



Air Quality Monitoring at Stansted Airport 2016

Report for Stansted Airport Ltd
ED60985

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Executive summary

This report provides details of air quality monitoring conducted around Stansted Airport during 2016. The work, carried out by Ricardo Energy and Environment on behalf of Stansted Airport Ltd, is a continuation of monitoring undertaken at Stansted Airport since 2004. The aims of the programme are to monitor air pollution around the airport, to assess compliance with relevant air quality objectives, and to investigate changes in air pollutant concentrations over time.

Automatic continuous monitoring was carried out at two locations, referred to as Stansted 3 and Stansted 4. Stansted 3 was located to the south-east of the airport at High House, and Stansted 4 was located to the north of the runway. Both sites monitored oxides of nitrogen (nitric oxide and nitrogen dioxide); PM₁₀ particulate matter was monitored at Stansted 3 only. Measured PM₁₀ concentrations were adjusted using the King's College London Volatile Correction Model to correct for potential losses of volatile and semi-volatile components from the Tapered Element Oscillating Microbalance (TEOM) particulate monitor. At the end of 2016 both sites were upgraded to have FIDAS equipment measuring PM₁₀ and PM_{2.5}, at Stansted 3 this replaced the TEOM equipment.

In addition to automatic monitoring, indicative monitoring of nitrogen dioxide was carried out using diffusion tubes. These were co-located with the continuous automatic monitor at Stansted 3 and also used at four other sites, to the north, south, east and west of the airport.

The minimum applicable data capture target of 85% (recommended in the European Commission Air Quality Directive¹ and Defra Technical Guidance LAQM.TG (16)⁴) was achieved for all pollutants at Stansted 3 (NO_x and PM₁₀) and Stansted 4 (NO_x).

The UK AQS hourly mean objective for NO₂ is 200 µg m⁻³, with no more than 18 exceedances allowed each year. Stansted 3 met this objective, with no hourly means recorded above the objective. Stansted 4 recorded ten hourly means above the objective, all on December 5th and 6th, when a generator next to the site was turned on, however as this is still below 18 exceedances Stansted 4 also met the objective.

The annual mean AQS objective for NO₂ is 40 µg m⁻³. This was met at Stansted 3, Stansted 4, and at all five of the diffusion tube monitoring sites.

PM₁₀ may exceed the 24-hour mean limit of 50 µg m⁻³ no more than 35 times per year to meet the AQS objective. The annual mean AQS for PM₁₀ is 40 µg m⁻³. These objectives were met at Stansted 3, with only one instances of concentrations exceeding the 24-hour mean value.

Wind speed and direction data accessed via the National Oceanic and Atmospheric Administration (NOAA) were used to produce bivariate plots showing hourly mean pollutant concentrations against the corresponding weather conditions. The bivariate plots for NO and NO₂ for Stansted 3 show elevated concentrations when wind speeds are low, indicating sources are close possibly being attributed to airport activity and the A120 road. The bivariate plot for PM₁₀ at Stansted 3 showed a source to the east of the site, possibly arising from agricultural activities, however a source from the west/southwest is also show when wind speeds are moderate to high, indicating a potential source from the M11 motorway. The bivariate plots for NO and NO₂ at Stansted 4 generally show elevated concentrations when wind speeds are calm to moderate and prevailing from the south-west and south-east, indicating sources being attributed to airport activity and the A120 road.

Few episodes of high concentrations for NO_x and PM₁₀ occurred during 2016. At Stansted 3, particularly high concentrations of NO_x and PM₁₀ were recorded on the 18th and 19th of January, 11th and 12th of March and 29th and 30th of October. Local emissions, combined with trans-boundary atmospheric transport of industrial pollution and calm atmospheric conditions are the origin of these high concentration episodes. It is suspected that celebrations of Diwali contributed to PM episodes on the 29th and 30th of October.

Average NO₂ concentrations are broadly similar to those from comparable urban background monitoring sites and have remained lower than those for London Heathrow Airport. PM₁₀ levels at Stansted 3 have declined from a peak in 2006, although slightly increased from 2015.

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1 Introduction

1.1 Background

Stansted Airport is London's third busiest international airport, handling approximately 24 million passengers a year. The airport is situated approximately 40 miles north of London, in North West Essex. It is situated outside the general urbanised area of Greater London, and its surroundings are rural.

Stansted Airport Ltd is required, under the terms of its Section 106 Planning Agreement with the Local Authority (Uttlesford District Council), to carry out monitoring of oxides of nitrogen and particulate matter at an agreed location. Prior to 2006, monitoring was required for three months per year; from 2006 onwards, continuous monitoring throughout the year has been required.

Ricardo Energy & Environment was contracted by Stansted Airport Ltd to carry out the required programme of air pollution measurements during 2016, the eleventh full year of continuous monitoring.

