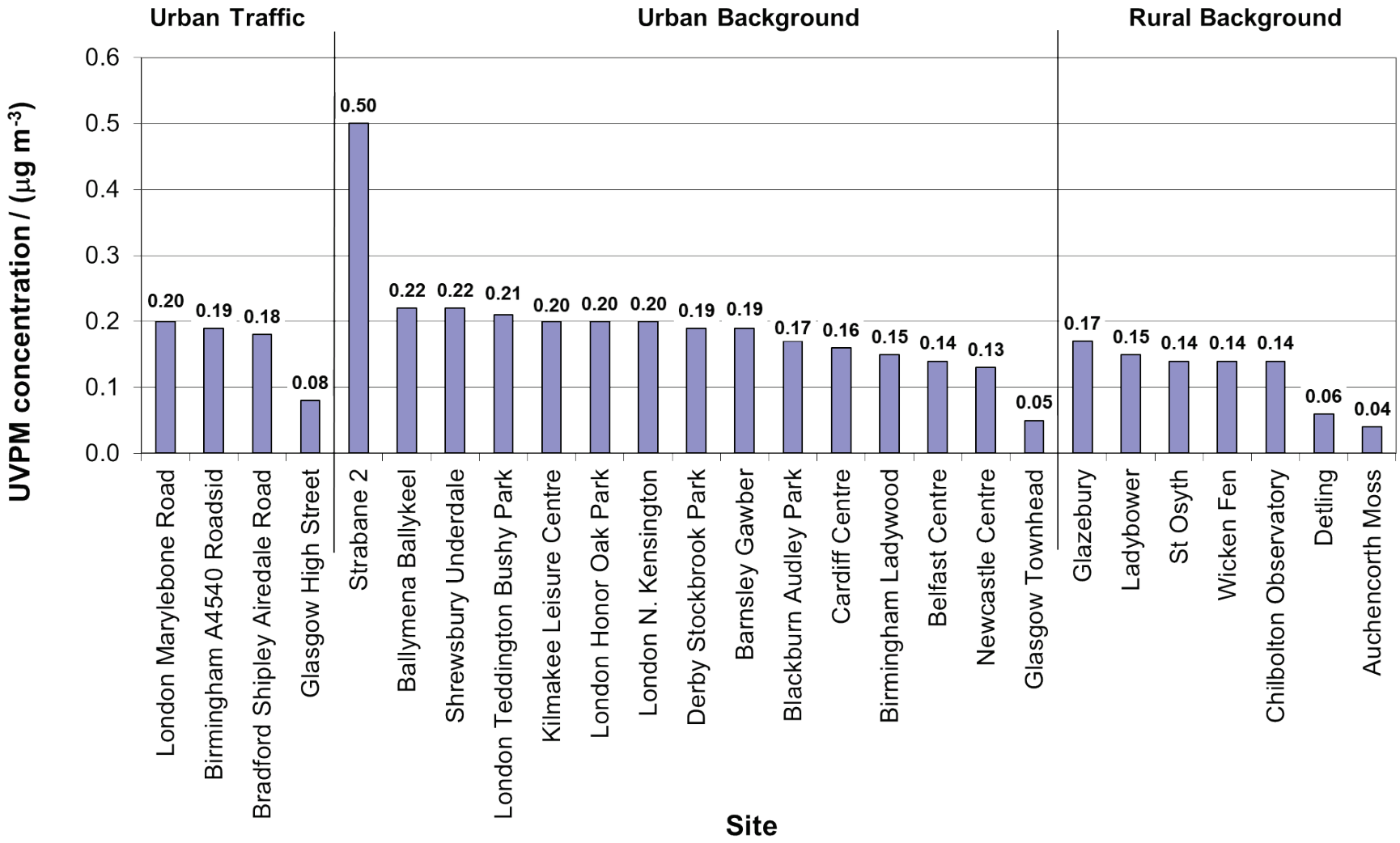

Figure 67 - Annual mean UVPM concentrations in 2025.

4.6.4 Diurnal, weekly, and monthly profiles - BC and UVPM

This section presents the within-year temporal variation in BC and UVPM concentrations. Figure 68 to Figure 74 present data from seven of the 26 sites operating in 2025. The seven sites were chosen to represent those sites with the highest reported BC mass concentrations within each site classification, urban traffic, urban background and rural background (see Figure 66), and geographical grouping (defined in section 2.2).

At urban traffic sites on weekdays, the BC concentrations generally followed the expected profile resulting from traffic emissions through the day, with elevated concentrations in the morning and evening rush hours. This double peak can be seen at all the urban traffic sites (Figure 68, Figure 69 and Figure 71) apart from London Marylebone Road (Figure 73), where concentrations remain relatively consistent during daytime, reflecting the steady traffic volume at this site. Weekends showed slightly lower and less variable BC concentrations, particularly at London Marylebone Road. There was little UVPM observed at any of the urban traffic sites.

BC and UVPM concentrations measured at the urban background site of Strabane 2 indicate a domestic emission source, likely associated with secondary heating and can be seen during weekdays and weekends (see Figure 74). However, at other urban background sites, a signature from traffic, with a BC peak in the morning rush hour, is more prominent, with little corresponding increase in UVPM concentrations (plots not shown).

At rural sites, the BC concentrations were lower than at the other site classifications and, as expected, did not exhibit morning or evening rush hour peaks (see Figure 72 as an example). The rise in concentrations in the evening occurred at later times than would be expected for a traffic signal, and were also observed in the UVPM, suggesting a domestic heating source (see Figure 70).

