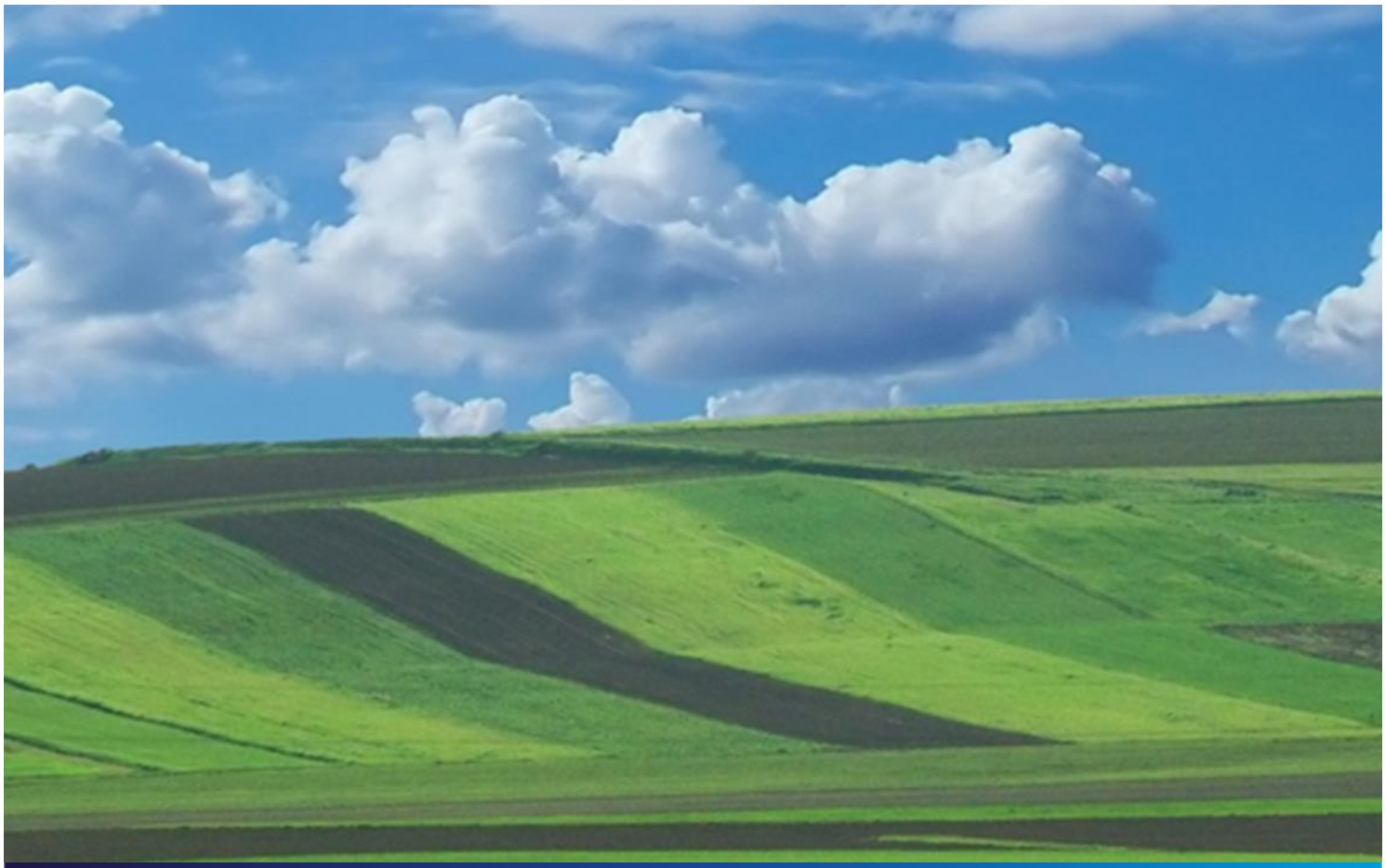

AIR QUALITY MONITORING

Report for Edinburgh Airport 2023

Report for: Edinburgh Airport Ltd

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EXECUTIVE SUMMARY

Ricardo was commissioned by Edinburgh Airport Ltd to undertake a six-month air quality monitoring survey investigating nitrogen dioxide (NO_2) and particulate matter (PM_{10} and $PM_{2.5}$) concentrations at Edinburgh Airport during 2023. This survey follows on from similar studies carried out during the prior 20 years.

Passive diffusion tubes for NO_2 were deployed over approximately six-monthly periods, at airside and non – airside locations around the airport. Estimated annual mean NO_2 concentrations above the objective of 40 µg m^{-3} were not breached at any locations during the 2023 study. The highest annual mean recorded was 31.9 µg m^{-3} at Eastfield Road Roundabout.

As stated in technical guidance LAQM.TG (22), the hourly mean objective is likely to have been breached if the annual mean NO_2 concentration is 60 µg m^{-3} or greater. Therefore, the hourly NO_2 objective of no more than 18 exceedances in a year of 200 µg m^{-3} was unlikely to have been breached. In 2023, there is continuation of the general trend of decreasing NO_2 concentrations relative to what was measured in prior studies.

Two AQMesh sensors were also deployed for the duration of the study monitoring NO_2 and Particulate Matter. One was placed at an airside location and the second outside the pick up and drop off zone (PUDO).

Period means recorded by both AQMesh instruments were lower than the annual mean targets for all measured pollutants. Seasonal and diurnal variations for all pollutants were typical for an urban area, with lower concentrations in the summer months than the winter, and evidence of morning and afternoon rush hour peaks.

Directional analysis was carried out using data from the two AQMesh sensors which showed elevated concentrations of all measured pollutants in calm conditions when pollutants are poorly dispersed. The landside sensor, placed near the pick up and drop off zone, recorded an elevated NO_2 concentration from that direction, with both landside and airside sensors also picking up signals at higher windspeeds from the surface level carparks and main airport infrastructure.

When grouped into similar sites the diffusion tubes placed in and around the PUDO gave the highest average reading of 19.7 µg m^{-3}, the average of all the non co-located tubes being 18 µg m^{-3}.

CONTENTS

1. INTRODUCTION

1.1 BACKGROUND

Edinburgh Airport Ltd (referred to hear as "Edinburgh Airport") has undertaken multiple short term diffusion tube-based air quality monitoring studies in and around the airport premises. Ricardo was commissioned by Edinburgh Airport to undertake a six-month air quality monitoring survey investigating nitrogen dioxide (NO_2), particulate matter$_{10}$ (PM_{10}) and particulate matter ($PM_{2.5}$) at Edinburgh Airport during 2023.

This report has been prepared by Ricardo on behalf of Edinburgh Airport, to provide analysis and commentary on the 2023 dataset.

1.2 AIMS AND OBJECTIVES

The aim of this monitoring programme was to monitor concentrations of NO_2, PM_{10} and $PM_{2.5}$ at the airport. The results of the monitoring are used to assess whether applicable national air quality objectives may have been met, and how pollutant concentrations in the area have changed over time.

It is important to note that the pollutants measured in this study could have originated from a wide variety of sources, both local and long range. Not all these sources will be directly connected with the airport.

2. DETAILS OF THE MONITORING PROGRAMME

2.1 POLLUTANTS MONITORED, NITROGEN OXIDES

The monitoring programme concentrates on some of the pollutants which may be of concern around airports. The emission statistics presented here all come from the National Atmospheric Emission Inventory (NAEI)[2].

2.1.1 Nitrogen Oxides (NOx)

Combustion processes emit a mixture of oxides of nitrogen – nitric oxide (NO) and NO_2 - collectively termed NO_x. NO is described as a primary pollutant (meaning it is directly emitted from source). NO is not known to have any harmful effects on human health at ambient concentrations. However, it undergoes oxidation in the atmosphere to form the secondary pollutant NO_2.

NO_2 has a primary (directly emitted) component and a secondary component, formed by oxidation of NO. NO_2 is a respiratory irritant and is toxic at high concentrations. It is also involved in the formation of photochemical smog and acid rain and may cause damage to crops and vegetation.

Based on 2022 calendar year emissions data from the 2024 submission of NAEI data to the EU, in the UK, civil aircraft taking off and landing (up to a height of 1000 m) are estimated to contribute 1.6% to the total reported UK emissions of NO_x [2].

The Air Quality Expert Group[1] has stated that: "Around a third of all NO_x emissions from the aircraft (including ground-level emissions from auxiliary power units, engine testing etc., as well as take-off and landing) occur below 100 m in height. The remaining two-thirds occur between 100 m and 1000 m and contribute little to ground-level concentrations. Receptor modelling studies show the impact of airport activities on ground-level NO_2 concentrations. Studies have shown that although emissions associated with road traffic are smaller than those associated with aircraft, their impact on population exposure at locations around the airport are larger." Previous rounds of review and assessment within the Local Air Quality Management (LAQM) process have not highlighted any cases where airports appear to have caused exceedances of air quality objectives for particulate matter measured as PM_{10}. Therefore, in the context of LAQM, the key pollutant of concern from airports is NO_2. Local authorities whose areas contain airports with over 10 million passengers per annum must take these into account in their annual review and assessment of air quality.

2.1.2 Particulate Matter (PM_{10} and $PM_{2.5}$)

Airborne particulate matter varies widely in its physical and chemical composition, source and particle size. Particulate matter is categorised by particle size: it is most commonly monitored as PM_{10} (i.e. particles whose effective size is <10 µm) and $PM_{2.5}$ (i.e. particles with effective size <2.5 µm). Fine particles are of most concern, as they are small enough to penetrate deep into the lungs, where they can have the greatest impact upon health.

The main sources of airborne particulate matter in the UK are combustion (industrial, commercial and residential fuel use). This is followed by road vehicle emissions. Based on 2022 calendar year emissions data from the 2024 submission of National Atmospheric Emissions Inventory (NAEI) data to the EU, civil aircraft taking off and landing (up to a height of 1000 m) was estimated to contribute 0.1% to the total reported UK emissions of PM_{10} and $PM_{2.5}$ [1].

Previous rounds of review and assessment within the LAQM process have not highlighted any cases where airports appear to have caused exceedances of air quality objectives for particulate matter measured as PM10.

2.2 AIR QUALITY LIMIT VALUES AND OBJECTIVES

This report compares the results of the monitoring survey with air quality limit values and objectives applicable in the UK. These are summarised in Table 2-1.

2.2.1 World Health Organisation

The World Health Organisation (WHO) issued non-mandatory, advisory, guidelines for a variety of pollutants in 2005 using currently available scientific evidence on the effects of air pollution on human health. New, updated, guidelines were introduced in September 2021[3] which significantly reduced the Annual mean limit of NO_2 from 40 µg m^{-3} to 10 µg m^{-3} and the 24-hr mean being reduced to 25 µg m^{-3}.

In light of the growing evidence of harm associated with PM_{10} and $PM_{2.5}$, annual mean limits were reduced from 20 µg m^{-3} to 15 µg m^{-3} and 10 µg m^{-3} to 5 µg m^{-3} respectively.

2.2.2 The UK Air Quality Strategy

The Environment Act 1995 required the UK to transpose the original EU Directive on Ambient Air Quality and Cleaner Air for Europe (2008/50/EC and its update EU/1480) (“Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on Ambient Air Quality and Cleaner Air for Europe” 2008) into UK law[7]. It also placed a requirement on the Secretary of State for the Environment to produce a national Air Quality Strategy (AQS) containing standards, objectives and measures for improving ambient air quality. The original AQS was published in 1997 and contained air quality objectives based on the recommendations of the Expert Panel on Air Quality Standards (EPAQS) regarding the levels of air pollutants at which there would be little risk to human health.