Provisional data are reported to Stansted Airport Ltd quarterly throughout the year. This annual report presents and summarises the fully validated and quality controlled dataset for the entire calendar year (though please note the caveat in section 2.2.3 about VCM correction of the PM₁₀ data). Data in the annual report have been processed according to the rigorous quality assurance and quality control procedures used by Ricardo Energy & Environment. These ensure the data are reliable, accurate and traceable to UK national measurement standards.

This report covers the period 01st January to 31st December 2016.

1.2 Aims and Objectives

The aim of this monitoring programme is to monitor concentrations of two important air pollutants around the airport. The results of the monitoring are used to assess whether applicable air quality objectives have been met, and how pollutant concentrations in the area have changed over time.

The pollutants monitored were as follows:

- Oxides of nitrogen (nitric oxide NO and nitrogen dioxide NO₂), using automatic techniques at two locations: Stansted 3 (High House) and Stansted 4 (Runway).
- Particulate matter (PM₁₀) at Stansted 3.

The automatic monitoring was supplemented by indicative monitoring of NO₂ using diffusion tubes at five locations.

Monitoring data collected at Stansted are compared in this report with:

- Relevant UK air quality limit values and objectives.
- Corresponding results from a selection of national air pollution monitoring sites.
- Statistics related to airport activity.

In addition, periods of relatively high pollutant concentrations are examined in more detail.

1.3 UK Air Quality Strategy

Within the European Union, controls on ambient air quality are covered by Directive 2008/50/EC on Ambient Air Quality and Cleaner Air for Europe¹, known as the Air Quality Directive. This consolidated three previously existing Directives, which set limit values for a range of air pollutants with known health impacts. The original Directives were transposed into UK law through The Environment Act 1995 which 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 Environment Act 1995 also introduced the system of local air quality management (LAQM). This requires local authorities to review and assess air quality in their areas against the national air quality objectives. Where any objective is unlikely to be met by the relevant deadline, the local authority must designate an air quality management area (AQMA). Local authorities then have a duty to carry out further assessments within any AQMAs and draw up an action plan specifying the measures to be carried out, and the timescales, to achieve the air quality objectives. The legal framework given in the

Environment Act has been adopted in the UK through the UK AQS. The most recent version of the AQS was published by Defra in 2007², and the currently applicable air quality objectives are summarised in Appendix 1 of this report.

2 Air Quality Monitoring

2.1 Pollutants Measured

2.1.1 Nitrogen Oxides (NO_x)

Combustion processes emit a mixture of oxides of nitrogen – NO and NO₂ - collectively termed NO_x.

i) 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 NO₂.

ii) NO₂ has a primary (directly emitted) component and a secondary component, formed by oxidation of NO. NO₂ 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.

Of the NO_x emissions (including NO₂) considered to be airport-related, over 50 % arise from aircraft during take-off and landing, with around two-thirds of all emissions occurring at some distance from airport ground-level. The Air Quality Expert Group (AQEG)³ 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 NO₂ 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 LAQM process have not highlighted any cases where airports appear to have caused exceedances of air quality objectives for particulate matter measured as PM₁₀. Therefore, in the context of LAQM, the key pollutant of concern from airports is NO₂. 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 quality⁴.

2.1.2 Particulate Matter

Airborne particulate matter varies widely in its physical and chemical composition, source and particle size. The term PM₁₀ is used to describe particles with an effective size less than 10 µm. These are of greatest concern with regard to human health, as they are small enough to penetrate deep into the lungs. They can cause inflammation and a worsening of the condition of people with heart and lung diseases. In addition, they may carry surface absorbed carcinogenic compounds into the lungs. Larger particles, meanwhile, are not readily inhaled, and are removed relatively efficiently from the air by sedimentation.

The main sources of airborne particulate matter in the UK are combustion (industrial, commercial and residential fuel use). The next most significant source is road vehicle emissions. Based on 2014 National Atmospheric Emissions Inventory (NAEI) data, less than 0.1% of UK total PM₁₀ emissions were believed to originate from civil aircraft taking off and landing⁵.

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 PM₁₀⁴.

2.2 Monitoring sites and Methods

2.2.1 Site Locations

Automatic monitoring was carried out at two sites during 2016. These are referred to as Stansted 3 and Stansted 4 (the numbering of the sites continues the sequence used for previous short-term sites in earlier monitoring studies). The location descriptions of both sites fall into the category "other" as defined by the Defra Technical Guidance on air quality monitoring LAQM.TG(16)⁴, (i.e. *"any special source-oriented or location category covering monitoring undertaken in relation to specific emission sources such as power stations, car-parks, airports or tunnels"*).