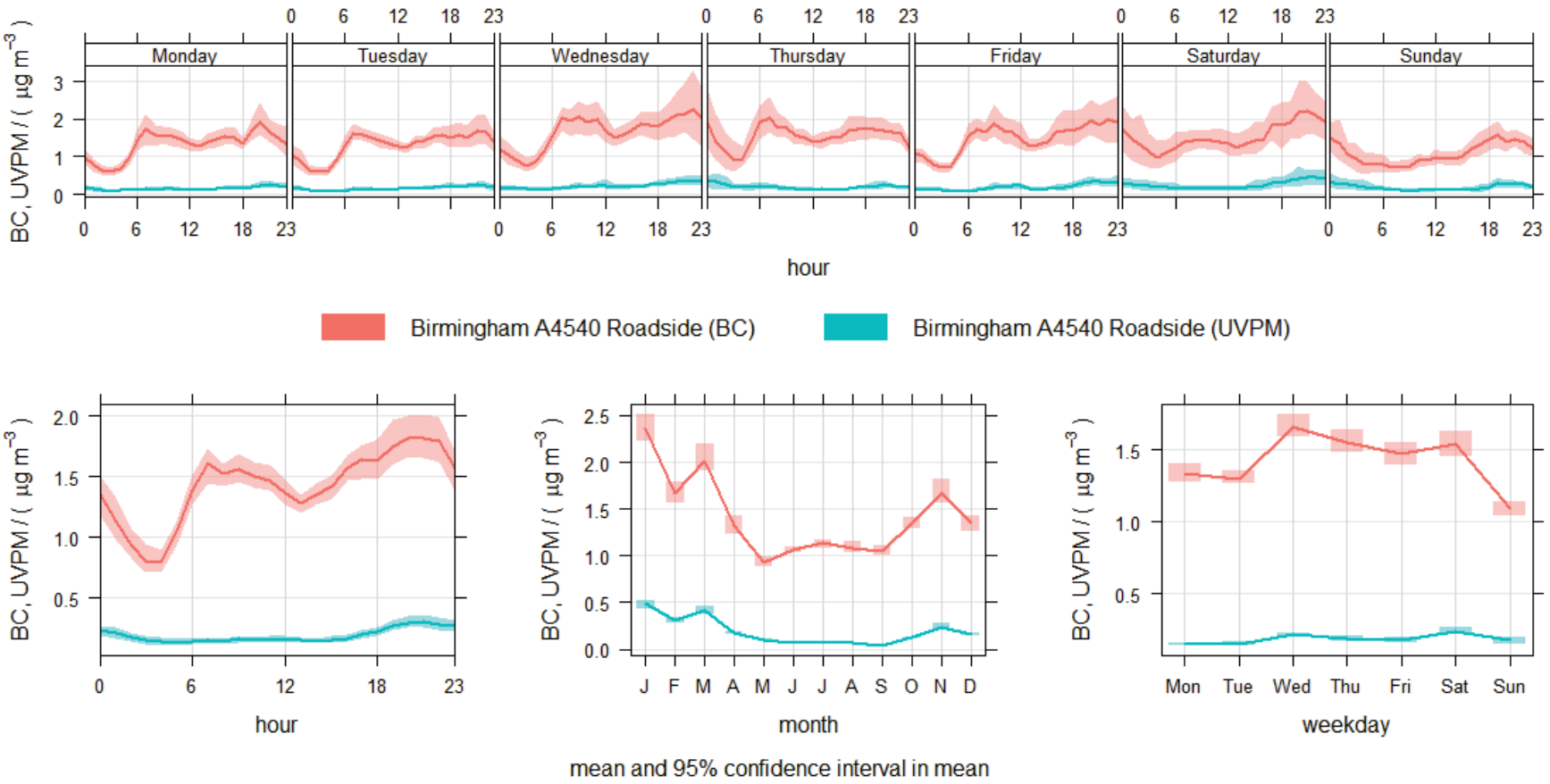

Figure 68 - Diurnal, weekly and monthly variations in BC and UVPM mass concentrations at Birmingham A4540 Roadside (an urban traffic site) for 2025. The solid lines represent the mean black carbon or UVPM mass concentration, and the shaded areas represent the 95 % confidence interval in the mean.

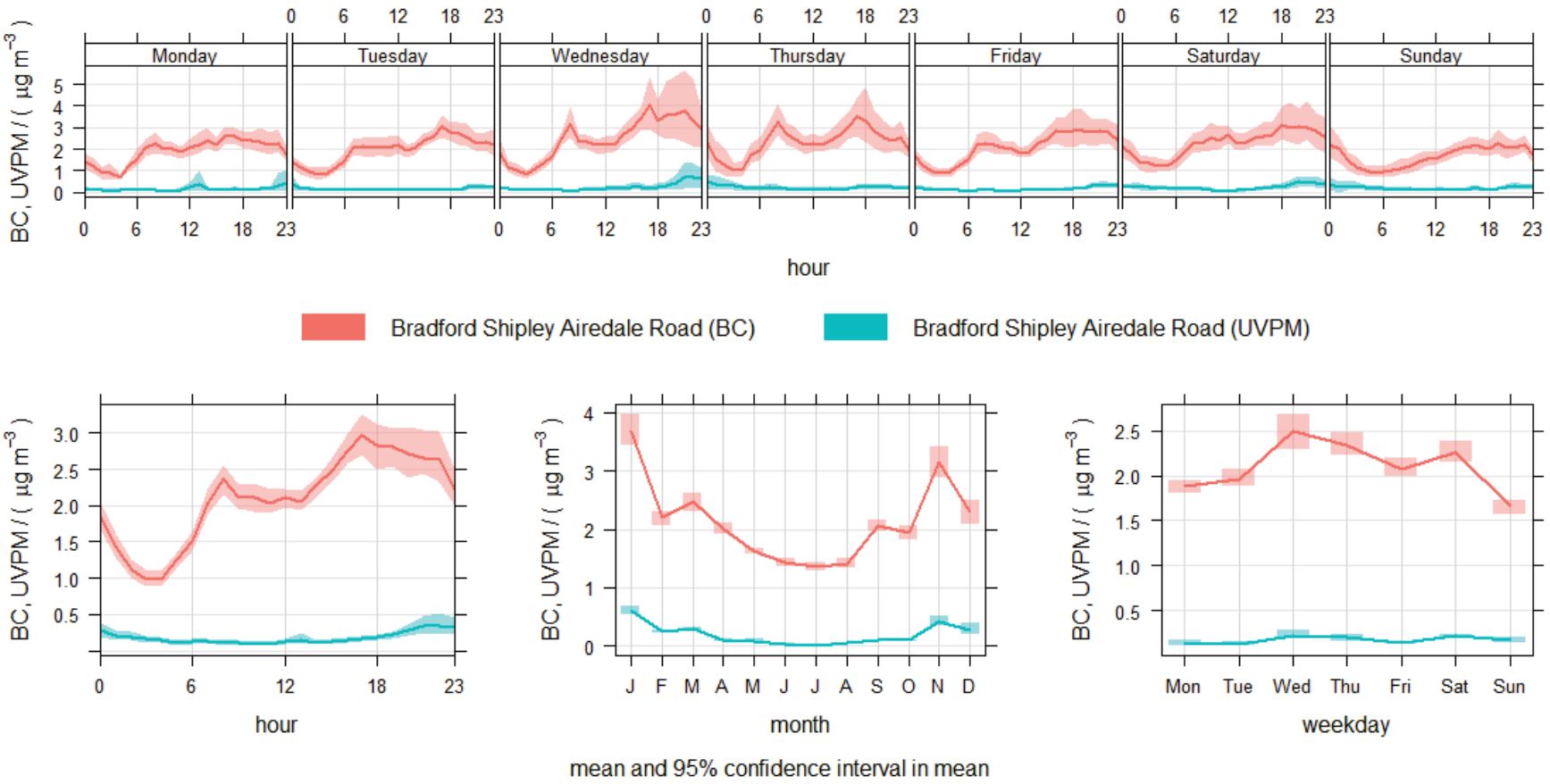

Figure 69 - Diurnal, weekly and monthly variations in BC and UVPM mass concentrations at Bradford Shipley Airedale Road (an urban traffic site) for 2025. The solid lines represent the mean black carbon or UVPM mass concentration, and the shaded areas represent the 95 % confidence interval in the mean.