The AQS has since undergone a number of revisions, and as of the Environment Act 2021 must be reviewed at least every 5 years. These revisions have reflected improvements in the understanding of air pollutants and their health effects. They also incorporated new European limit values, both for pollutants already covered by the Strategy and for newly introduced pollutants such as polycyclic aromatic hydrocarbons and $PM_{2.5}$ particulate matter. The latest version of the strategy which impacts Scotland was published by Defra in 2007[4]. With the UK’s exit from the EU the UK’s AQS is no longer tied to that of the EU, however the current objectives are at least as stringent as the EC limit values. In addition, Scotland has its own, Cleaner Air for Scotland 2 (CAFS2) strategy for improving air quality between 2021 and 2026[6].

As stated in the Local Air Quality Management Technical Guidance LAQM.TG (22)[5], the hourly mean objective is likely to have been breached if the annual mean NO_2 concentration is 60 µg m^{-3} or greater. Therefore, if the 40 µg m^{-3} annual mean value is achieved for NO_2, there is likely to be no risk of the hourly-mean objective being breached.

Table 2-1: UK, and Scotland, air quality objectives for protection of human health, 2023

Pollutant	Metric	Type	Legal Value
NO_2	1-hour mean	Limit Value	200 µg m^{-3} (not to be exceeded more than 18 times a year)
NO_2	Annual mean	Limit Value	40 µg m^{-3}
PM_{10}	24-hr	Limit Value (Scotland)	50 µg m^{-3} (7 allowed)
PM_{10}	Annual mean	Limit Value (Scotland)	18 µg m^{-3}
$PM_{2.5}$	Annual mean	Limit Value (Scotland)	10 µg m^{-3}

2.3 MONITORING SITES AND METHODS

2.3.1 Monitoring Methods

Diffusion tubes are 'passive' samplers, i.e. they work by absorbing the pollutants direct from the surrounding air and need no power supply. They are located in places and heights of relevant exposure, usually attached approximately 2 m - 4 m above ground. Some details of the chemistry of diffusion tube samplers for NO_2 are provided in Appendix 1. Single diffusion tube samplers for NO_2 were exposed at approximately monthly intervals for six-months at selected airside and non-airside locations. These were chosen to reflect a variety of potential NO_2 concentration-situations, including local sources and more general background areas around Edinburgh Airport. In addition, two AQMesh were installed for the project, one was located in the newly redeveloped pick up and drop off zone (PUDO) and the other on the airside side of the perimeter fence near one of the stands.

2.3.1.1 NO_2 Diffusion tubes

Palmes-type diffusion tubes were used for monitoring NO_2. These consist of a small plastic tube, approximately 7 cm long. During sampling, one end is open and the other closed. The closed end contains an absorbent for the gaseous species (in this case NO_2) to be monitored. The tube is mounted vertically with the open end at the bottom. Ambient NO_2 diffuses up the tube during exposure and is absorbed as nitrite. The average ambient pollutant concentration for the exposure period is calculated from the amount of pollutant absorbed. Further information can be found in Appendix 1.

2.3.1.2 Preparation and analysis

Diffusion tubes were prepared and analysed by SOCOTEC. They were supplied to Edinburgh Airport, who carried out the tube changing after being trained by Ricardo staff. The tubes were supplied in a sealed condition prior to exposure. After exposure, the tubes were again sealed and returned to SOCOTEC for analysis. Each monthly batch of diffusion tubes was accompanied by a 'travel blank' NO_2 tube. This tube was taken with the exposure tubes to the site but was not exposed. When the exposed tubes were collected, the 'travel blank' tube was taken by the operator to the site. The travel blank was sent with the exposed tubes for analysis.

2.3.1.3 Calendar of diffusion tube exposure periods

The calendar of exposure periods used for the NO_2 diffusion tubes is shown in Table 2- 2. They were intended to be an approximation to calendar months, while allowing for the tubes to be changed on a consistent day of the week. It is not always possible to stick to the intended dates, actual change over dates are also shown in the below Table 2-2.

Table 2-2: Diffusion tube exposure periods

Month	Month Intended Start	Month Intended End	Month Actual Start	Month Actual End
July	05/07/2023	02/08/2023	05/07/2023	03/08/2023
August	02/08/2023	06/09/2023	03/08/2023	06/09/2023
September	06/09/2023	04/10/2023	06/09/2023	05/10/2023
October	04/10/2023	01/11/2023	05/10/2023	01/11/2023
November	01/11/2023	06/12/2023	01/11/2023	06/12/2023
December	06/12/2023	03/01/2024	06/12/2023	03/01/2024

2.3.1.4 AQMesh

The diffusion tube monitoring of NO_2 was supplemented with automatic monitoring of NO_2 and PM using two AQMesh, a small sensor monitoring system that measures particles using a light scattering optical particle counter and NO_2 with an electrochemical sensor. The AQMesh used in this study were solar powered.

2.3.2 Monitoring Site Locations

2.3.2.1 Diffusion tubes

The study deployed 28 individual diffusion tubes at a number of airside and no airside locations, one set of triplicate diffusion tubes at the St. Johns Road Automatic monitoring station and one travel blank.

The location and description are provided in Table 2-3 and Figures 2-1, 2-2 and 2-3. Site codes starting with “A” were airside locations, “L” were landside locations, “R” were reference locations and “P” were in the multistorey car park, of which the ground floor is the PUDO. “P” sites are not mapped as the locations are too close together/ on different floors.

Photos of the tubes are provided in Appendix 2.

Table 2-3: Diffusion tube monitoring locations

Site Code	Location Name	Site Coordinates		Site Description
A1	Fire Station	55.9467457	-3.3738642	Fitted on the airside side of the fence next to the airport fire station.
A2	End of Runway	55.9413617	-3.3978935	Fitted to a post at the end of the main runway.
A3	Gate 8	55.9594183	-3.3537171	Fitted to a post on the perimeter fence by access Gate 8.
A4	2-4 Approach Lights	55.9573502	-3.3506299	Fitted to a post on the perimeter fence.
A5	Control Post 1	55.9513179	-3.3519747	Fitted to a post on the perimeter fence by a control post.
A6	Stand 9 Assembly Point 4	55.948965	-3.3641157	Fitted to a post at the fire assembly point at aircraft stand 9.
A7	Control Post 3	55.9480019	-3.369679	Fitted to a post on the perimeter fence by a control post.
L1	Check in Zone A	55.9478973	-3.3646485	Fitted to a post outside Check in Zone A.
L2	Front Terminal Tunnel	55.9481896	-3.3635112	Fitted to a post at the end of a covered pedestrian walkway.
L3	Bus Stop B Skylink	55.9479999	-3.3617065	Fitted to a pedestrian crossing post, next to the bus stop used by Skylink.
P1	PUDO Help Point	55.9477351	-3.3625389	Fitted next to the Pick Up and Drop Off zone (PUDO) help point.
P2	Car Park Office	55.947838	-3.3630898	Fitted inside the Multistorey car park office.
P3	PUDO Entrance	55.9476889	-3.3632477	Fitted outside the vehicle and pedestrian entrance of the PUDO.
R1,2,3	Co-Lo St. Johns 1,2,3	55.942500	-3.281111	Co-located tubes at the Edinburgh Council owned St. Johns Road automatic monitoring site.
L4	Signature Building	55.9443262	-3.3517575	Fitted to a fence post on the perimeter road (Eastfield Avenue).
L5	Double Tree Hotel	55.9443756	-3.3588931	Fitted to a post outside a hotel located next to the airport.
L6	Eastfield Road Roundabout	55.9394729	-3.3586524	Fitted to a post on the main road in and out of the airport.
L7	Eastfield Road	55.9411998	-3.3597726	Fitted to a post on the main road in and out of the airport.
L8	Stand 1B Landside	55.94569	-3.3654709	Fitted on the landside side of the perimeter fence by Stand 1B.

Site Code	Location Name	Site Coordinates		Site Description
L9	Lochend Road	55.9418598	-3.3998625	Fitted on a post next to an emergency vehicle entrance.
P4	PUDO Entrance Corner Lanes 3+4	55.9476401	-3.3627669	Fitted to a pillar in the covered area of the PUDO.
P5	PUDO Entrance Corner Lanes 1+2	55.9479073	-3.3625802	Fitted to a pillar in the covered area of the PUDO.
P6	PUDO Exit Corner Lanes 1+2	55.9475605	-3.3614208	Fitted to a pillar in the covered area of the PUDO.
P7	PUDO Exit Corner 3+4	55.9473075	-3.3616813	Fitted to a pillar in the covered area of the PUDO.
P8	Multistorey Level 1	55.9480402	-3.3628511	Fitted to a pillar in the Multistorey carpark.
P9	Multistorey Level 2	55.9480402	-3.3628511	Fitted to a pillar in the Multistorey carpark.
P10	Multistorey Level 3	55.9480402	-3.3628511	Fitted to a pillar in the Multistorey carpark.
L10	300 Stand	55.9464044	-3.3481982	Fitted on the landside side of the perimeter fence by Stand 300.
L11	Lenniemuir Road	55.9541753	-3.347821	Fitted on a telephone poll on a residential area next to the Airport.