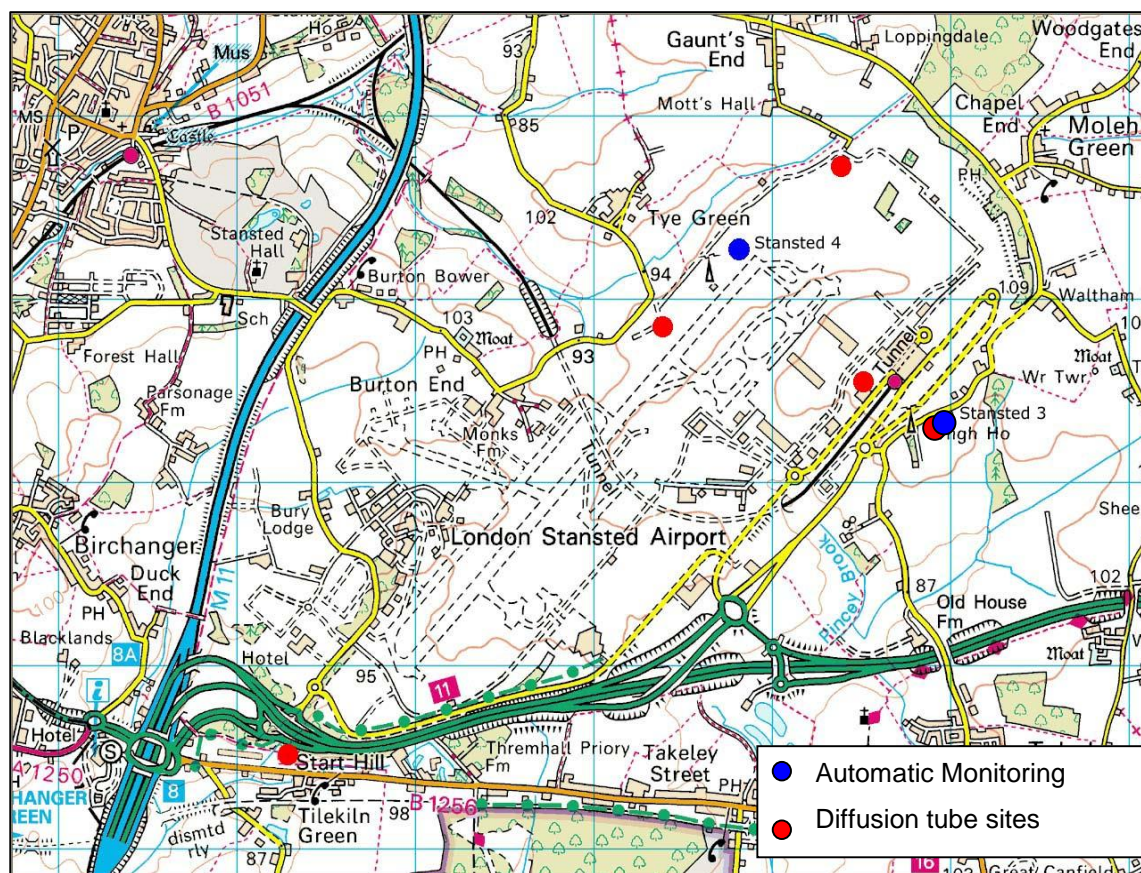
These two automatic sites were supplemented by five sites at which diffusion tubes were used to monitor NO₂ on a monthly basis. These were located at the Stansted 3 automatic site, and four sites to the north, east, south and west of the airport.

Table 2.1 describes the monitoring locations. Figure 2.1 shows a map of the locations of all monitoring sites used in this study. Automatic monitoring sites are shown by blue dots, diffusive samplers by red dots.

Table 2.1 - Locations of air quality monitoring sites at Stansted.

Site name	Description	Parameters monitored	Grid reference
Stansted 3	East of High House	Automatic monitoring of NO _x and PM ₁₀ . Diffusion tube monitoring of NO ₂ monthly (co-located).	TL 558 233
Stansted 4	Grass area near runway	Automatic monitoring of NO _x .	TL 548 243
Stansted North	North lights, north end of runway	Diffusion tube monitoring of NO ₂ monthly.	TL 555 248
Stansted East	Enterprise House offices	Diffusion tube monitoring of NO ₂ monthly.	TL 555 234
Stansted South	Balancing pond south of site	Diffusion tube monitoring of NO ₂ monthly.	TL 522 215
Stansted West	Radar tower, Burton End	Diffusion tube monitoring of NO ₂ monthly.	TL 536 235

Figure 2.1 - Locations of monitoring sites © Crown Copyright Ordnance Survey. Reproduced from Landranger 1:50000 map series, Licence number 100040905.



The location of the automatic monitoring site at High House (Stansted 3) was agreed with Stansted Airport, Uttlesford District Council and Ricardo Energy & Environment. It is located just outside the eastern perimeter of the airport. It is considered to be close enough to the airport to detect effects relating to airport emissions. It is also close to vulnerable receptors, being located in a nursery school car park. The A120 main road runs approximately 1.5 km to the south of the site. The monitoring apparatus is housed in a purpose-built enclosure. Figure 2.2 shows a photograph of the Stansted 3 site.

Figure 2.2 – Stansted 3 automatic monitoring site.



Stansted 4 is located at the north-eastern end of the main runway, within the airport perimeter. It is intended to monitor any effects on air quality related to airport emissions. The location of Stansted 4 is included in Figure 2.1, and a photograph is provided in Figure 2.3.