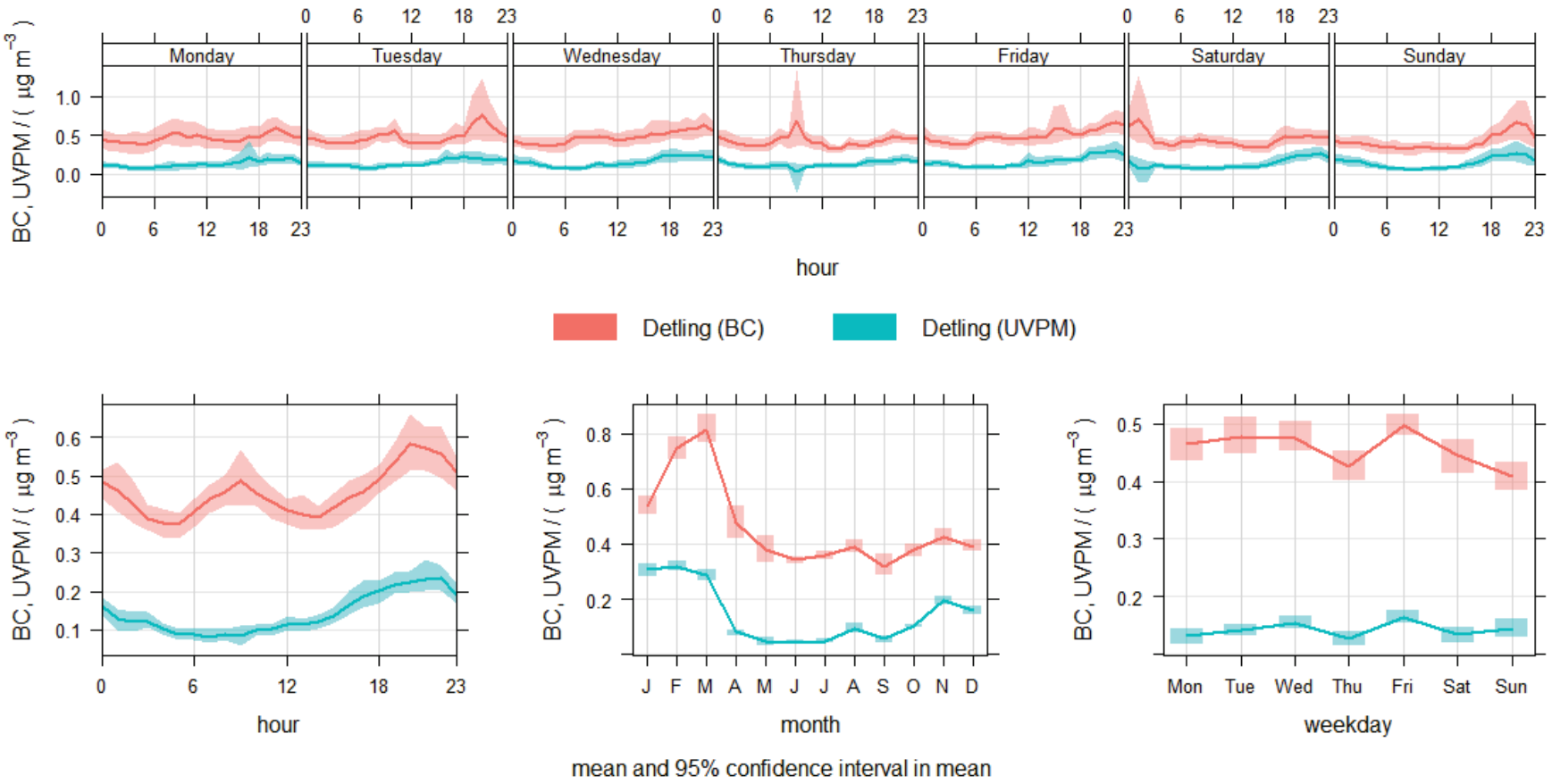

Figure 70 - Diurnal, weekly and monthly variations in BC and UVPM mass concentrations at Detling (a rural background site) for 2025. The solid lines represent the mean black carbon or UVPM mass concentration, and the shaded areas represent the 95 % confidence interval in the mean.

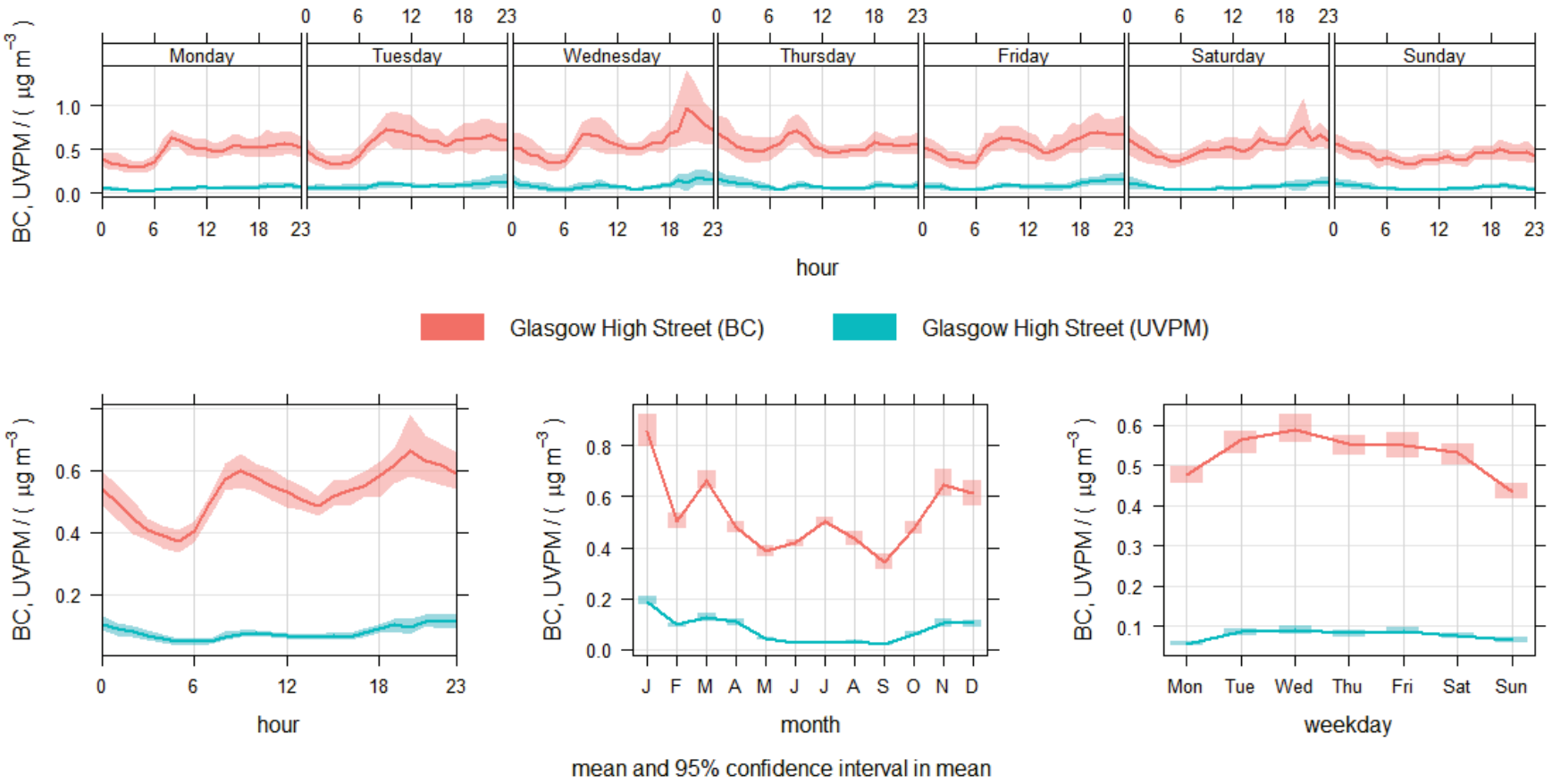

Figure 71 - Diurnal, weekly and monthly variations in BC and UVPM mass concentrations at Glasgow High Street (an urban traffic site) for 2025. The solid lines represent the mean black carbon or UVPM mass concentration, and the shaded areas represent the 95 % confidence interval in the mean.