Figure 2-1: Airside monitoring locations

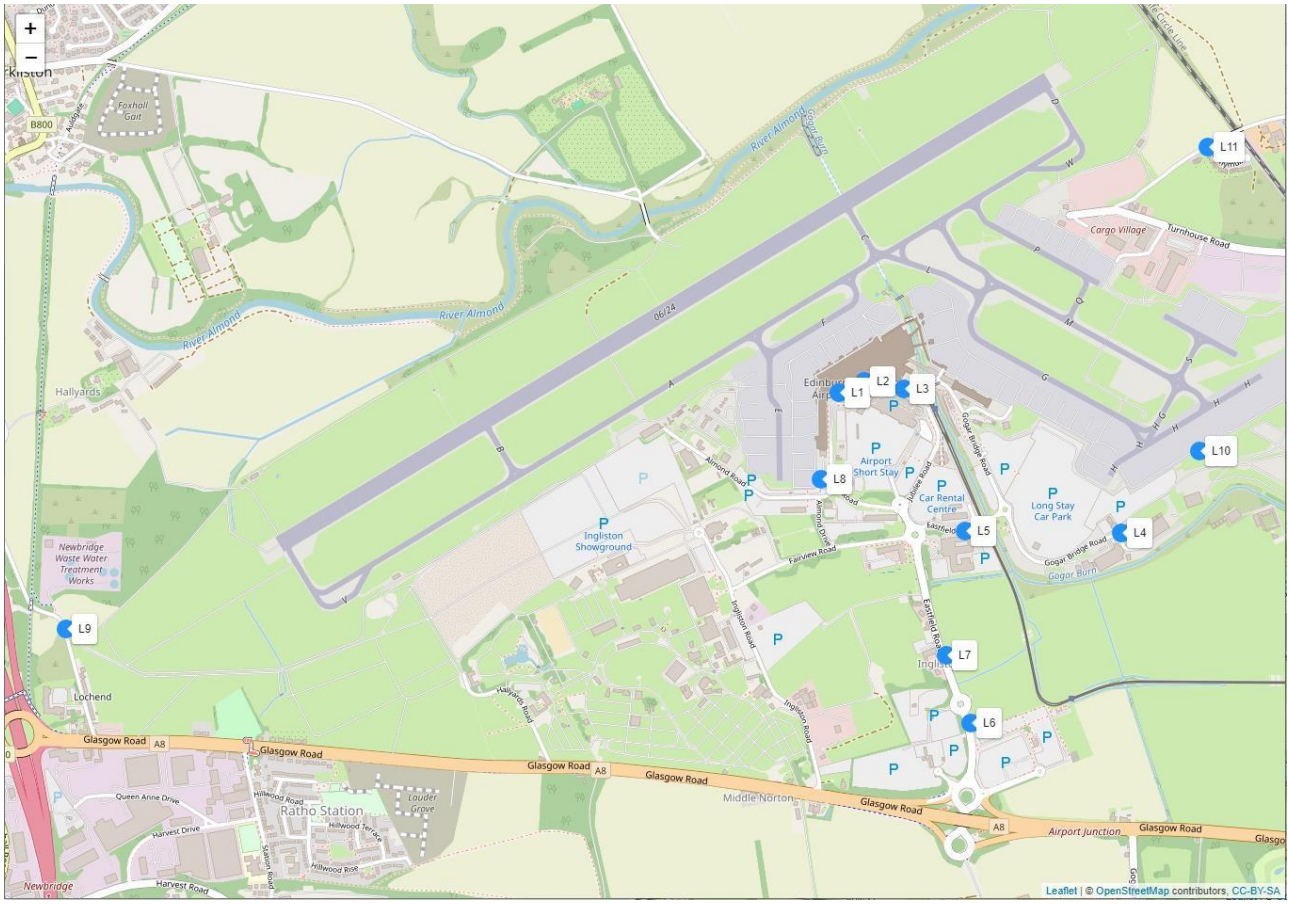


Figure 2-2: Landside monitoring locations

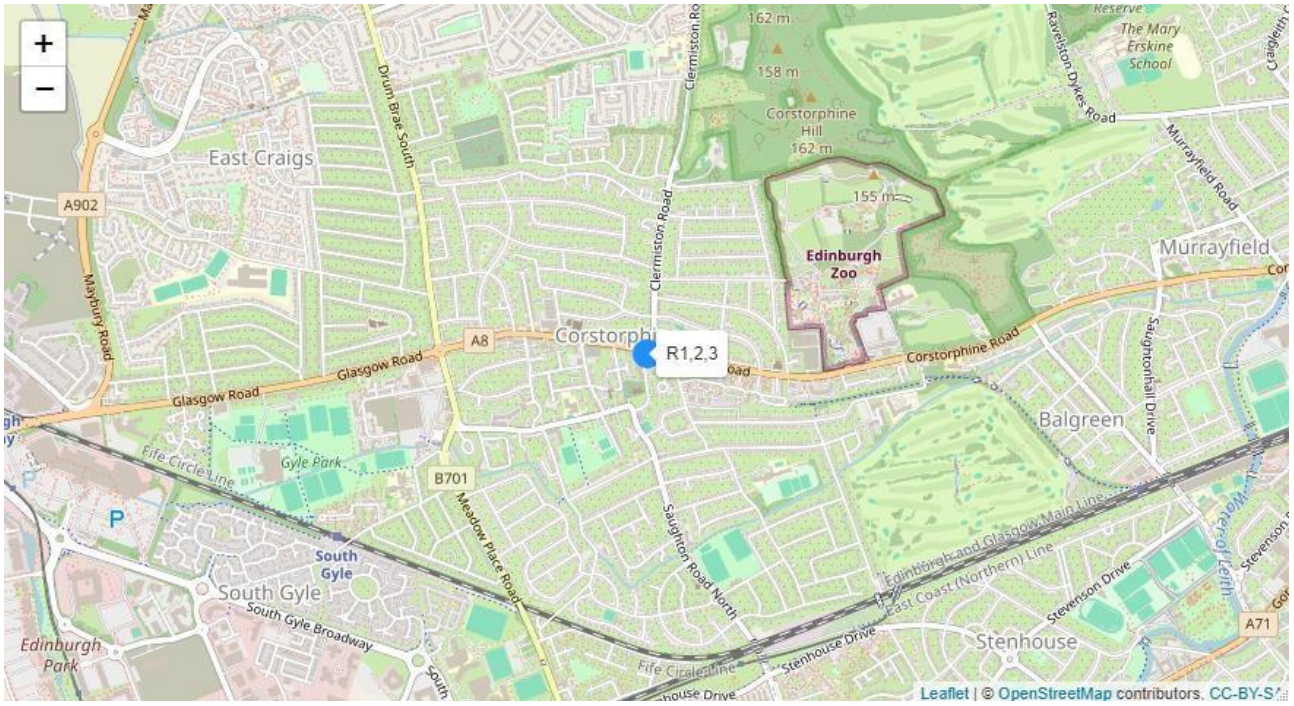


Figure 2-3: Colocation with Edinburgh St. Johns Road Automatic monitoring site

2.3.2.2 AQMesh

The study deployed two AQMesh, one airside and the second landside. The colocations were conducted at the automatic monitoring site of St Johns Road. The location for both is provided in Table 2-4 and Figure 2-4. A photo is provided in Appendix 2.

Table 2-4: AQMesh monitoring locations

Map Code	Location Name	Site Coordinates		Site Description
AS	Airside	55.948713	-3.360681	Fitted on the perimeter fence next to an aircraft stand.
LS	Landside	55.947780	-3.363460	Fitted to a lamppost at the entrance to PUDO.

Figure 2-4: AQMesh monitoring locations

2.4 QA/QC PROCEDURES

This section outlines the quality assurance / quality control (QA/QC) procedures applied for the purposes of this study. To ensure the monitoring data were of a high quality, the following QA/QC procedures were put in place:

- Daily checks of the monitoring data.
- Audits of the automatic monitoring site.
- Analysis of NO_2 diffusion tubes using UKAS-accredited laboratory.
- Data ratification of resulting dataset.

2.4.1 NO_2 Diffusion Tubes

Analysis of the diffusion tube samples was carried out using UV spectrophotometry by Socotec. Socotec holds current UKAS accreditation (Testing Laboratory No 1015, ISO 17025) for this type of analysis. The NO_2 tubes were prepared by spiking a 50:50 triethanolamine (TEA) in acetone solution onto grids, which are located in the end cap of the diffusion tube. During exposure NO_2 passively diffuses up the tube towards the spiked grid where it is absorbed by the TEA. Following exposure, the tubes were desorbed with distilled water and the extract analysed using a segmented flow auto analyser with ultraviolet detection to estimate the concentration of nitrate ions.

Socotec participate in the AIR-PT scheme, operated by LGC Standards and supported by the Health and Safety Laboratory, with yearly assessment against agreed performance criteria. AIR-PT combines two long

running PT schemes: LGC Standards STACKS PT scheme and HSL Workplace Analysis Scheme for Proficiency (WASP) PT scheme. Socotec currently hold the highest rank of a Satisfactory laboratory for the analysis of NO_2 diffusion tubes. A copy of the latest round of results can be found on the Defra LAQM website (https://laqm.defra.gov.uk/air-quality/air-quality-assessment/national-bias/).

The diffusion tube sampling method is only indicative and can give results which under read or over read the true NO_2 concentration. Hence, in line with the Local Air Quality Management Technical Guidance LAQM.TG (22)[5] recommendations on the use of diffusion tubes, triplicate tubes were co-located with a suitable chemiluminescent NO_x analyser. For this study the St. Johns Road automatic air quality monitoring station was selected as the most suitable for the co-location exercise.

A further check of the diffusion tube sampling regime was carried out with the use of a travel blank. The travel blank is a capped diffusion tube that is stored on-site and travels with the exposed diffusion tubes. The travel blank is then used to identify contamination of the samples that could occur during transportation and storage. The travel blanks used within this study showed no significant contamination of tubes during transportation and storage. For this reason, no data have been rejected due to contamination.

2.4.2 AQMesh

Data were downloaded on an hourly basis from the monitoring site and checked by data checkers to ensure that any faults were quickly identified and thus minimising data loss.

The data from the AQMesh was ratified in three-monthly blocks; January to March, April to June, July to September and October to December. Ratification consists of scaling the data using the results of the colocation. Any unreliable data are rejected, and the final ratified dataset produced.

In order to gain colocation factors, the pod was co-located at the St. Johns Road automatic site. This site forms part of the Scottish Air Quality Database (SAQD) network and measures PM_{10}, $PM_{2.5}$ and NO_2.

2.4.3 Automatic NO_x Analyser

The St. Johns Road automatic monitoring station is part of the SAQD. As part of the SAQD, a full QA/QC regime is applied to both the monitoring equipment and data. This includes:

- Hourly download of data.
- Daily checks of data.
- On-site calibrations.
- Six-monthly site audits.
- Three-monthly data ratification.

Data are downloaded on an hourly basis from the monitoring site and checked by data checkers to ensure that any faults are quickly identified and thus minimising data loss. Manual calibrations of the NO_x analyser are carried out by the local authority.

To confirm that the monitoring equipment is working correctly, six-monthly audits of the monitoring site using UKAS-accredited (Laboratory No: 0401, ISO 17025) tests were carried out in June 2023 and February 2024; and consisted of the following performance checks:

- Site cylinder concentration test.
- Site calibration system check.
- Automatic analysers flow and leak check.
- NO_x analyser converter test.
- NO_x analyser linearity test.

All results were within specified tolerances confirming that there were no faults with the equipment.

The data from the automatic monitoring is ratified in three-monthly blocks; January to March, April to June, July to September and October to December. Ratification consists of scaling the data using the results of the audit and all on-site calibrations. Any unreliable data are rejected, and the final ratified dataset produced.

3. RESULTS AND DISCUSSION

3.1 BIAS ADJUSTMENT CALCULATIONS

Diffusion tubes are considered to be an indicative method of measuring NO_2. In order to improve the accuracy of diffusion tube data, all results should be bias adjusted using triplicate diffusion tubes co-located with an automatic chemiluminescent NO_x analyser. For this study, the SAQD site St. Johns Road was used. Using the results from the collocation study and the LAQM Review and Assessment bias adjustment spreadsheet a local bias adjustment factor of **0.79** was calculated. Details of the bias adjustment calculation are shown in Appendix 3.

In addition to the locally derived bias adjustment factor, the LAQM helpdesk collates NO_2 diffusion tube bias adjustment factors derived from collocation studies carried out throughout the UK. From the most up-to-date diffusion tube national bias adjustment spreadsheet, available here https://laqm.defra.gov.uk/air-quality/air-quality-assessment/national-bias/, published in March 2024, the 2023 national bias factor for Socotec's 50:50 TEA in Acetone diffusion tubes was found to be **0.77**. For this study and in order to take the worst-case approach, the Local bias adjustment factor was used to correct all diffusion tube data.

3.2 ESTIMATION OF NO_2 ANNUAL MEAN

To assess against the annual mean objective for NO_2, data from short term monitoring programs, such as this study, need to be adjusted to estimate the annual mean. The methodology for estimating the annual mean can be found in LAQM.TG (22)[5]. The monitoring locations and 2023 equivalent annualisation adjustment factors used for estimating the annual mean concentrations for the diffusion tubes are detailed in Table 3-1. Using period mean (05/07/2023 – 03/01/2024) and annual mean (01/01/2023 – 31/12/2023) NO_2 concentrations from one SAQD and two sites from the national Automatic, Urban and Rural Network (AURN) monitoring sites, an annualisation factor of **0.961** was derived.

Table 3-1: Annualisation of Diffusion Tube Data

Long Term Site	Annual Mean (AM)	Period Mean (PM)	Ratio (AM/PM)
St. Johns Road	30	31	0.967
Edinburgh St. Leonard's	11	12	0.917
Bush Estate	4	4	1
		Average	0.961

3.3 SUMMARY STATISTICS

3.3.1 NO_2 Diffusion Tubes

NO_2 diffusion tube results are presented in Table 3-2. Results are reported by the analyser to one decimal place. The table shows raw (unadjusted) monthly data, the raw period-mean and the bias adjusted annualised mean. For this report the bias adjusted annualised annual mean will be used unless otherwise stated.