Figure 2.3 – Stansted 4 automatic monitoring site.



2.2.2 Automatic Monitoring

The following techniques were used for the automatic monitoring of NO_x (i.e. NO and NO₂) and PM₁₀:

- PM₁₀ - Tapered element oscillating microbalance (TEOM) and Fine Dust Analysis Systems (FIDAS);

- NO, NO₂ - Chemiluminescence.

Further information on these techniques is provided in Appendix 2 of this report. These analysers provide a continuous output, proportional to the pollutant concentration. This output is recorded and stored every 10 seconds, and averaged to 15-minute mean values by internal data loggers. The analysers are connected to a modem and interrogated through a GPRS internet device to download the data to Ricardo Energy & Environment. Data are downloaded hourly. The data are converted to concentration units at Ricardo Energy & Environment then averaged to hourly mean concentrations.

2.2.3 King's College London Volatile Correction Model

The TEOM particulate monitor uses a 50 °C heated sample inlet to prevent condensation on the filter. Although necessary, this elevated temperature can result in the loss of volatile and semi-volatile components of PM₁₀ such as ammonium nitrate⁶.

It is not possible to address this problem by applying a simple correction factor. However, King's College London (KCL) has developed a Volatile Correction Model⁷ (VCM), which allows TEOM PM₁₀ data to be corrected for the volatile components lost as a result of the TEOM's heated inlet. It uses data from nearby TEOM-FDMS (Filter Dynamics Measurement System) particulate analysers in the national air quality monitoring network, which measure the volatile and non-volatile components of PM₁₀. The volatile component (which typically does not vary much over a large region), can be added to the TEOM measurement. KCL states that the resulting corrected measurements have been demonstrated as equivalent to the gravimetric reference equivalent.

Correction using the VCM is now the preferred approach when comparing TEOM data with air quality limit values and objectives. In this report, it is clearly indicated when the VCM has been used to correct PM₁₀ data. In some cases, when investigating diurnal patterns and long term trends (which started prior to the development of the VCM), the VCM has not been applied and this too is clearly indicated.

The methodology for the VCM correction of PM₁₀ data is presented in Appendix 2 of this report.

2.2.4 Diffusive Samplers

Diffusion tubes were used for additional indicative monitoring of NO₂. These are "passive" samplers which work by absorbing the pollutants direct from the surrounding air and need no power supply.

Diffusion tubes for NO₂ 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 to be monitored, in this case NO₂. The tube is mounted vertically with the open end at the bottom. Ambient NO₂ 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.

Diffusion tubes were prepared by a commercial laboratory (Gradko International Ltd). The tubes were supplied in a sealed condition prior to exposure. They were exposed at the sites for a set period of time. After exposure, the tubes were again sealed and returned to the laboratory for analysis. The exposure periods used were approximately equivalent to calendar months.

3 Quality assurance and data capture

3.1 Quality assurance and Quality control

In line with current operational procedures within the Defra Automatic Urban and Rural Network (AURN)⁸, full intercalibration audits of the Stansted air quality monitoring sites took place at six-monthly intervals. Full details of these UKAS-accredited calibrations, together with data validation and ratification procedures, are given in Appendix 3 of this report. In addition to instrument and calibration standard checking, the air intake sampling systems were cleaned and all other aspects of site infrastructure were checked.

Following the instrument and calibration gas checking, and the subsequent scaling and ratification of the data, the overall accuracy and precision figures for the pollutants monitored at Stansted are summarised in Table 3.1.

Table 3.1 – Estimated precision and accuracy of the data presented.

Pollutant	Precision	Accuracy
NO	± 2.5	± 15 %
NO ₂	± 6.9	± 15 %
PM ₁₀	± 4	Estimated* accuracy of a TEOM ± 30 % or better. With VCM correction, estimated as ± 25 %. FIDAS: ±25% (estimated)

* Accuracy of particle measurements with a TEOM instrument cannot be assessed reliably.

When using diffusion tubes for indicative NO₂ monitoring, the LAQM Technical Guidance LAQM.TG(16)⁴ states that correction should be made for any systematic bias (i.e. over-read or under-read compared to the automatic chemiluminescent technique, which is the reference method for NO₂). Throughout this study, diffusion tubes have been exposed alongside the automatic NO_x analyser at Stansted 3. These co-located measurements were used for bias adjustment of the annual mean diffusion tube data from the other sites.

The diffusion tube methodologies used for this monitoring programme provide data that are accurate to ± 25 % for NO₂. The limits of detection vary from month to month, but typically equate to 0.4 µg m⁻³ for NO₂. Diffusion tube results that are below 10 times the limit of detection have a higher level of uncertainty associated with them. All were above this threshold.

3.2 Data capture

Data capture statistics for the two monitoring sites are given in Table 3.2. A data capture target of 85 % is recommended in the European Commission Air Quality Directive¹ and Defra Technical Guidance LAQM.TG (16)⁴.

Table 3.2 – Data capture statistics, 2016.