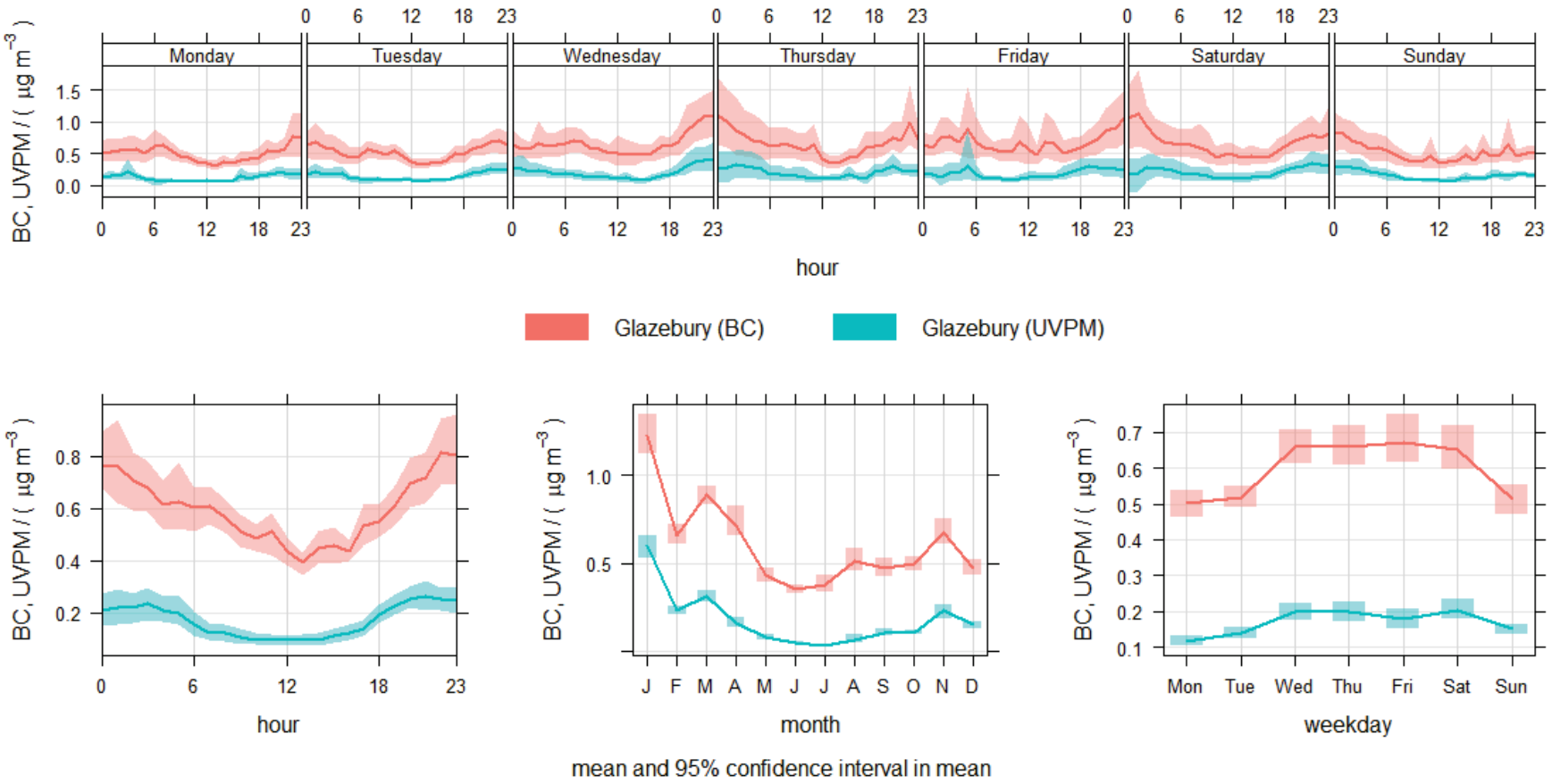

Figure 72 - Diurnal, weekly and monthly variations in BC and UVPM mass concentrations at Glazebury (a rural background site) for 2025. The solid lines represent the mean black carbon or UVPM mass concentration, and the shaded areas represent the 95 % confidence interval in the mean.

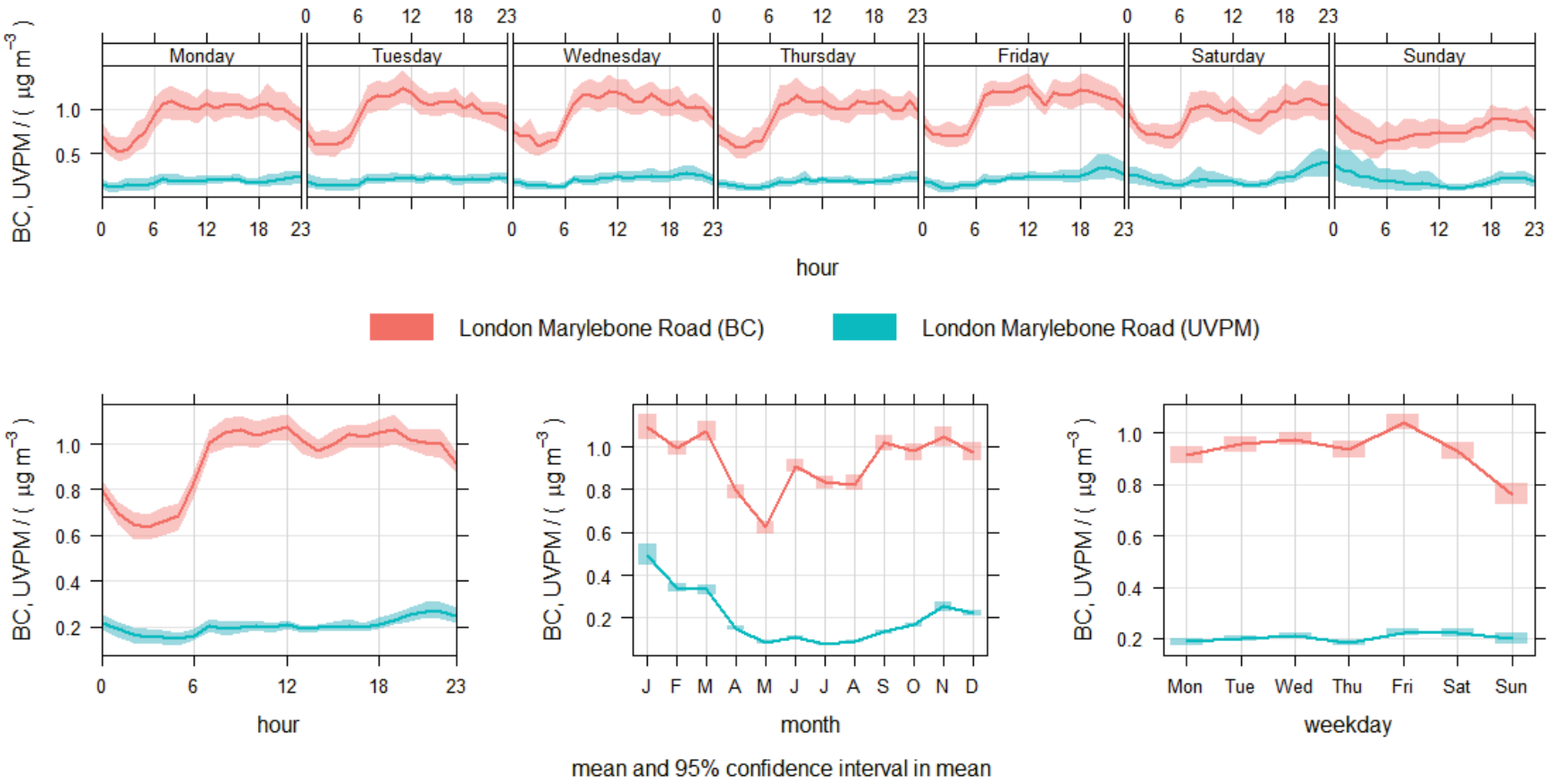

Figure 73 - Diurnal, weekly and monthly variations in BC and UVPM mass concentrations at London Marylebone Road (an urban traffic site) for 2025. The solid lines represent the mean black carbon or UVPM mass concentration, and the shaded areas represent the 95 % confidence interval in the mean.