Table 3-2: Raw monthly and period mean data as well as BIAS adjusted Annualised mean data

Site	July	August	September	October	November	December	Raw Mean	Bias & Annualised Mean
R1	26.2	39.5	42.3	26.6	50.8	43.1	38.1	28.9
R2	34.1	39.4	37	37.1	47.8	40	39.2	29.8
R3	34.2	36.8	42.6	34.5	42.8	40.9	38.6	29.3
Triplicate Mean	**31.5**	**38.6**	**40.6**	**32.7**	**47.1**	**41.3**	**38.7**	**29.4**
A1	13.8	14.8	17.2	22.4	23.7	18.4	18.4	14.0
A2	11.1	14	17.2	21.7	25.7	17	17.8	13.5
A3	7.4	8.8	11.6	10	15.9	11.7	10.9	8.3
A4	16.2	18.4	18	18.5	22.8	24	19.7	14.9
A5	15.7	18.7	23	19.3	27.8	23.6	21.4	16.2
A6	31.8	33.9	37.1	35.3	36.9	25.9	33.5	25.4
A7	21.6	24.9	20	36.7	34.7	15.5	25.6	19.4
L1	22.4	24.3	27.6	30.5	34	24.8	27.3	20.7
L2	23.4	-	26.1	31.4	26.3	29	27.2	20.7
L3	27.3	29.6	27.9	30.1	35.2	33.4	30.6	23.2
L4	9.5	12.6	16.4	17.8	23.5	17.1	16.2	12.3
L5	18.9	21.4	22.6	20.8	11.7	10.4	17.6	13.4
L6	-	-	44.9	40.3	43.9	38.8	42.0	31.9
L7	19.4	22.7	24.4	17.6	36.4	24.7	24.2	18.4
L8	20.5	-	22.4	28.9	32.7	23.6	25.6	19.5
L9	14.2	14.1	16.9	23.9	23.7	12	17.5	13.3
L10	11	13.7	12.6	14.4	22.8	19	15.6	11.8
L11	9.9	10.8	14.5	14	15.4	13.1	13.0	9.8
P1	24.6	29.2	26	17.8	38.1	26.5	27.0	20.5
P2	19.5	22	20.4	25.1	26.5	21	22.4	17.0
P3	21.4	22.7	29.8	34.9	16.2	26.7	25.3	19.2
P4	25.8	30.6	31.2	38.7	40.1	29.9	32.7	24.9
P5	30.3	34.6	43.4	33.6	37.3	17.5	32.8	24.9
P6	27.1	29.2	23.9	24.1	37.3	21	27.1	20.6
P7	20.4	25.4	24.6	26.6	29.4	20.9	24.6	18.6
P8	18.7	20.6	20.8	24.1	35.9	14.3	22.4	17.0
P9	18	21	15.6	27.7	29.2	24.7	22.7	17.2
P10	13.9	19.5	22	24.7	31	20.6	22.0	16.7

Site	July	August	September	October	November	December	Raw Mean	Bias & Annualised Mean
Travel Blank	0.04	<0.03	<0.03	0.06	<0.03	<0.03		
Average of non co-location tubes	**19.0**	**21.5**	**23.5**	**25.4**	**29.1**	**21.6**	**23.7**	**18.0**
Average of Airside tubes	**16.8**	**19.1**	**20.6**	**23.4**	**26.8**	**19.4**	**21.0**	**16.0**
Average of PUDO/ multistorey tubes	**22.0**	**25.5**	**25.8**	**27.7**	**32.1**	**22.3**	**25.9**	**19.7**
Average of other landside tubes	**17.7**	**18.7**	**23.3**	**24.5**	**27.8**	**22.4**	**23.3**	**17.7**

Estimated annual mean NO_2 concentrations above the objective level of 40 µg m^{-3} were not measured at any sites. The highest measured annual mean NO_2 concentration was measured at site L6 (Eastfield Road Roundabout), with a concentration of 31.9 µg m^{-3}. However, this site had missing tubes on two occasions and so needs to be treated with caution.

A further comparison can be made to the hourly NO_2 objective of no more than 18 exceedances in a year of 200 µg m^{-3}. This objective is relevant at locations where you would expect people to be exposed for one hour or greater. As stated in technical guidance LAQM.TG (22)[5], the hourly mean objective is likely to have been breached if the annual mean NO_2 concentration is 60 µg m^{-3} or greater. Therefore, it can be concluded that it is not likely that the hourly mean objective has been exceeded at any location in this study.

The remaining sites exhibit estimated annual mean concentrations between 8.3 and 25.3 µg m^{-3}, which are lower than the Kerbside levels measured at St. Johns Road in Edinburgh.

When grouped into sites of similar location; airside, PUDO/multistorey and other landside, as might be expected the grouping of tubes around the PUDO and multistorey carpark recorded the highest concentrations.

3.3.2 AQMesh

Table 3-3 show the key statistics for NO, NO_2, PM_{10} and $PM_{2.5}$ measured by the AQMesh at both monitoring locations.

Table 3-3: AQMesh summary statistics for study period (July 2023 – January 2024), µg m^{-3}

Pollutant	NO		NO_2		PM_{10}		$PM_{2.5}$	
Site	Airside	Landside	Airside	Landside	Airside	Landside	Airside	Landside
Maximum hourly mean	155	170	116	99	69	131	62	49
Maximum running 8-hour mean	111	104	81	80	51	78	47	36

Pollutant	NO		NO_2		PM_{10}		$PM_{2.5}$	
Maximum running 24-hour mean	84	71	67	74	39	38	41	28
Maximum daily mean	77	67	57	23	29	34	29	20
Period average	22	14	28	23	7	8	4	5
Annualised mean	21	14	27	22	7	8	4	5
Data capture	85.4	94.9	85.4	94.9	85.4	94.9	85.4	94.9

3.4 COMPARISON WITH AIR QUALITY OBJECTIVES

There were no diffusion tubes with raw or Bias Adjusted annual mean NO_2 concentrations above the objective level of 40 µg m^{-3} therefore, this objective is not likely to have been breached at any location during 2023. An estimated annual mean NO_2 concentration of 22 and 27 µg m^{-3} were measured by the landside and airside AQMesh respectively.

A further comparison can be made of the hourly NO_2 objective of no more than 18 exceedances in a year of 200 µg m^{-3}. This objective is relevant at locations where you would expect people to be exposed for one hour or greater. As stated in LAQM.TG (22), the hourly mean objective is likely to be breached if the annual mean NO_2 concentration, as recorded by diffusion tubes, is 60 µg m^{-3} or greater. Therefore, it can be concluded that it is not likely that the hourly mean objective has been exceeded at any location.

The AQMesh instruments recorded no hourly mean NO_2 value above the objective limit so were well within the 18 allowed.

The landside AQMesh recorded a period mean of 8 µg m^{-3} and 5 µg m^{-3} for PM_{10} and $PM_{2.5}$ respectively, both below the objective limits of 18 µg m^{-3} and 10 µg m^{-3}, however due to the length of the study this can only be indicative.

The airside AQMesh recorded a period mean of 7 µg m^{-3} and 4 µg m^{-3} for PM_{10} and $PM_{2.5}$ respectively, both below the objective limits of 18 µg m^{-3} and 10 µg m^{-3}, however due to the length of the study this can only be indicative.

The AQMesh recorded no days of PM_{10} above the 24h limit of 50 µg m^{-3}, the total number of exceedances allowed is 7, so this was within the limit.

3.5 TIME SERIES PLOT

Figure 3-1 (landside) and Figure 3-2 (airside) shows hourly data for NO_2, PM_{10} and $PM_{2.5}$ for the AQMESH over the study period (July 2023 – January 2024). Significant spikes in PM concentrations can be seen in early September and in early December.

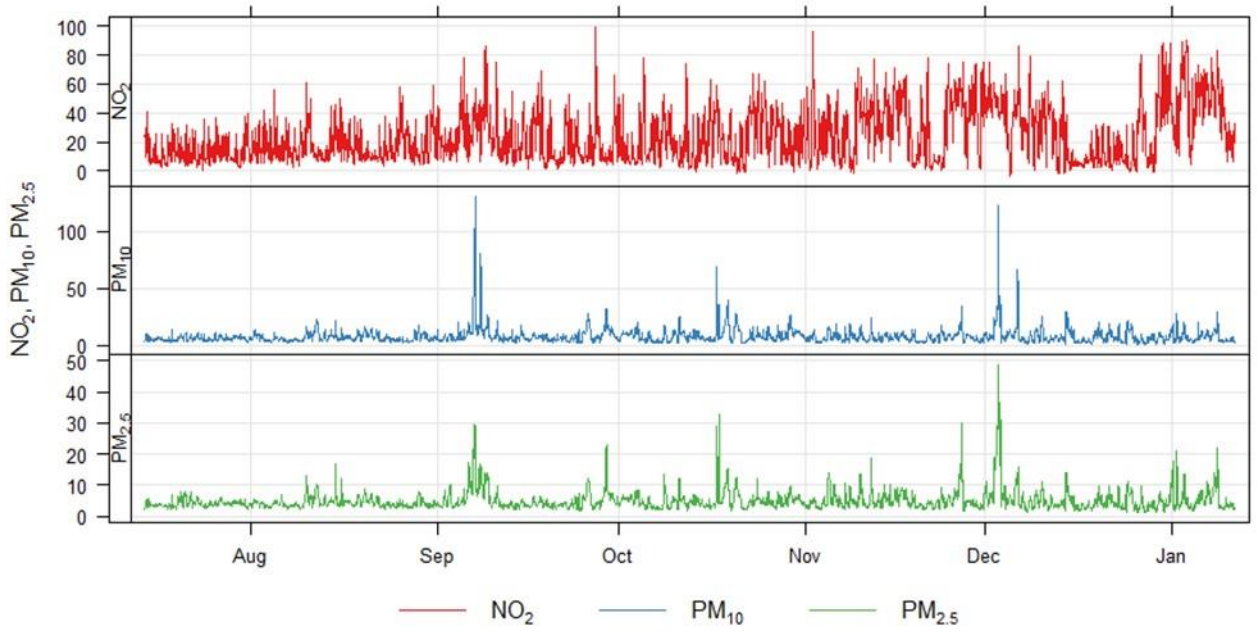


Figure 3-1: Time series of landside AQMESH data, µg m^{-3}

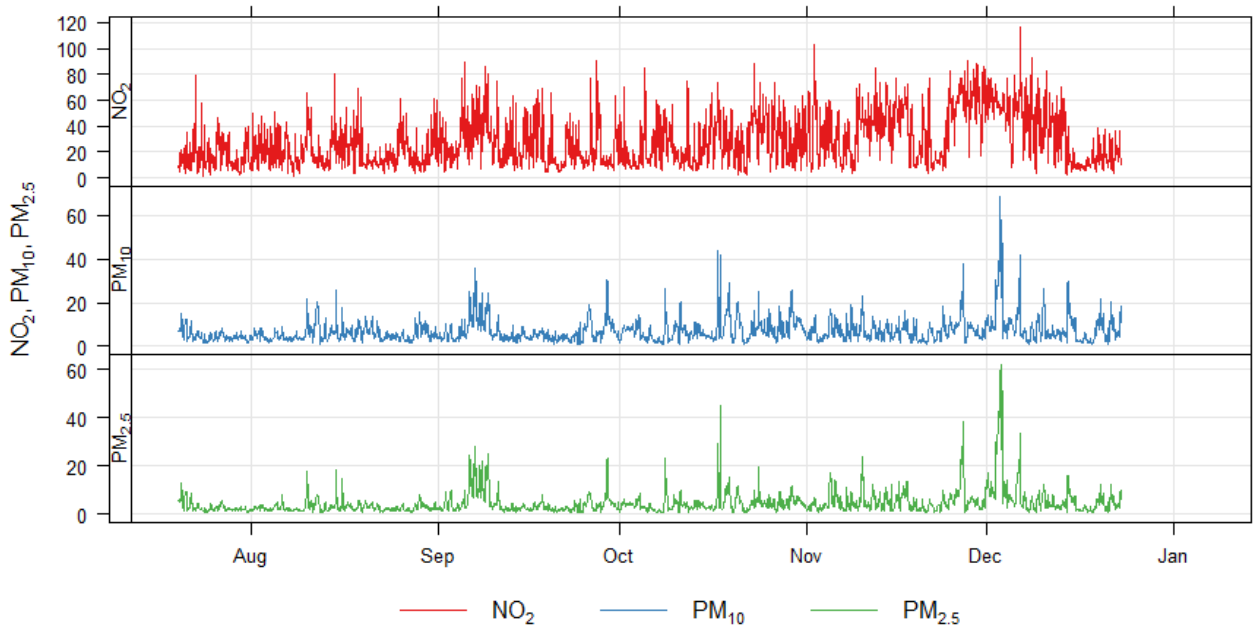


Figure 3-2: Time series of airside AQMESH data, µg m^{-3}

3.6 TIME VARIATION PLOTS

The following figures show how concentrations of NO_2, PM_{10} and $PM_{2.5}$, typically varied over monthly, weekly, daily and hourly timescales, as measured by both AQMesh, and averaged over the course of the study period (July 2023 – January 2024).