Sites	NO _x	NO ₂	PM ₁₀
Stansted 3	94.8%	94.8%	96.3%
Stansted 4	89.7%	89.7%	-

The 85 % data capture target was therefore achieved for all the measured pollutants at Stansted 3 and Stansted 4. Significant data gaps for the stations are shown in Table 3.3.

Table 3.3 – Significant data gaps, 2016.

Site	Pollutant	Start date	End date	No. of days	Reason	Comments
Stansted 3	NO ₂	01/01/2016	07/01/2016	7	Sampling fault	Sampling fault
Stansted 3	PM ₁₀	11/3/16	11/3/16	0.5	Instrument fault	Analyser Issue
Stansted 4	NO ₂	15/07/2016	17/07/2016	1.1	Service	Routine service
Stansted 3	NO ₂	15/07/2016	17/07/2016	2.1	Service	Routine service
Stansted 3	NO ₂	25/07/2016	26/07/2016	0.5	Communications	Communication Issue
Stansted 4	NO ₂	25/07/2016	26/07/2016	1.1	Communications	Communication Issue
Stansted 4	NO ₂	30/07/16	19/08/16	20.5	Instrument fault	Auto calibration run on
Stansted 3	NO ₂	09/11/2016	11/11/2016	1.8	Power cut	Power cut
Stansted 3	PM ₁₀	09/11/2016	11/11/16	1.9	Power cut	Power cut
Stansted 4	NO ₂	09/11/16	15/11/16	7	Instrument fault	Water ingress into analyser
Stansted 3	PM ₁₀	14/12/2016	21/12/2016	7	New PM analyser installation	Upgrade to FIDAS analyser

4 Results and discussion

4.1 Automatic monitoring data

The summary statistics for 2016 are given in Table 4.1, and the time series of data for the full year, as measured by the automatic monitoring sites, are shown in Figure 4.1 and Figure 4.2.

Table 4.1 – Air pollution statistics for Stansted 3, from 1st January to 31st December 2016.

Stansted 3	NO ($\mu\text{g m}^{-3}$)	NO ₂ ($\mu\text{g m}^{-3}$)	NO _x ($\mu\text{g m}^{-3}$)	PM ₁₀ as measured ($\mu\text{g m}^{-3}$)*	PM ₁₀ VCM corrected ($\mu\text{g m}^{-3}$)+
Maximum 15-minute mean	446	162	838	351	-
Maximum hourly mean	400	129	739	210	200
Maximum running 8-hour mean	201	90	394	64	-
Maximum running 24-hour mean	139	79	289	57	-
Maximum daily mean	128	78	273	57	56
Average	8	21	33	18	18
Data capture	94.8%	94.8%	94.8%	96.3%	96.3%
Stansted 4	NO ($\mu\text{g m}^{-3}$)	NO ₂ ($\mu\text{g m}^{-3}$)	NO _x ($\mu\text{g m}^{-3}$)	PM ₁₀ as measured ($\mu\text{g m}^{-3}$)	PM ₁₀ VCM corrected ($\mu\text{g m}^{-3}$)
Maximum 15-minute mean	1946	898	3469	-	-
Maximum hourly mean	1474	777	3029	-	-
Maximum running 8-hour mean	626	363	1318	-	-
Maximum running 24-hour mean	433	224	884	-	-
Maximum daily mean	260	154	524	-	-
Average	8	19	32	-	-
Data capture	89.6%	89.7%	89.7%	-	-

* combined TEOM and FIDAS data.

+combined VCM and FIDAS data

In this report PM₁₀ measured using the TEOM instrument were converted to gravimetric equivalent using the King's College London Volatile Correction Model⁷ where appropriate. See section 2.2.3 for an explanation of this.

Figure 4.1 – Time series of hourly averaged concentrations in $\mu\text{g m}^{-3}$ at Stansted 3 – 2016.