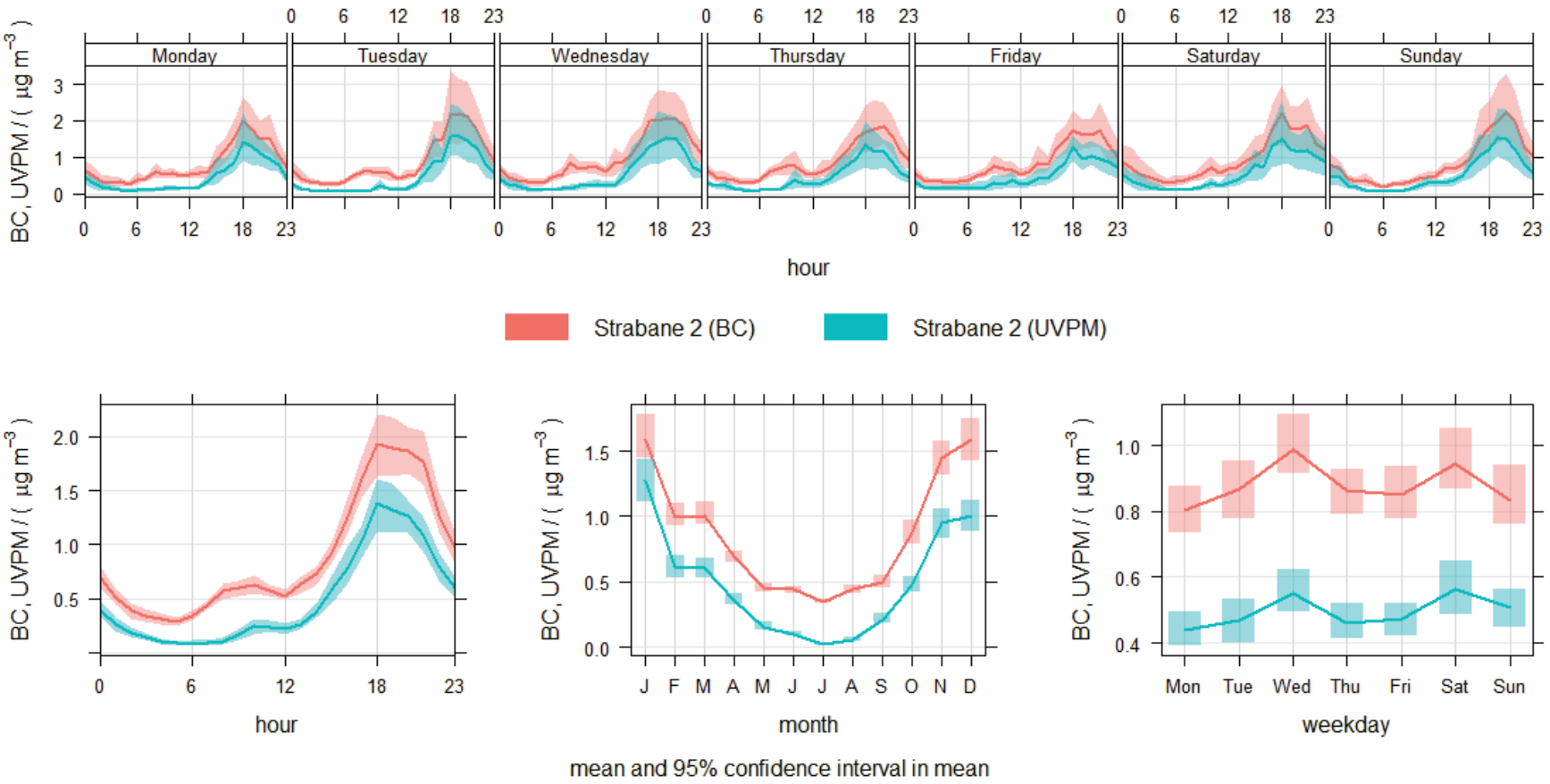

Figure 74 - Diurnal, weekly and monthly variations in BC and UVPM mass concentrations at Strabane 2 (an urban background site) for 2025. The solid lines represent the mean black carbon or UVPM mass concentration, and the shaded areas represent the 95 % confidence interval in the mean.

4.6.5 Long-term trends

Figure 75 to Figure 79 show the trend in BC concentrations from the five longest running sites in the Network, as monthly averages over the full calendar years 2009 to 2025.

The Theil-Sen method[28,29] in the OpenAir software package was used to calculate the regression parameters including slope and uncertainty in the slope. This method chooses the median slope among all lines through pairs of two-dimensional sample points. The Theil-Sen estimator tends to yield accurate confidence intervals even with non-normal data and heteroscedasticity (non-constant error variance). It is also resistant to outliers.

Bootstrap resampling provides the confidence interval for the regression slope. For these analyses the 2.5th and 97.5th percentile slopes are taken from all possible slopes shown as dashed lines with values provided in square brackets on each plot in Figure 75 and Figure 79. A statistically significant trend can be assumed when the probability value p is < 0.001 (as indicated by *** on the charts, while ** is for p < 0.01, * is for p < 0.05 and the + symbol is for p < 0.1).

Over the period 2009 to 2025 all the long-running sites on the Network, apart from Strabane 2, have shown a significant downward trend in BC concentrations. The decrease at London Marylebone Road (where BC concentrations have been falling consistently since 2011) is significantly larger than that at the other sites. However, the rate of change has decreased since 2020, thus the overall long-term trend from 2009-2025 should be treated with caution for this site.

Figure 80 and Figure 84 show the long-term trends in UVPM concentration for the same five sites, which showed slight downward trends over the period 2009 to 2025 at all sites except London Marylebone Road. However, these results should be treated with caution as only the trends determined for the London North Kensington and Kilmakee Leisure Centre sites are statistically significant.

As discussed in section 4.6.1. the Aethalometers were upgraded in November 2019 from Aerosol Magee Scientific model AE22 to model AE33. Although the methodology of both models is, in principle, the same, they use different algorithms and factors to calculate the final BC mass concentration. Thus, all results provided in this report should be treated with caution when comparing data from the AE33 model with data from the AE22 model used in earlier years.

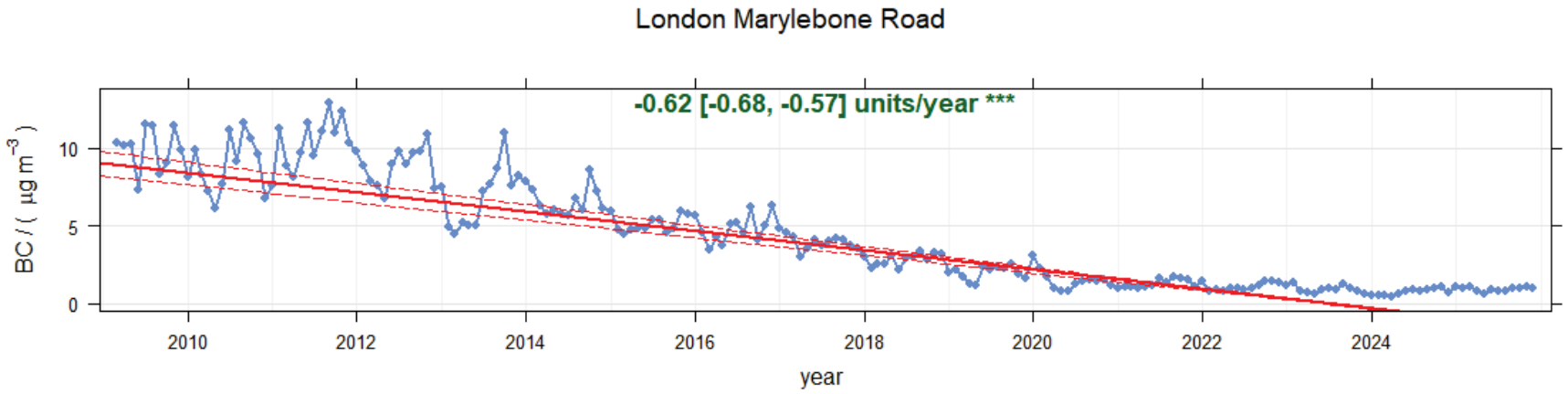

Figure 75 - Long-term trends in BC mass concentration at London Marylebone Road (urban traffic), 2009 – 2025 (***$p < 0.001$).