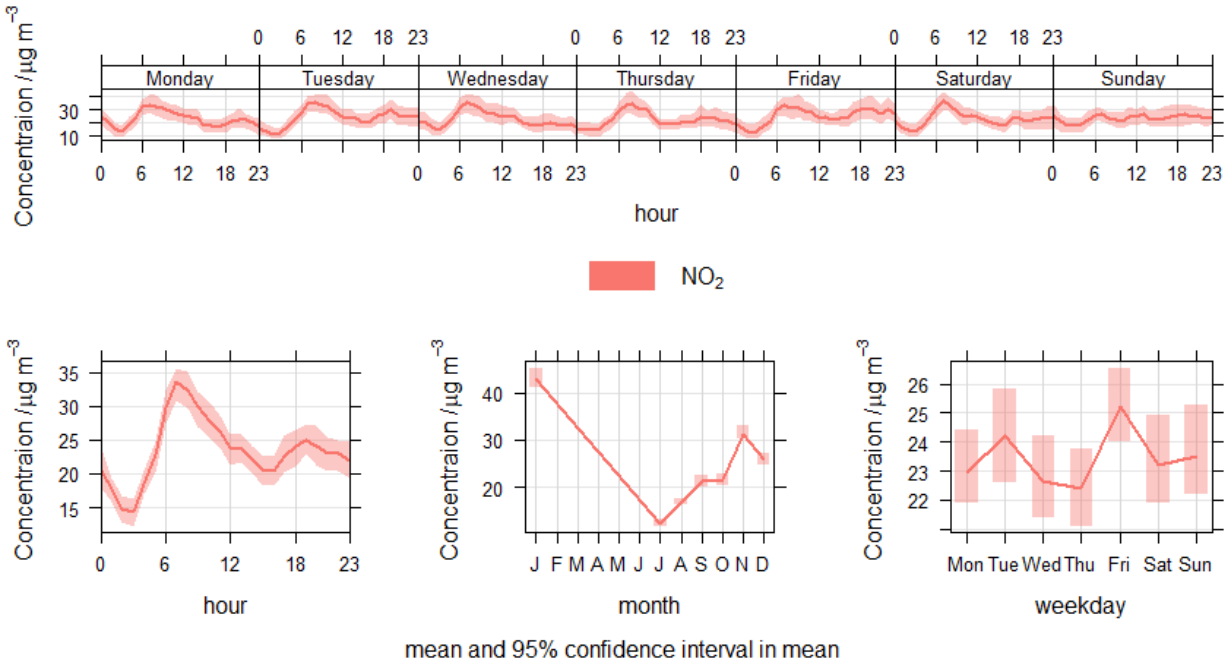


Figure 3-3: Temporal variation in concentrations of NO2 at the landside site

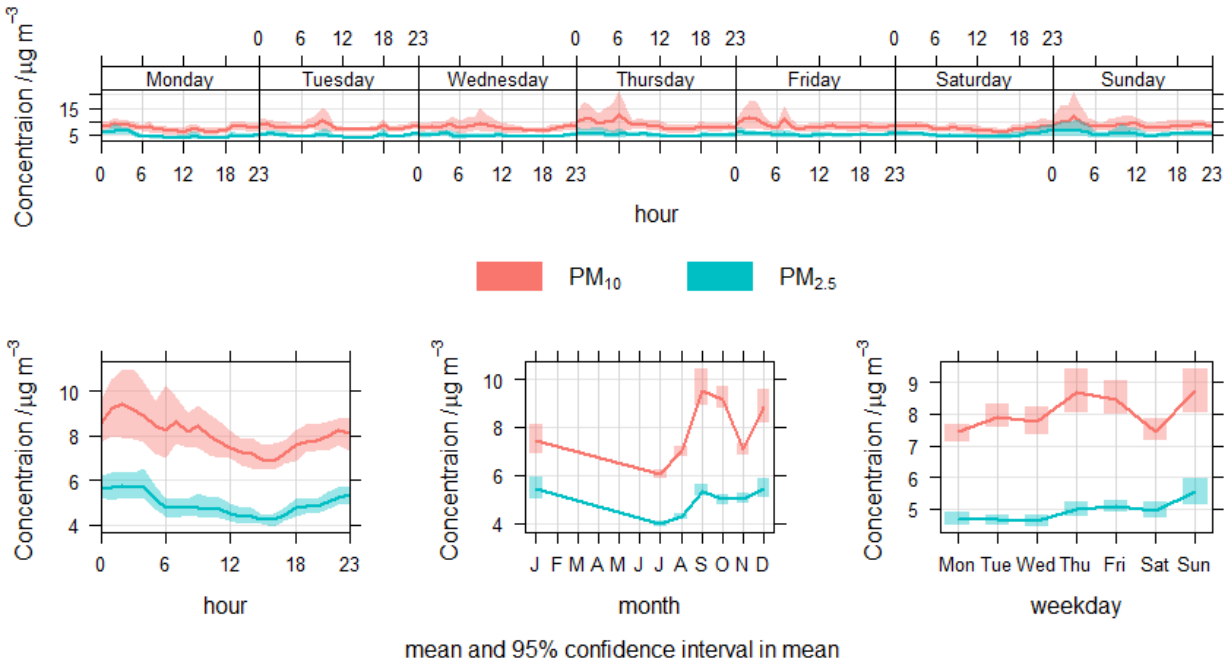


Figure 3-4: Temporal variation in concentrations of PM_{10} and $PM_{2.5}$ at the landside site

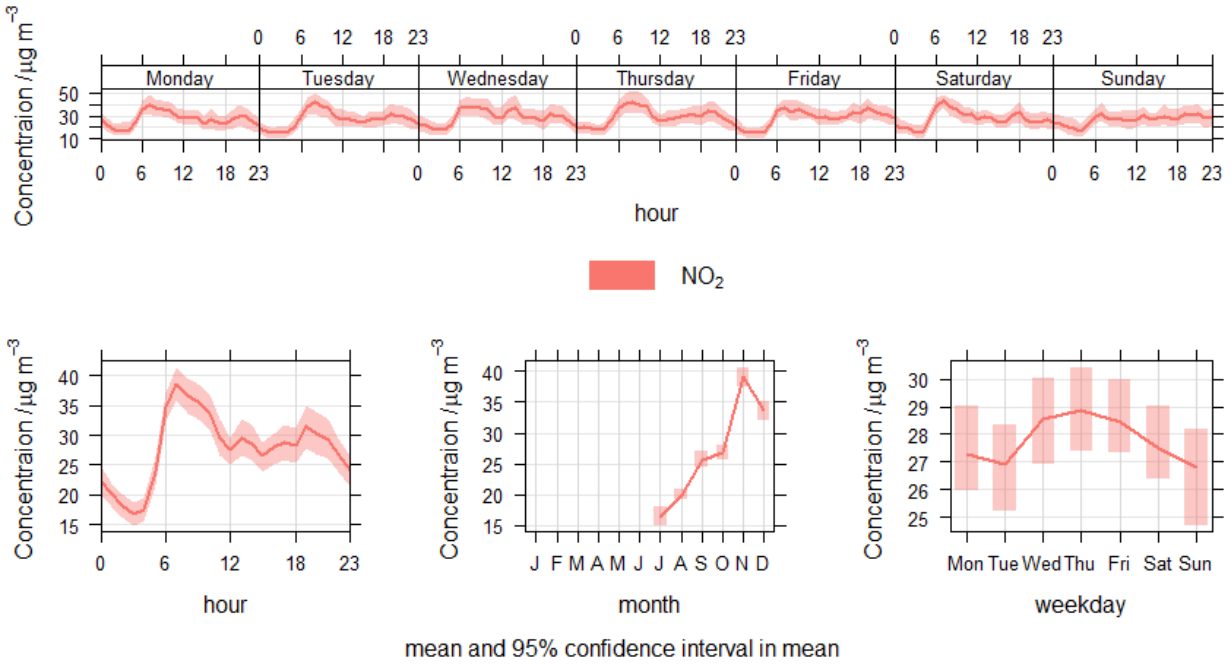


Figure 3-5: Temporal variation in concentrations of NO_2 at the airside site

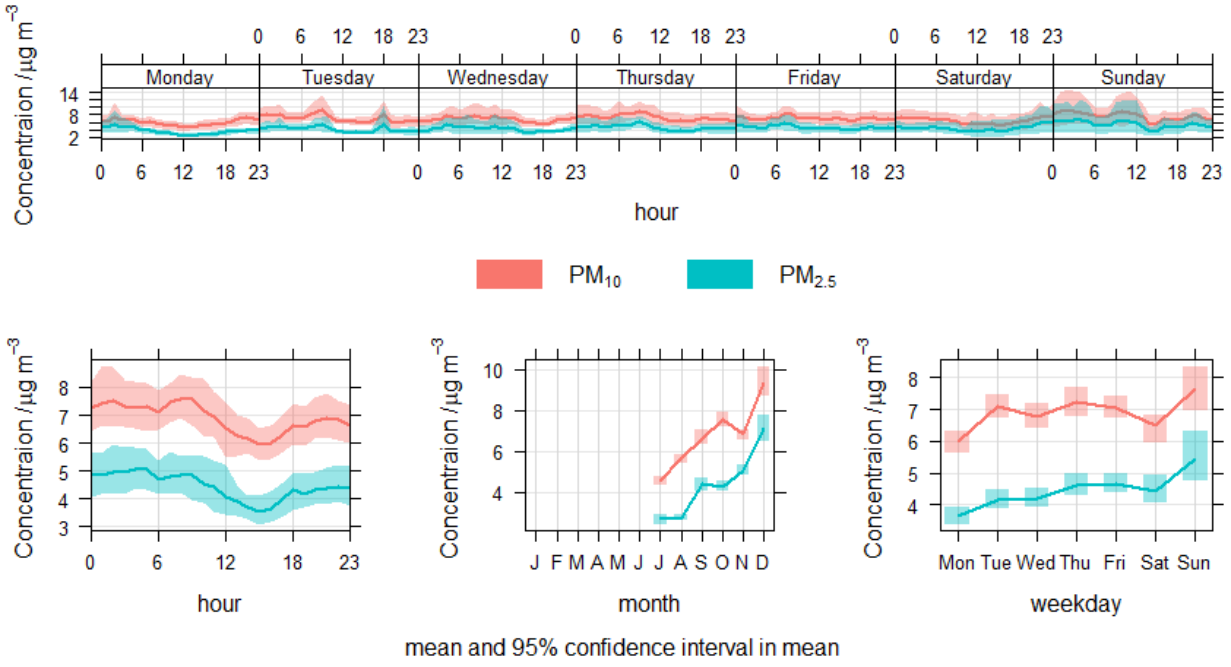


Figure 3-6: Temporal variation in concentrations of PM_{10} and $PM_{2.5}$ at the airside site

Seasonal variations are common for the pollutants measured at this site and can be observed in the 'month' plots of Figure 3-3 to Figure 3-6. Clear seasonal variation can be seen in the NO_2 and PM concentrations. The winter months recorded higher levels when emissions may be higher due to periods of cold, still weather which reduce pollutant dispersion.