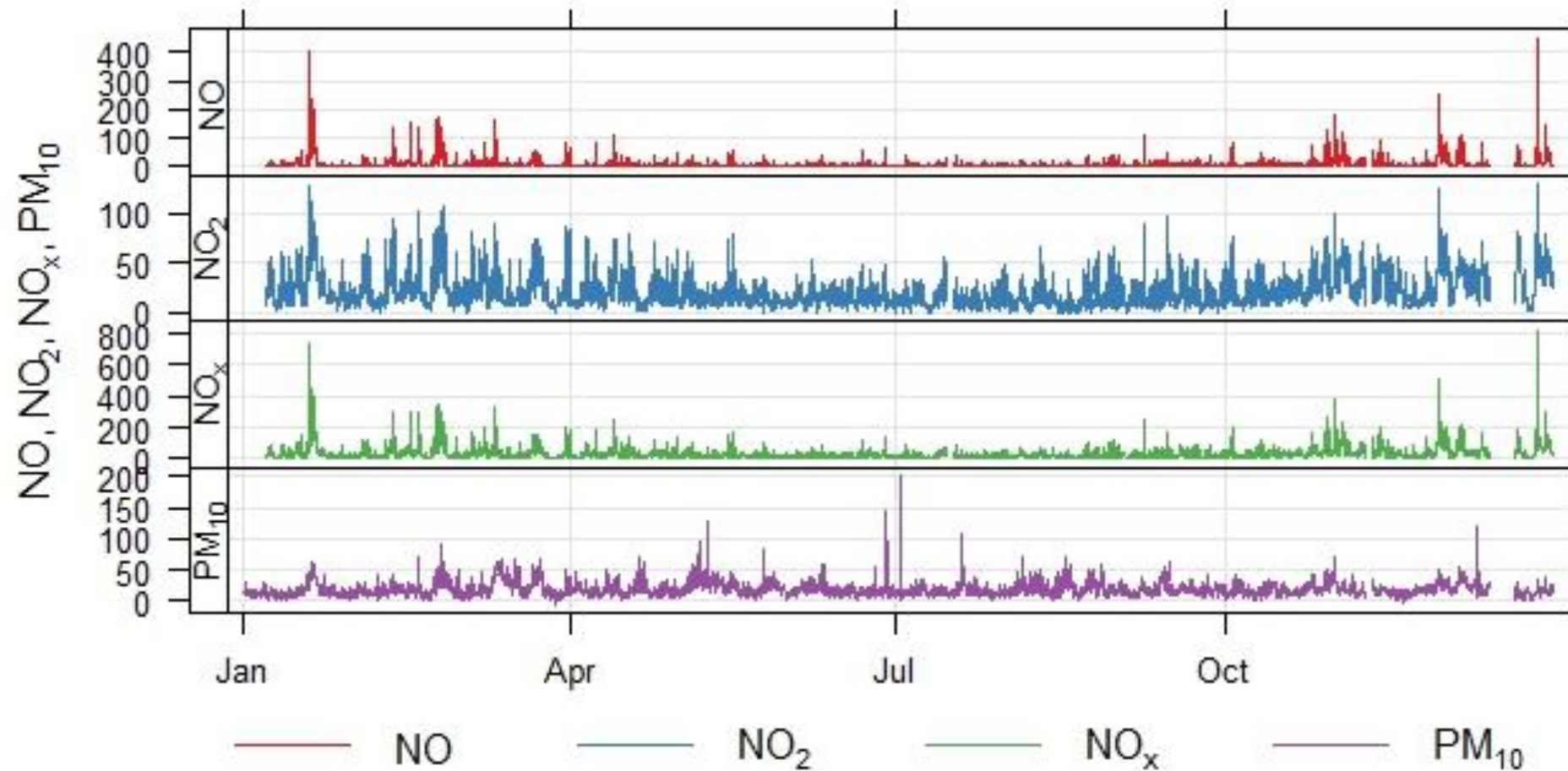
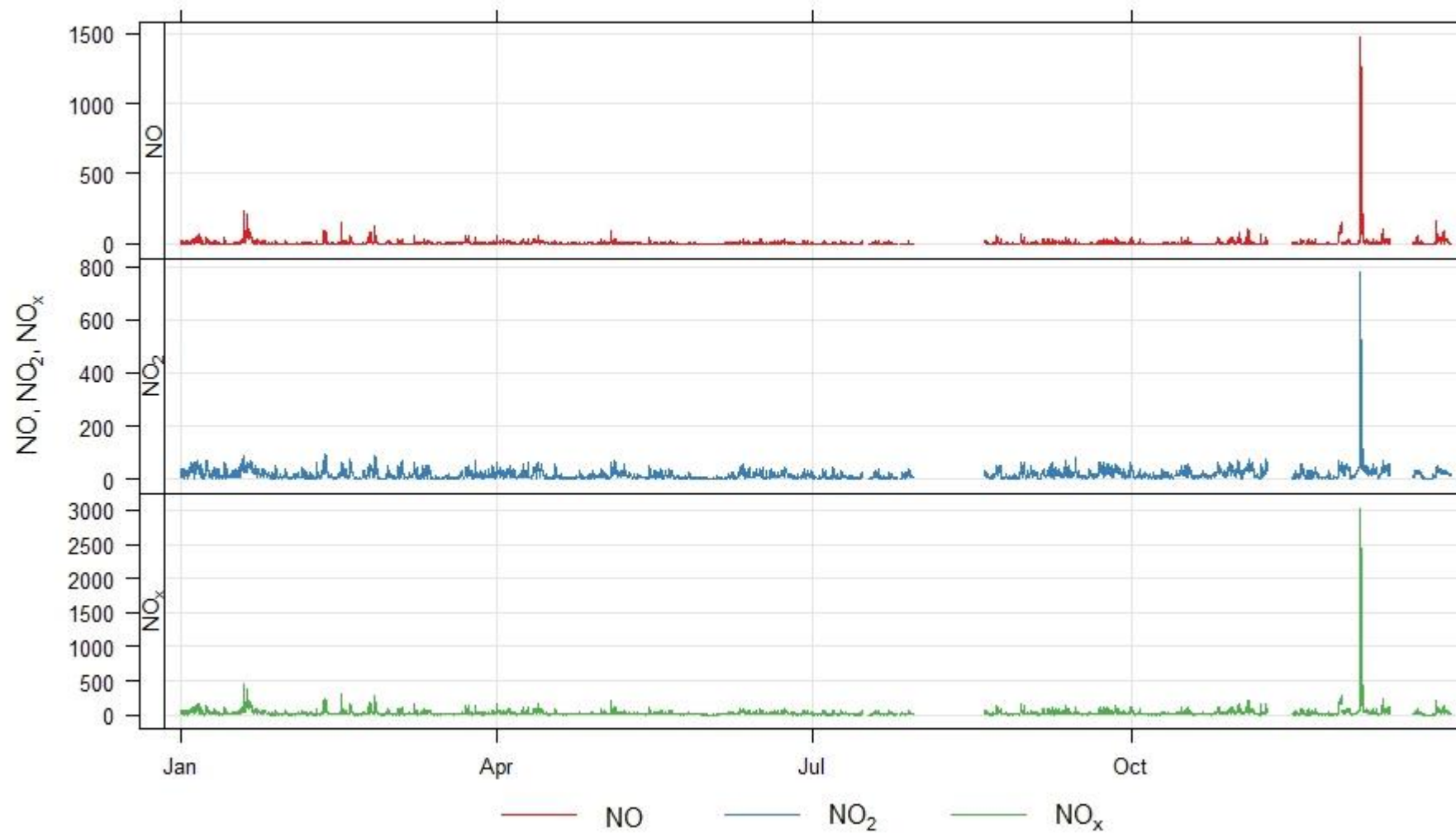