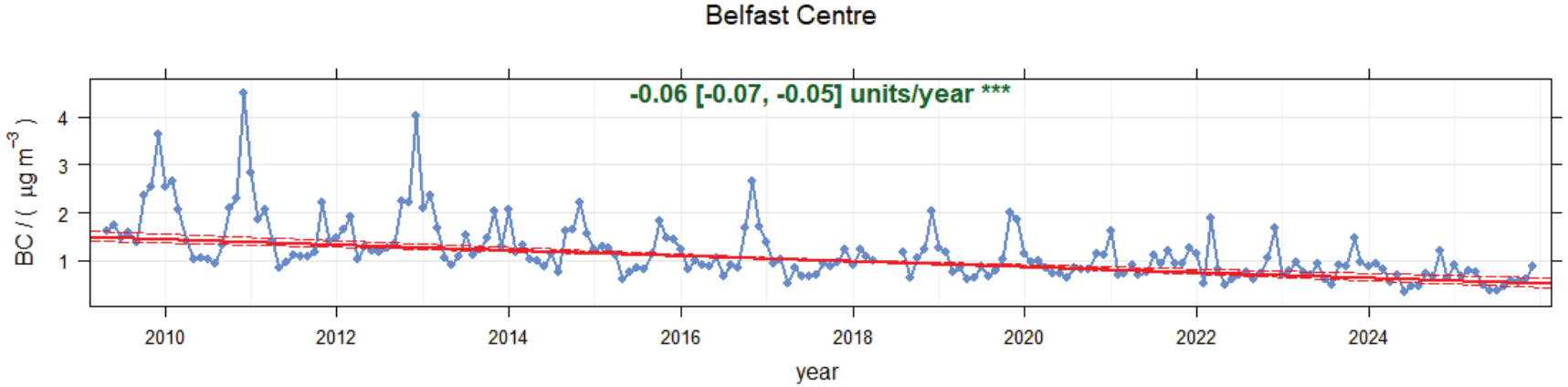

Figure 76 - Long-term trends in BC mass concentration at Belfast Centre (urban background), 2009 – 2025 (***$p < 0.001$).

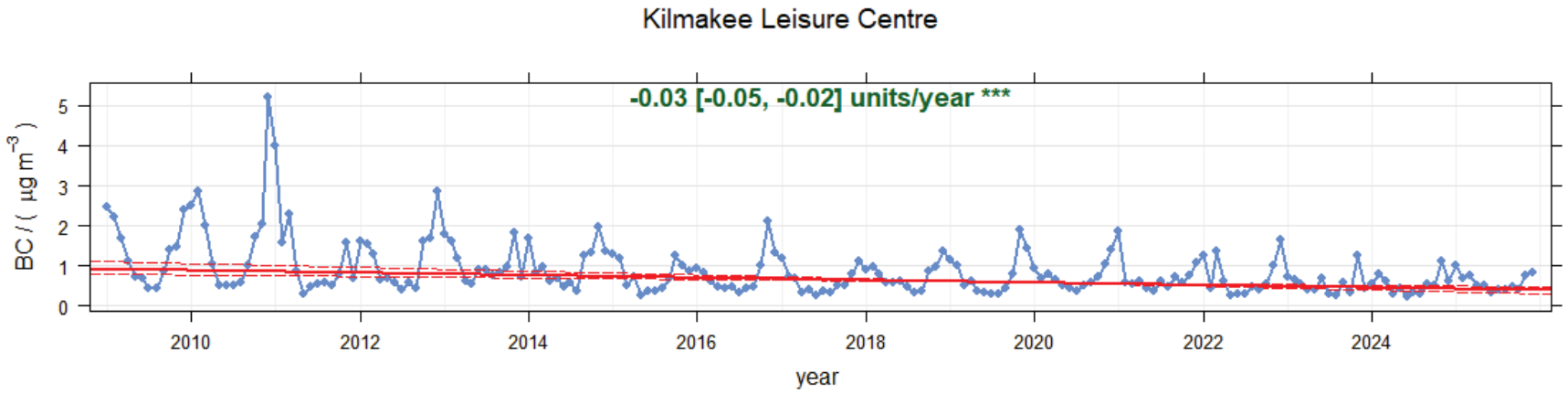

Figure 77 - Long-term trends in BC mass concentration at Kilmakee Leisure Centre (urban background), 2009 – 2025 (***p < 0.001).

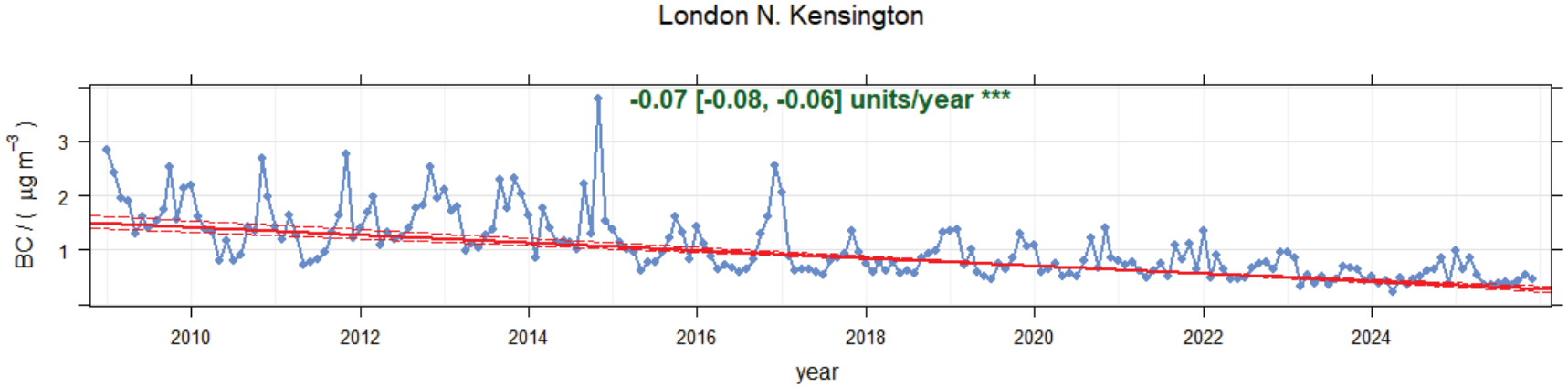

Figure 78 - Long-term trends in BC mass concentration at London North Kensington (urban background), 2009 – 2025 (***p < 0.001).

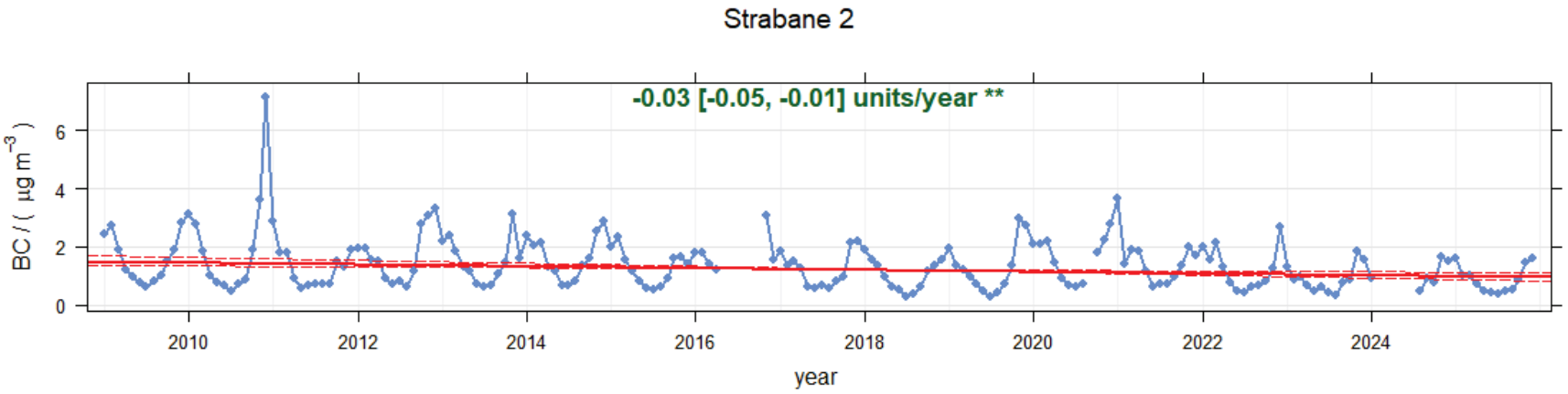

Figure 79 - Long-term trends in BC mass concentration at Strabane 2 (urban background), 2009 – 2025 (**p < 0.01).