The diurnal variation analyses for the can be viewed in the 'hour' plots and show typical urban area daily patterns for all pollutants. Pronounced peaks can be seen during the morning, corresponding to rush hour traffic at around 07:00 to 08:00. Concentrations tend to decrease during the middle of the day, with a much broader evening road traffic rush-hour peak, building up slightly from early afternoon.

PM does exhibit elevated concentrations in the mornings and overnight with a decrease during the day however doesn't display prominent peaks.

3.7 POLAR PLOTS

In order to investigate the possible sources of air pollution being monitored at the AQMesh monitoring location meteorological data measured at Edinburgh Airport were used to add a directional component to the air pollutant concentrations. Wind speed and direction data was gathered using data from the National Oceanic and Atmospheric Administration (NOAA) meteorological database.

Figure 3-7 shows the measured wind speed and direction data. The lengths of the "spokes" against the concentric circles indicate the percentage of time during the year that the wind was measured from each direction. The prevailing wind can be seen to be from the southwest. Each "spoke" is divided into coloured sections representing wind speed intervals of 2 m s^{-1}. The mean wind speed during the monitoring period 3.9 m s^{-1}. The maximum measured wind speed during the study period was 12.9 m s^{-1}.

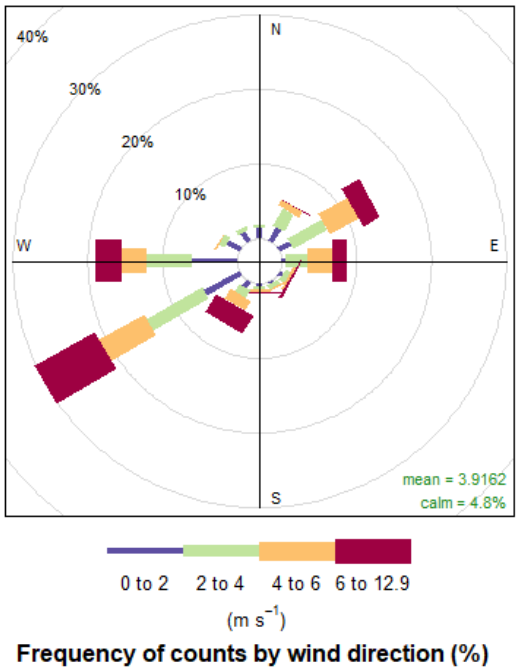


Figure 3-7: Wind rose showing wind speed and direction at Edinburgh Airport (July 2023 - January 2024)

Figure 3-8 to Figure 3-10 show bivariate plots of hourly mean concentrations of NO_2, PM_{10} and $PM_{2.5}$ against wind speed and wind direction for the study period. These plots should be interpreted as follows:

- The wind speed is indicated by the distance from the centre of the plot; the grey circles indicate wind speeds in 5 ms^{-1} intervals.
- The pollutant concentration is indicated by the colour (as indicated by the scale).

These plots therefore show how pollutant concentrations varied with wind direction and wind speed. The plots do not show distance of pollutant emission sources from the monitoring site. However, in the case of primary pollutants, the concentrations at very low wind speeds are dominated by emission sources close by, while at higher wind speeds, effects are seen from sources further away.

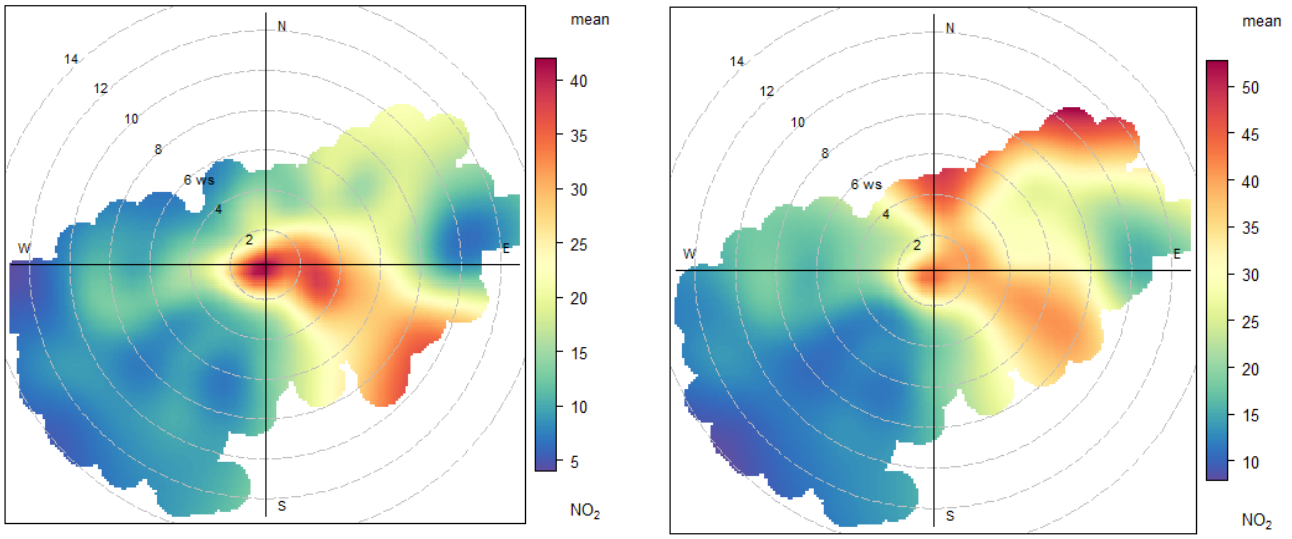


Figure 3-8: Pollution rose for NO_2 as measured by the landside (left) and airside (right) AQMesh

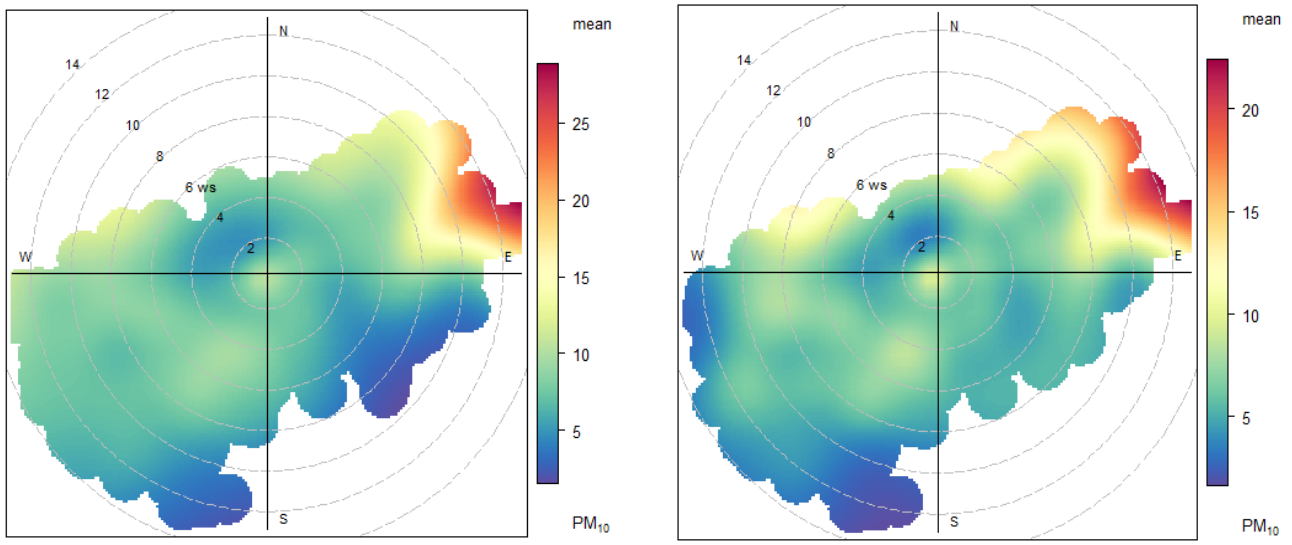


Figure 3-9: Pollution rose for PM_{10} as measured by the landside (left) and airside (right) AQMesh

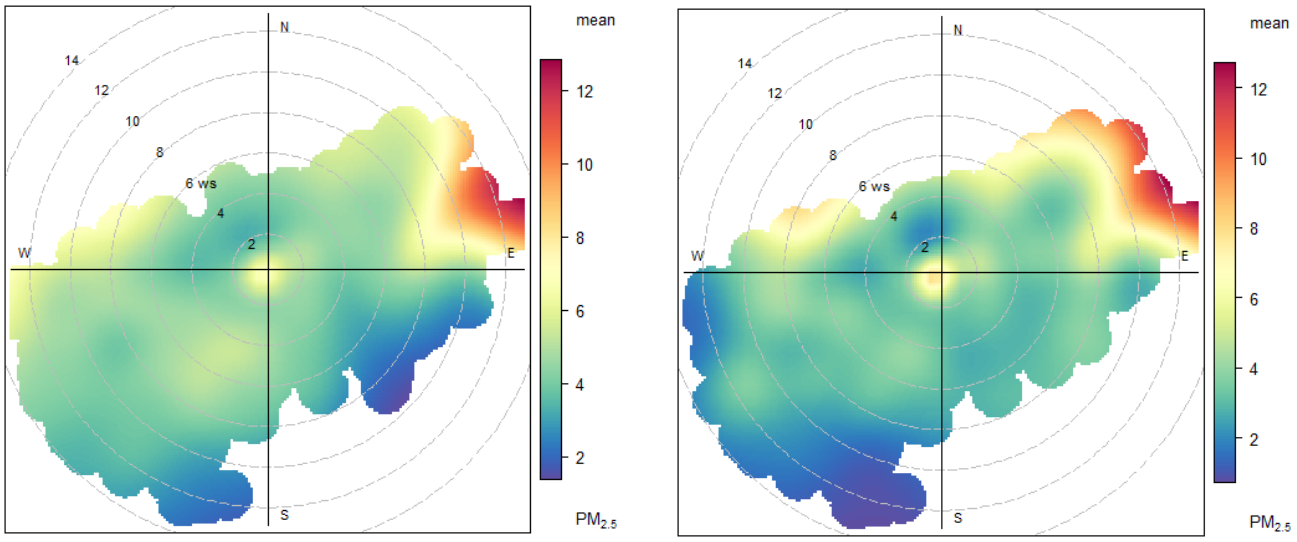


Figure 3-10: Pollution rose for $PM_{2.5}$ as measured by the landside (left) and airside (right) AQMesh

The landside NO_2 plot shows that the highest concentrations occurred at low wind speeds and in the case of the landside sensor, light winds from the east and east southeast. This is likely associated with the pick up and drop off zone. Elevated concentrations at low wind speeds were also measured at the airside site. Both sites recorded elevated concentrations at moderate winds from the southeast and higher winds from the northeast. This is likely from the carparks and terminal areas respectively.