Figure 4.2 – Time series of hourly averaged concentrations in $\mu\text{g m}^{-3}$ at Stansted 4 – 2016.

At Stansted 3, the highest concentration of high hourly average PM₁₀ was recorded in early July 2016. The explanation for this fact is described on the sub chapter 4.4 of the report. The highest NO₂ hourly mean registered for the year of 2016 was of 129 µg m⁻³.

At Stansted 4, high hourly means (777 µg m⁻³) are clearly visible at the beginning of December. This can be attributed to a generator that lies a few metres north of the site. It has been confirmed that this was switched on during the 5th and 6th of December, which can directly be associated to the high NO_x, NO and NO₂ levels seen during this period.

The highest concentrations of NO and NO₂ (discounting the above episode) occurred during the winter months, when emissions tend to be higher, due to periods of cold, and still weather, which reduce pollutant dispersion.

The maximum hourly mean for NO₂ (discounting the above episode) is registered on the 11th February with a concentration of 97 µg m⁻³. Although it appears to be an elevated reading, this value still continues to be way below the hourly mean NO₂ concentrations exceedance of 200 µg m⁻³, which is the AQS objective for hourly mean NO₂.

4.2 Diffusion data

Table 4.2 shows the NO₂ diffusion tube results for 2016. Tubes were exposed in triplicate at all sites. The results shown are the means of those replicate measurements. The full dataset is shown in Appendix 4. The analyst provided diffusion tube data to two decimal places. These have been rounded to one decimal place in the table below, but are quoted as integer values in this report, in accordance with the reported uncertainty of the method.

Table 4.2 – NO₂ diffusion tube results 2016 (µg m⁻³).

Start date	End Date	Stansted North	Stansted East	Stansted South	Stansted West	Stansted 3
06/01/2016	03/02/2016	29.2	36.7	29.7	23.0	25.6
03/02/2016	02/03/2016	24.4	34.8	32.5	21.1	27.7
02/03/2016	30/03/2016	16.9	25.6	30.3	13.9	22.9
30/03/2016	27/04/2016	17.0	31.6	30.8	16.2	22.7
27/04/2016	25/05/2016	13.8	23.8	23.3	13.8	17.1
25/05/2016	23/06/2016	12.3	21.2	21.1	11.4	16.1
23/06/2016	27/07/2016	15.6	25.9	20.0	12.0	18.5
27/07/2016	25/08/2016	15.7	27.9	23.3	13.3	20.0
25/08/2016	28/09/2016	22.5	31.0	25.2	18.7	22.9
28/09/2016	26/10/2016	17.1	29.7	31.2	15.9	23.2
26/10/2016	30/11/2016	22.7	34.5	29.6	17.9	27.5
30/11/2016	04/01/2017	39.4	45.8	38.1	28.7	35.6
Mean	-	20.6	30.7	27.9	17.2	23.3
Bias adjusted	-	18.8	27.9	25.4	15.7	21.2

Two results were rejected as they were suspected to be spurious. Details of this results are shown in Table 4.3. All results considered to be “outliers”; results much lower than those of the other two co-exposed tubes.

Table 4.3 – Details of NO₂ diffusion tube result rejected.