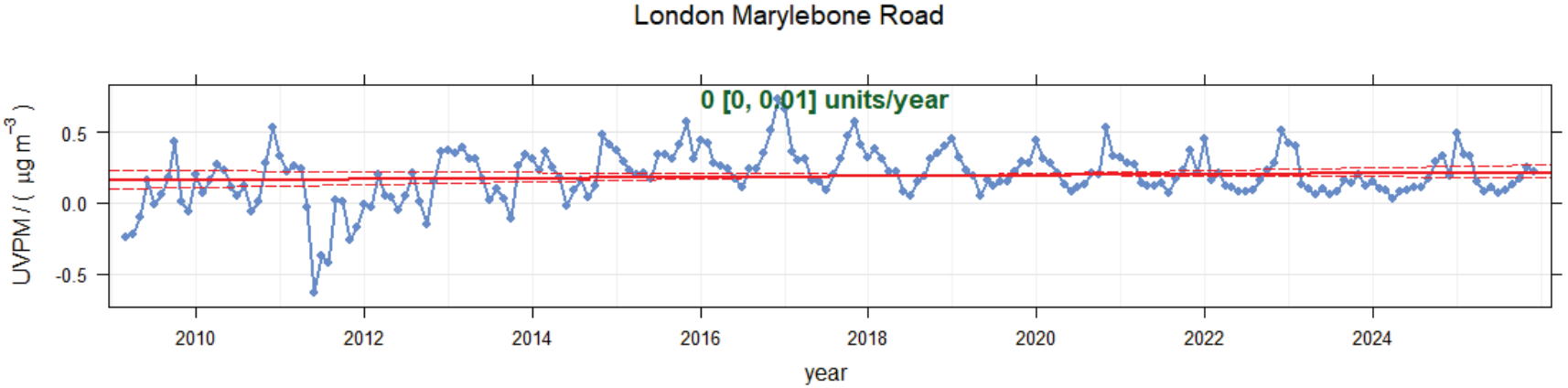

Figure 80 - Long-term trend in UVPM mass concentration at London Marylebone (urban traffic), 2009 – 2025 (no significant trend).

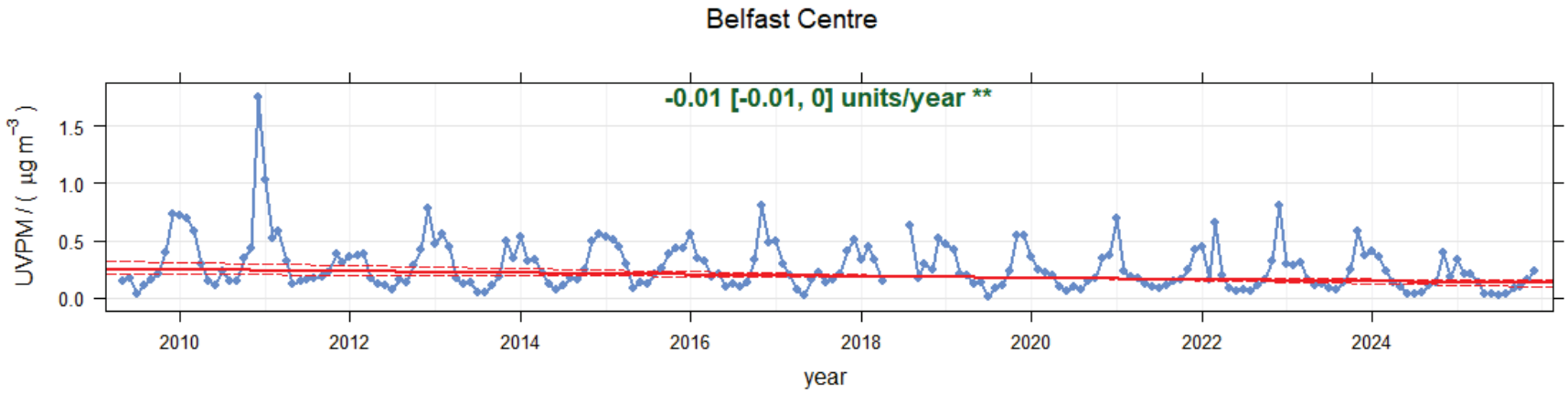

Figure 81 - Long-term trends in UVPM mass concentration at Belfast Centre (urban background), 2009 – 2025 (**p < 0.01).

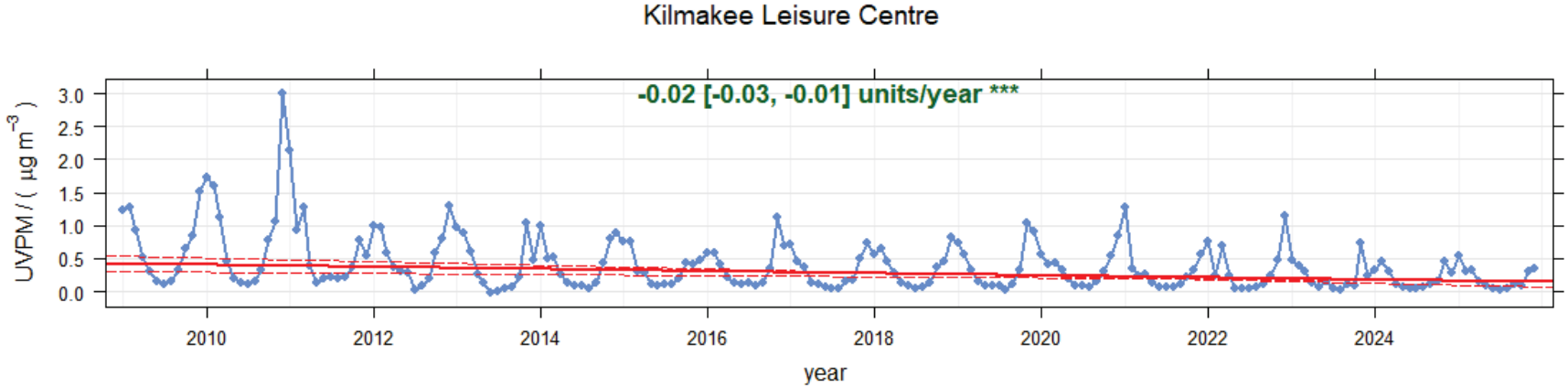

Figure 82 - Long-term trends in UVPM mass concentration at Kilmakee Leisure Centre (urban background), 2009 – 2025 (**p < 0.01).