Both sensors recorded very similar PM_{10} and $PM_{2.5}$ roses, with elevated concentrations being seen from the northeast, the direction of the main airport infrastructure. However, multiple smaller signals can be seen at other wind speeds and directions suggesting several sources such as the Terminal Surface parking and the main aircraft infrastructure. Transboundary pollution events will have also played a part in this, in particular many sites in central Scotland, including the two AQMesh sensors, recorded elevated PM concentrations on the 4th of December for this reason.

3.8 COMPARISON WITH PREVIOUS YEARS NO_2 CONCENTRATIONS

Previous rounds of this study have been carried out in 1999, 2003/2004, 2006/2007, 2010/2011, 2013/2014 and 2017/2018. Over this time period there have been significant changes to the airport layout and tube locations have changed so direct comparisons are not possible. Table 3-4 shows the averaged annual mean concentrations for: all sites, just airside locations and just landside locations, for the studies undertaken since 2003.

There is a general trend of decreasing NO_2 concentrations at all sites, as well as grouped airside and landside sites, over the 20-year monitoring period with a marked increase in the 2010/2011 study. The 2023 study provides the lowest bias adjusted annualised averages of any of the studies. However, it must be noted that each study is only six months long and not all the studies were taken during the same six-month period. This means that while trends can be inferred, direct comparisons can't be made.

Table 3-4: Annual mean NO_2 concentrations at Edinburgh Airport between 2003 and 2023

Site Name	Average (µg m^{-3}) 2003/2004	Average (µg m^{-3}) 2007/2008	Average (µg m^{-3}) 2010/2011	Average (µg m^{-3}) 2013/2014	Average (µg m^{-3}) 2017/2018	Average (µg m^{-3}) 2023
All Sites	28	26	35	30	24	18
Airside Sites	24	21	31	25	18	16
Landside Sites	31	29	38	32	28	19

4. CONCLUSIONS

Ricardo Energy & Environment was commissioned by Edinburgh Airport Ltd to undertake a six-month air quality monitoring survey investigating nitrogen dioxide (NO_2) and Particulate Matter (PM_{10} and $PM_{2.5}$) concentrations at Edinburgh Airport during 2023.

Estimated annual mean NO_2 concentrations above the objective of 40 µg m^{-3} were not breached at any site during this study. Period means recorded by both AQMesh instruments were lower than the Annual mean targets for PM_{10} and $PM_{2.5}$.

The hourly NO_2 objective of no more than 18 exceedances of 200 µg m^{-3} in a year is not likely to have been exceeded at any location. In 2023, there is continuation of the general trend of decreasing NO_2 concentrations relative to what was measured in prior studies.

Seasonal and diurnal variations for all pollutants were typical for an urban area, with lower concentrations in the summer months than the winter, and evidence of morning and afternoon rush hour peaks.

Directional analysis was carried out using data from the two AQMesh sensors which showed elevated concentrations of all measured pollutants in calm conditions when pollutants are poorly dispersed. The landside sensor, placed near the pick up and drop off zone, recorded an elevated NO_2 concentration from that direction, with both landside and airside sensors also picking up signals at higher windspeeds from the surface level carparks and main airport infrastructure.

When grouped into similar sites the diffusion tubes placed in and around the PUDO gave the highest average reading of 19.7 µg m^{-3}, the average of all the non co-located tubes being 18 µg m^{-3}.

For future air quality monitoring studies in Edinburgh Airport, it is recommended that diffusion tubes and sensors are deployed for 12 months to increase reliability of data and to better understand the pollutant concentrations at the airport throughout off peak and peak travel times.

REFERENCES

[1] Air Quality Expert Group,. 2004. “Nitrogen Dioxide in the United Kingdom.” http://uk-air.defra.gov.uk/library/aqeg/publications.

[2] NAEI, UK (beis.gov.uk),. 2024. “National Atmospheric Emissions Inventory (2022).” (https://naei.beis.gov.uk/reports/reports?report_id=1135).

[3] WHO, 2021. “WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide.” Word Health organisation. https://apps.who.int/iris/handle/10665/345329.

[4] “The Air Quality Strategy for England, Scotland, Wales and Northern Ireland (Volume 1).” 2007. Department for Environment, Food; Rural Affairs in partnership with the Scottish Executive, Welsh Assembly Government; Department of the Environment Northern Ireland. https://www.gov.uk/government/publications/the-air-quality-strategy-for-england-scotland-wales-and-northern-ireland-volume-1.

[5] “Local Air Quality Management - Technical Guidance LAQM.TG (22).” 2022. Department for Environment, Food; Rural Affairs in partnership with the Scottish Executive, Welsh Assembly Government; Department of the Environment Northern Ireland. https://laqm.defra.gov.uk/wp-content/uploads/2022/08/LAQM-TG22-August-22-v1.0.pdf.

[6] Scottish Government, 2021. “Cleaner Air for Scotland 2 (CAFS2) strategy”. https://www.gov.scot/publications/cleaner-air-scotland-2-towards-better-place-everyone/documents/

[7] “Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on Ambient Air Quality and Cleaner Air for Europe.” 2008. http://data.europa.eu/eli/dir/2008/50/oj/eng.

APPENDICES

APPENDIX 1 – NO_2 DIFFUSION TUBES

Passive sampling involves the collection of air pollutants using an absorbing material without the use of pumps; hence, no power supply is required. This makes these samplers very easy to deploy and flexible in terms of siting.

A passive sampler for gaseous species is defined as a device which is capable of sampling gas or vapour pollutants from the atmosphere, at a rate controlled by a physical process such as diffusion through a static layer or permeation through a membrane, but which does not involve the active movement of air through the sampler

Samplers are available for a wide range of pollutant species. The NO_2, SO_2, NH_3 and O_3 diffusion tubes supplied by Ricardo-AEA are based on the work of Palmes, and consist of a cylindrical plastic tube, approximately 71 mm long and 11 mm in diameter. During sampling, one end is open and the other end holds an absorbent for the gaseous species to be monitored.

The basic principle on which diffusion tube samplers operate is that of molecular diffusion, with molecules of a gas diffusing from a region of high concentration (open end of the sampler) to a region of low concentration (absorber end of the sampler). The movement of molecules of gas (1) through gas (2) is governed by Fick's law, which states that the flux is proportional to the concentration gradient:

$$J = -D_{12}\frac{dc}{dz} \qquad (1)$$

Where:

J	=	the flux of gas (1) through gas (2) across unit area in the Z direction ($\mu g/m^2/s$)
c	=	the concentration of gas (1) in gas (2) ($\mu g\ m^{-3}$)
z	=	the length of the diffusion path (m)
D_{12}	=	the molecular diffusion coefficient of gas (1) in gas (2) (m^2/s)

For a cylinder of cross-sectional area **a** (m^2) and length **l** (m), then **Q** (μg) the quantity of gas transferred along the tube in **t** seconds (taken as the quantity of gas absorbed during **t**) is given by

$$Q = \frac{D_{12}(C_1 - C_o)at}{l} \qquad (2)$$

Where C_o and C_1 are the gas concentrations at either end of the tube.

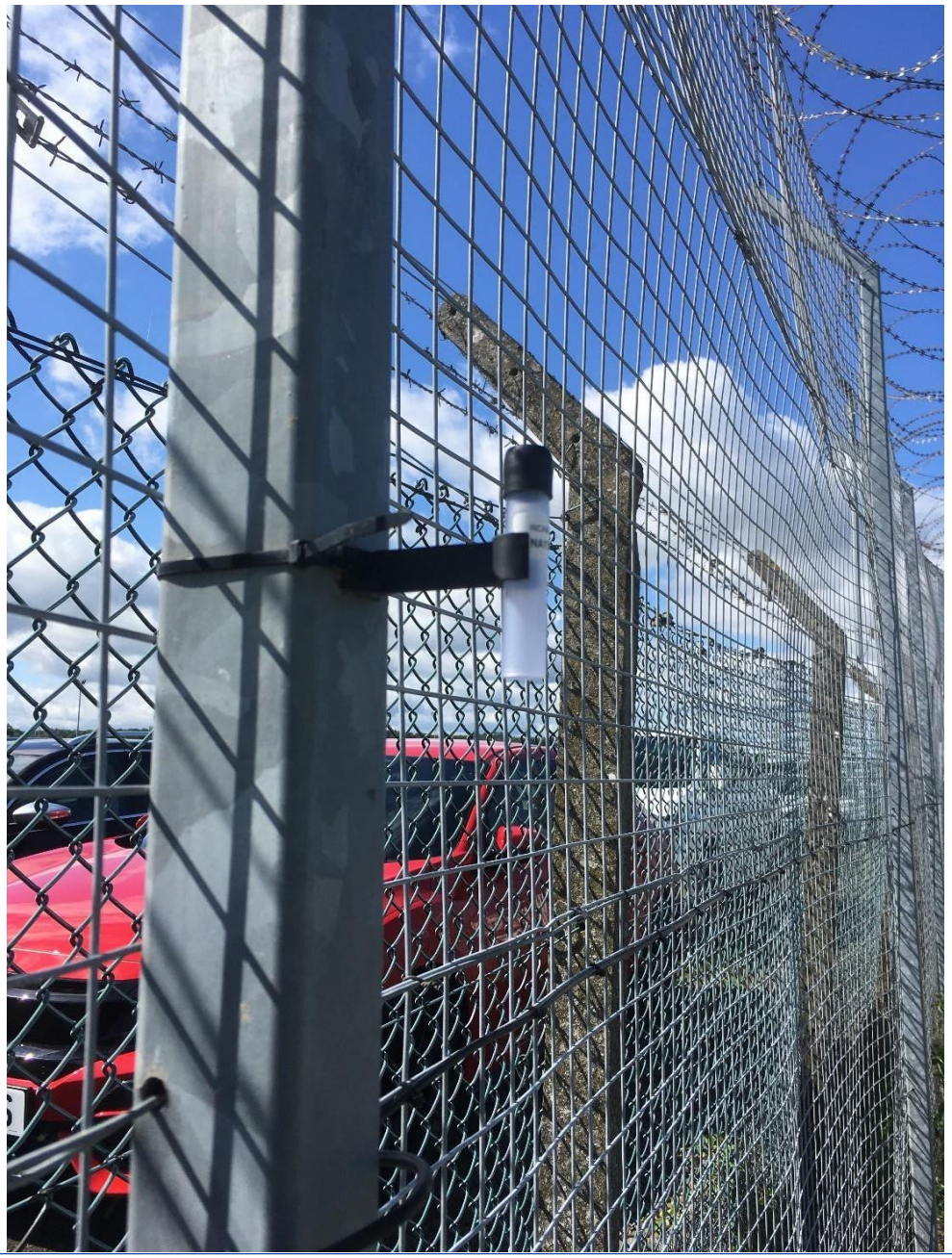
In a diffusion tube, the concentration of gas (1) is maintained at zero by an efficient absorber at one end of the tube (i.e. C_o = zero) and the concentration C_1 is the average concentration of the gas (1) at the open end of the tube over the period of exposure.

Hence:

$$C = \frac{Ql}{D_{12}at} \qquad (3)$$

The diffusion coefficient for the gas to be monitored must be determined, or obtained from the literature. A best estimate of the area and length of a typical tube must be determined by measurement using Vernier callipers. Nominal tube dimensions are set at 11mm (diameter) and 71mm (length). The gas concentration C, can be readily derived from the quantity of gas absorbed Q, (assessed by desorption & chemical analysis of the tube), and the exposure time t.

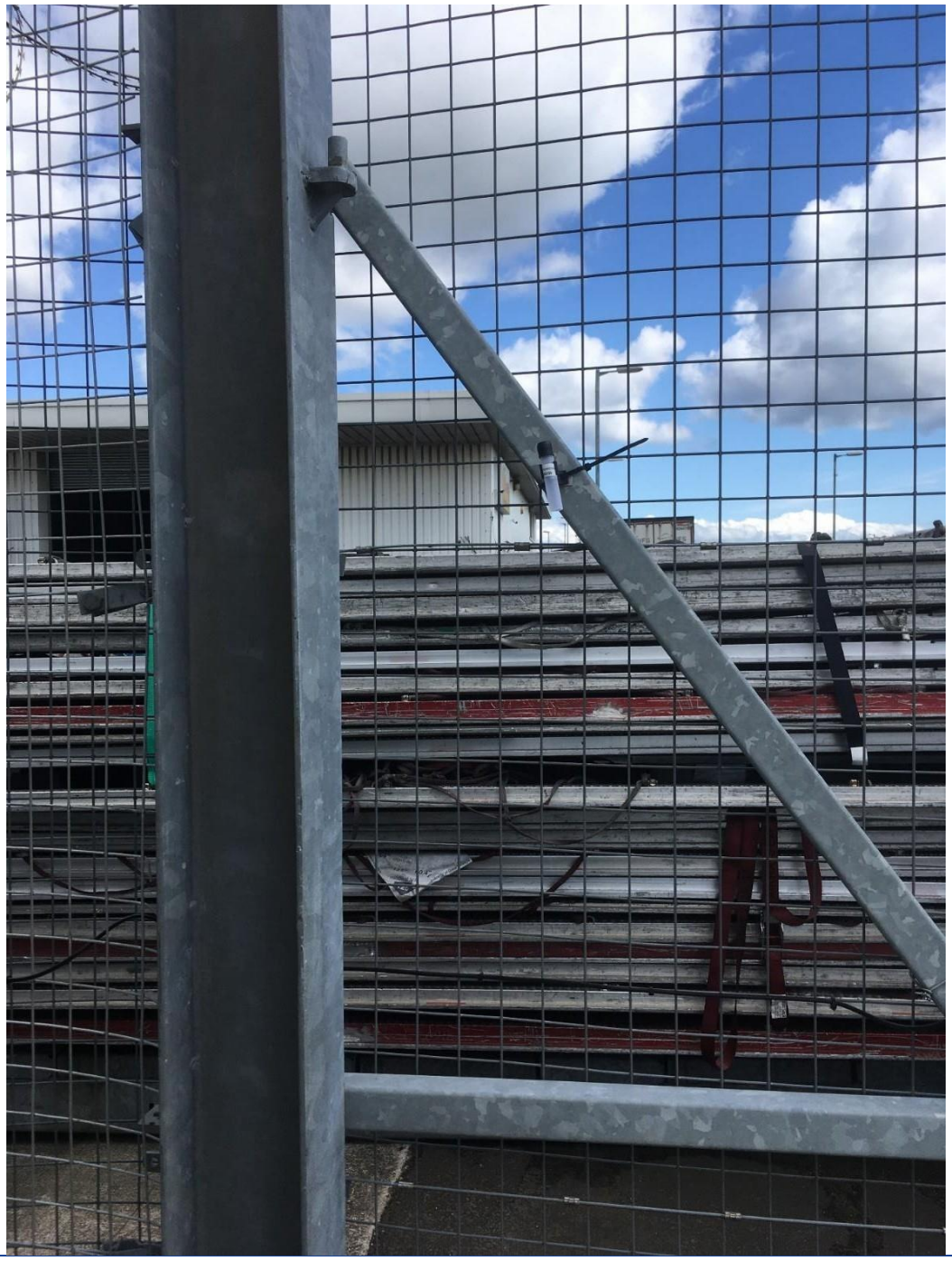
APPENDIX 2 SITE PHOTOS

Site Code	Location Image
Fire Station	

Site Code	Location Image
End of Runway	

Site Code	Location Image
Gate 8	

Site Code	Location Image
2-4 Approach Lights	

Site Code	Location Image
Control Post 1	

Site Code	Location Image
Stand 9 Assembly Point 4	

Site Code	Location Image
Control Post 3	

Site Code	Location Image
Check in Zone A	

Site Code	Location Image
Front Terminal Tunnel	

Site Code	Location Image
Bus Stop B Skylink	

Site Code	Location Image
PUDO Help Point	

Site Code	Location Image
Car Park Office	

Site Code	Location Image
PUDO Entrance	

Site Code	Location Image
Co-Lo St. Johns 1,2,3	

Site Code	Location Image
Signature Building	

Site Code	Location Image
Double Tree Hotel	

Site Code	Location Image
Eastfield Road Roundabout	

Site Code	Location Image
Eastfield Road	

Site Code	Location Image
Stand 1B Landside	

Site Code	Location Image
Lochend Road	

Site Code	Location Image
PUDO Entrance Corner Lanes 3+4	

Site Code	Location Image
PUDO Entrance Corner Lanes 1+2	

Site Code	Location Image
PUDO Exit Corner Lanes 1+2	

Site Code	Location Image
PUDO Exit Corner 3+4	

Site Code	Location Image
Multistorey Level 1	

Site Code	Location Image
Multistorey Level 2	

Site Code	Location Image
Multistorey Level 3	

Site Code	Location Image
300 Stand	

Site Code	Location Image
Lenniemur Road	

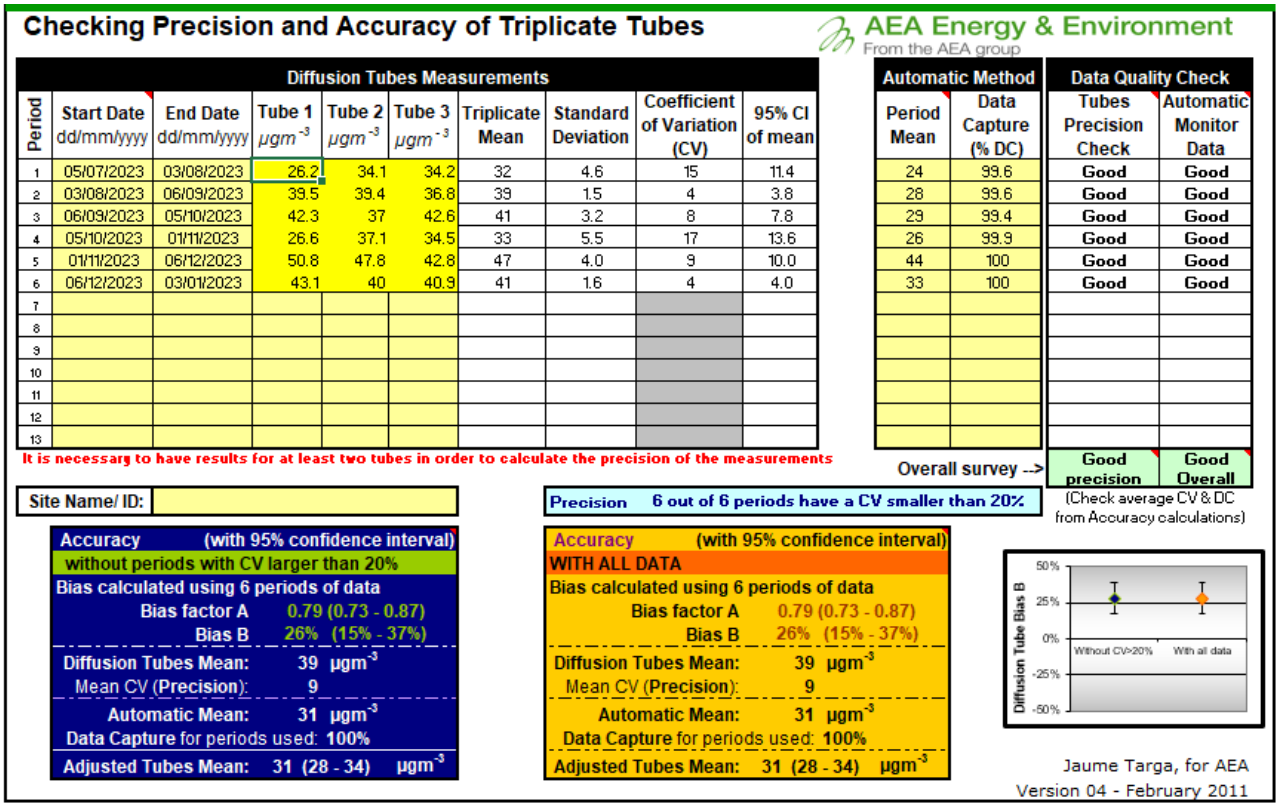
Site Code	Location Image
Airside AQMesh	

Site Code	Location Image
Landside AQMesh	

APPENDIX 3 ADJUSTEMENT FACTOR

Figure A3-1 shows the local bias adjustment factor calculation spreadsheet. As can be seen, the locally derived bias adjustment factor was calculated to be 0.74 when using all available diffusion tube data with a CV of less than 20%.

In line with the guidance detailed in LAQM.TG (22), the national bias adjustment factor spreadsheet was calculated. From the most up-to-date diffusion tube national bias adjustment spreadsheet, published in June 2023, the national bias factor for SOCOTEC's 50:50 TEA in Acetone diffusion tubes was found to be 0.76.



Checking Precision and Accuracy of Triplicate Tubes

AEA Energy & Environment
From the AEA group

Diffusion Tubes Measurements

Period	Start Date dd/mm/yyyy	End Date dd/mm/yyyy	Tube 1 µgm^{-3}	Tube 2 µgm^{-3}	Tube 3 µgm^{-3}	Triplicate Mean	Standard Deviation	Coefficient of Variation (CV)	95% CI of mean
1	05/07/2023	03/08/2023	26.2	34.1	34.2	32	4.6	15	11.4
2	03/08/2023	06/09/2023	39.5	39.4	36.8	39	1.5	4	3.8
3	06/09/2023	05/10/2023	42.3	37	42.6	41	3.2	8	7.8
4	05/10/2023	01/11/2023	26.6	37.1	34.5	33	5.5	17	13.6
5	01/11/2023	06/12/2023	50.8	47.8	42.8	47	4.0	9	10.0
6	06/12/2023	03/01/2023	43.1	40	40.9	41	1.6	4	4.0
7									
8									
9									
10									
11									
12									
13									

It is necessary to have results for at least two tubes in order to calculate the precision of the measurements

Automatic Method		Data Quality Check	
Period Mean	Data Capture (% DC)	Tubes Precision Check	Automatic Monitor Data
24	99.6	Good	Good
28	99.6	Good	Good
29	99.4	Good	Good
26	99.9	Good	Good
44	100	Good	Good
33	100	Good	Good
Overall survey -->		Good precision	Good Overall

(Check average CV & DC from Accuracy calculations)

Site Name/ ID:

Precision 6 out of 6 periods have a CV smaller than 20%

Accuracy (with 95% confidence interval)
without periods with CV larger than 20%
Bias calculated using 6 periods of data
Bias factor A 0.79 (0.73 - 0.87)
Bias B 26% (15% - 37%)
Diffusion Tubes Mean: 39 µgm^{-3}
Mean CV (Precision): 9
Automatic Mean: 31 µgm^{-3}
Data Capture for periods used: 100%
Adjusted Tubes Mean: 31 (28 - 34) µgm^{-3}

Accuracy (with 95% confidence interval)
WITH ALL DATA
Bias calculated using 6 periods of data
Bias factor A 0.79 (0.73 - 0.87)
Bias B 26% (15% - 37%)
Diffusion Tubes Mean: 39 µgm^{-3}
Mean CV (Precision): 9
Automatic Mean: 31 µgm^{-3}
Data Capture for periods used: 100%
Adjusted Tubes Mean: 31 (28 - 34) µgm^{-3}

Jaume Targa, for AEA
Version 04 - February 2011

Figure A3-0-1: Bias adjustment factor calculation spreadsheet

T: [redacted]
[redacted]
[redacted]