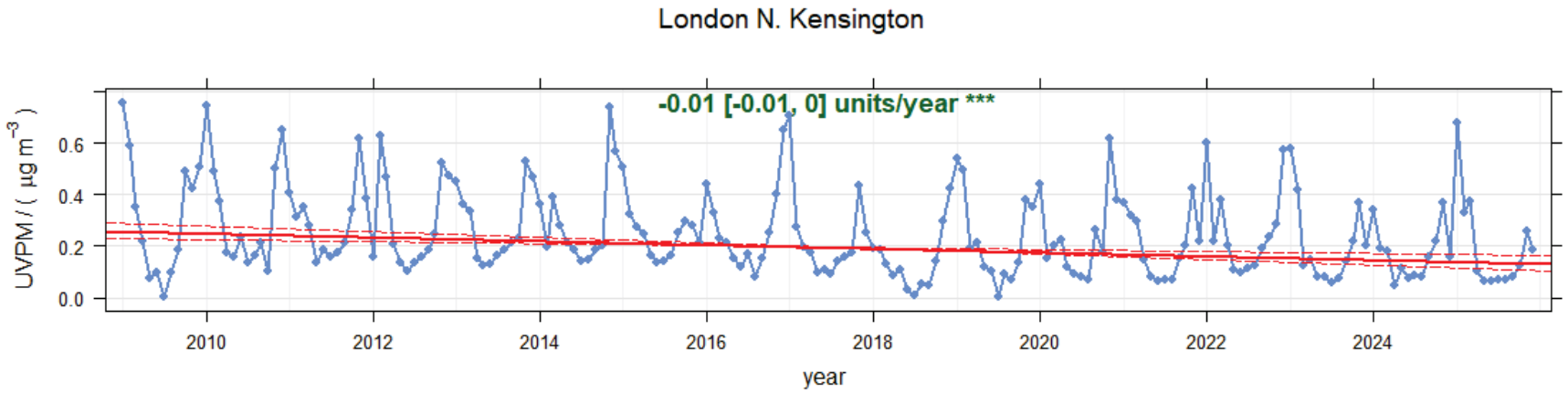

Figure 83 - Long-term trends in UVPM mass concentration at London North Kensington (urban background), 2009 – 2025 (***$p < 0.001$).

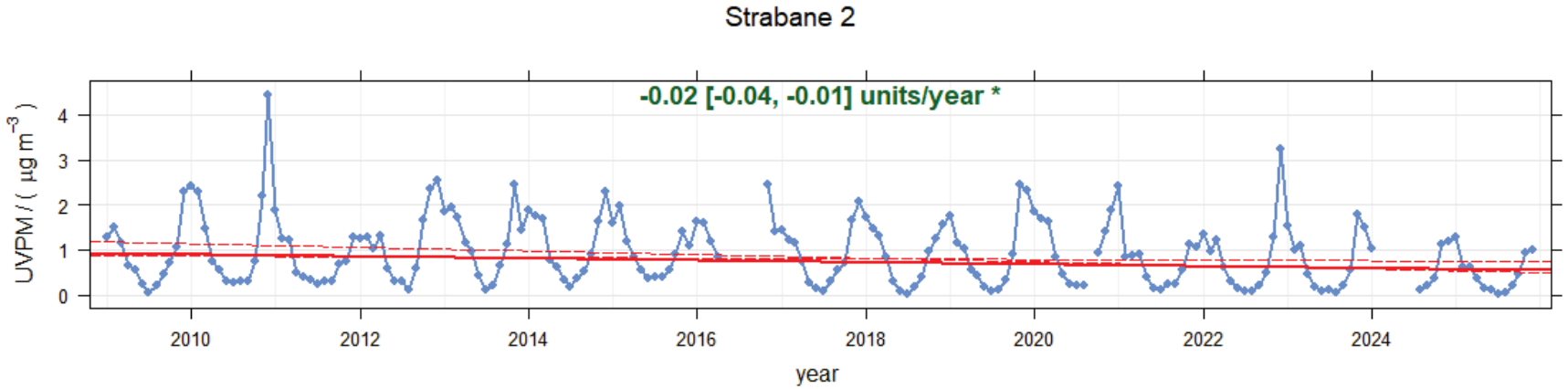

Figure 84 - Long-term trends in UVPM mass concentration at Strabane 2 (urban background), 2009 – 2025 (* $p < 0.05$).

5 Peer review publications

The peer-review papers that used Network data published in 2025 are listed below. A brief summary of each paper is also provided for context. The first five papers include co-authors who are members of the Network delivery team.

1. How COVID-19 related policies reshaped organic aerosol source contributions in Central London[30]

This paper investigated how COVID-19 interventions altered the sources of organic aerosol (OA) in central London using a year-long aerosol chemical speciation monitor (ACSM) dataset from the London Marylebone Road monitoring station. The paper identified five main OA sources: traffic (HOA), cooking (COA), biomass burning (BBOA), and two oxygenated secondary components (MO-OOA and LO-OOA). The paper also highlights that commercial cooking is an important urban PM_1 source and may currently be underestimated in air quality policy.

2. Two-stage Bayesian factor analysis for air pollution source apportionment and health risk assessment[31]

This paper discusses the development of a two-stage Bayesian framework to link air pollution source apportionment with health risk assessment, using particle number size distribution (PNSD) data from London. In stage 1, the study used a Bayesian dynamic factor model to identify four latent particle sources: nucleation, traffic, urban activities and secondary aerosols. In stage 2, authors related these source-specific exposures to children's respiratory hospital admissions using Poisson regression, while propagating uncertainty from the source model into the health model. This study found that traffic and secondary aerosols showed the strongest associations with increased admissions, and that ignoring uncertainty can overestimate health risks.

3. Mass absorption cross-section of ambient black carbon aerosols - a review[32]

This review examines the mass absorption cross-section of black carbon (MAC_{BC}) the key parameter used to convert between optical absorption measurements and BC mass concentration. It shows that MAC_{BC} for freshly emitted soot varies widely, and that particle aging, internal mixing, and coatings can further enhance absorption and increase uncertainty. The paper highlights that differences in measurement technique, wavelength, aerosol morphology, and mixing state are major reasons why reported MAC values are not fully consistent across studies.

4. Machine-Learning-Driven Reconstruction of Organic Aerosol Sources across Dense Monitoring Networks in Europe[33]

This work developed a machine-learning approach to reconstruct organic aerosol (OA) source contributions across Europe from limited AMS (aerosol mass spectrometer) and ACSM source-apportionment data and more widely available organic carbon (OC) measurements. The framework predicts the three main OA source classes: hydrocarbon-like OA (HOA), biomass-burning OA (BBOA), and oxygenated OA (OOA). This work provides a much denser Europe-wide OA source dataset, supporting improved pollution hotspot identification and high-resolution exposure assessment.

5. Analysis of source regions and transport pathways of sub-micron aerosol components in Europe[34]

This study combined year-long sub-micron aerosol datasets from 15 European countries with trajectory statistical methods (TSMs) to identify likely source regions and transport pathways for major aerosol components. The study examined total organic aerosol (OA), biomass-burning OA (BBOA), oxygenated OA (OOA), ammonium, nitrate and sulphate, and found clear seasonal and regional differences in their source influences.

6. Comparative receptor modelling for the sources of fine particulate matter ($PM_{2.5}$) at urban sites in the UK[35]

This study analysed $PM_{2.5}$ composition and sources at two urban background sites in Birmingham and observed that ammonium sulfate has declined compared with earlier years, while ammonium nitrate remains a major $PM_{2.5}$ component. The main $PM_{2.5}$ contributors were biomass burning, secondary aerosols, and resuspended dust/traffic emissions. A major finding was that biomass-burning aerosol concentrations were about seven times higher than those reported in 2008–2010, pointing to much greater wood-burning influence. The study concludes that cutting wood burning and road traffic emissions would likely give the biggest reduction in $PM_{2.5}$-related health risks in the West Midlands.

6 References

1 The Environmental Targets (Fine Particulate Matter) (England) Regulations 2023 (UK SI 2023/96). https://www.legislation.gov.uk/uksi/2023/96/contents/made

2 Defra UK-AIR website. https://uk-air.defra.gov.uk/

3 TOMPKINS, J. T., *et al.* Particle size comparison between scanning mobility particle sizer TSI 3936L75 and new TSI 3938W50-CEN conducted at NPL and London Marylebone Road monitoring sites. *NPL,* 2025. https://doi.org/10.47120/npl.ENV62

4 The Air Quality Standards Regulations 2010 (UK SI 2010/1001). https://www.legislation.gov.uk/uksi/2010/1001/contents/made

5 The Air Quality Standards Regulations (Northern Ireland) 2010 (NI SI 2010/188). https://www.legislation.gov.uk/nisr/2010/188/contents/made

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