Site	Month	Tube number	[NO ₂] (µg m ⁻³)	Reason for rejection
Stansted North	January	3	24.2	Spider and web in tube.
Stansted West	August	3	12.4	Dirt in tube from earwig (live) inside.

Across the five sites, annual mean NO₂ concentrations measured with diffusion tubes ranged from 17.2 to 30.7 µg m⁻³. At Stansted 3, where diffusion tube results could be compared directly with data from automatic monitoring, the (rounded) annual mean concentration was 23.3 µg m⁻³. This was in line with the annual mean of 21 µg m⁻³ obtained using the reference technique (the chemiluminescence analyser).

Diffusion tubes are affected by several artefacts, which can cause them to under-read or over-read with respect to the reference technique. It has therefore become common practice to calculate and apply a “bias adjustment factor” to annual mean NO₂ concentrations measured by diffusion tubes, using co-located diffusion tube and automatic analyser measurements. This bias adjustment factor is calculated as the ratio of the automatic analyser result to the diffusion tube result. This factor can then be used to correct the annual means measured at the other monitoring locations. The bias adjustment factor was calculated using unrounded values from all months. On this basis, the bias adjustment factor was calculated to be 0.91.

The annual mean values from the other four diffusion tube sites were all corrected using the same bias adjustment factor.

Please note:

- i. Only the annual mean concentration (not individual monthly values) should be adjusted in this way. This is because diffusion tube bias can vary considerably from month to month due to meteorological and other factors.
- ii. Even after application of a bias adjustment factor, diffusion tube measurements remain indicative only.

4.3 Comparison with air quality objective

Details of the UK air quality standards and objectives specified by Defra are provided in Appendix 1.

The AQS objective for hourly mean NO₂ concentration is 200 µg m⁻³ which may be exceeded up to 18 times per calendar year. At Stansted 3 there were no recorded hourly mean NO₂ concentrations in excess of the hourly mean AQS objective of 200 µg m⁻³, the site therefore met the AQS objective for this pollutant. At Stansted 4 there were ten recorded hourly means NO₂ concentrations in excess of the hourly mean AQS objective of 200 µg m⁻³, however this was below the maximum of 18 exceedances allowed each year, therefore meeting the AQS objective for this pollutant.

The annual mean NO₂ concentrations measured at Stansted 3 and Stansted 4 during 2016 were 21 µg m⁻³ and 19 µg m⁻³ respectively. Both automatic sites were therefore within the annual mean AQS objective for NO₂ of 40 µg m⁻³ for protection of human health and the objective of 30 µg m⁻³ for protection of vegetation and ecosystems.

The bias-adjusted annual mean NO₂ concentrations measured at the five diffusion tube sites were all well within the AQS objective of 40 µg m⁻³.

PM₁₀ was measured at Stansted 3 only. After correction of the data using the King's College VCM, the number of days when the 24-hour mean was in excess of 50 µg m⁻³ was one. This is well within the maximum permitted number of exceedances (35), therefore this site met the AQS objective for 24-hour mean PM₁₀.

4.4 Temporal variations in pollutant concentrations

Figure 4.3 and 4.4 shows the average NO_x, NO, NO₂ and PM₁₀ (VCM corrected) concentrations during 2016 at Stansted 3 and Stansted 4 for each hour on a given day (top), any hour (bottom left), each month (bottom centre) and any day (Bottom right).

4.41 Seasonal variation

Figure 4.3 shows different temporal averages of NO_x, NO, NO₂ and PM₁₀ recorded at Stansted 3. This graph shows elevated concentration peaks for all three pollutants in December, and a peak in PM concentration for May. NO and NO₂ also both showed increases in winter, a pattern that would be expected during periods of cold weather and relatively low wind speeds.

Figure 4.4 shows different temporal averages of NO_x, NO and NO₂ recorded at Stansted 4. This graph shows increases in winter, a pattern that would be expected during periods of cold weather and relatively low wind speeds. The elevated periods seen at Stansted 3 in December are equally pronounced at Stansted 4, indicating a more regional coverage of elevated data. The elevated periods at Stansted 4 were largely down to pollution episodes registered across the UK. This is explained in further detail below.

The historic Air Quality Index data presented at Defra's UK-Air website⁹ show air quality index bands that go from 2 (Low) to 10 (Very High) for most of the UK regions on the 30th of November, 20th January, 8th of May and during three days in March (11th, 12th and 13th). March and December 2016 also appear to be months where the monthly means (hourly measured) for PM₁₀ are higher in most of the monitoring stations across the UK¹⁰.

Outbreaks of high PM air pollution were identified in March 2016, occurring during the same periods of days as mentioned above (March 11th, 12th, 13th). Calm conditions contributed to a poor dispersal of local traffic emissions as shown in figure 4.5 below.

Figure 4.3 – Average NO_x , NO , NO_2 and PM_{10} (VCM corrected) concentrations for each hour on a given day (top), any hour (bottom left), each month (bottom centre) and any day (bottom right) at Stansted 3, 2016.

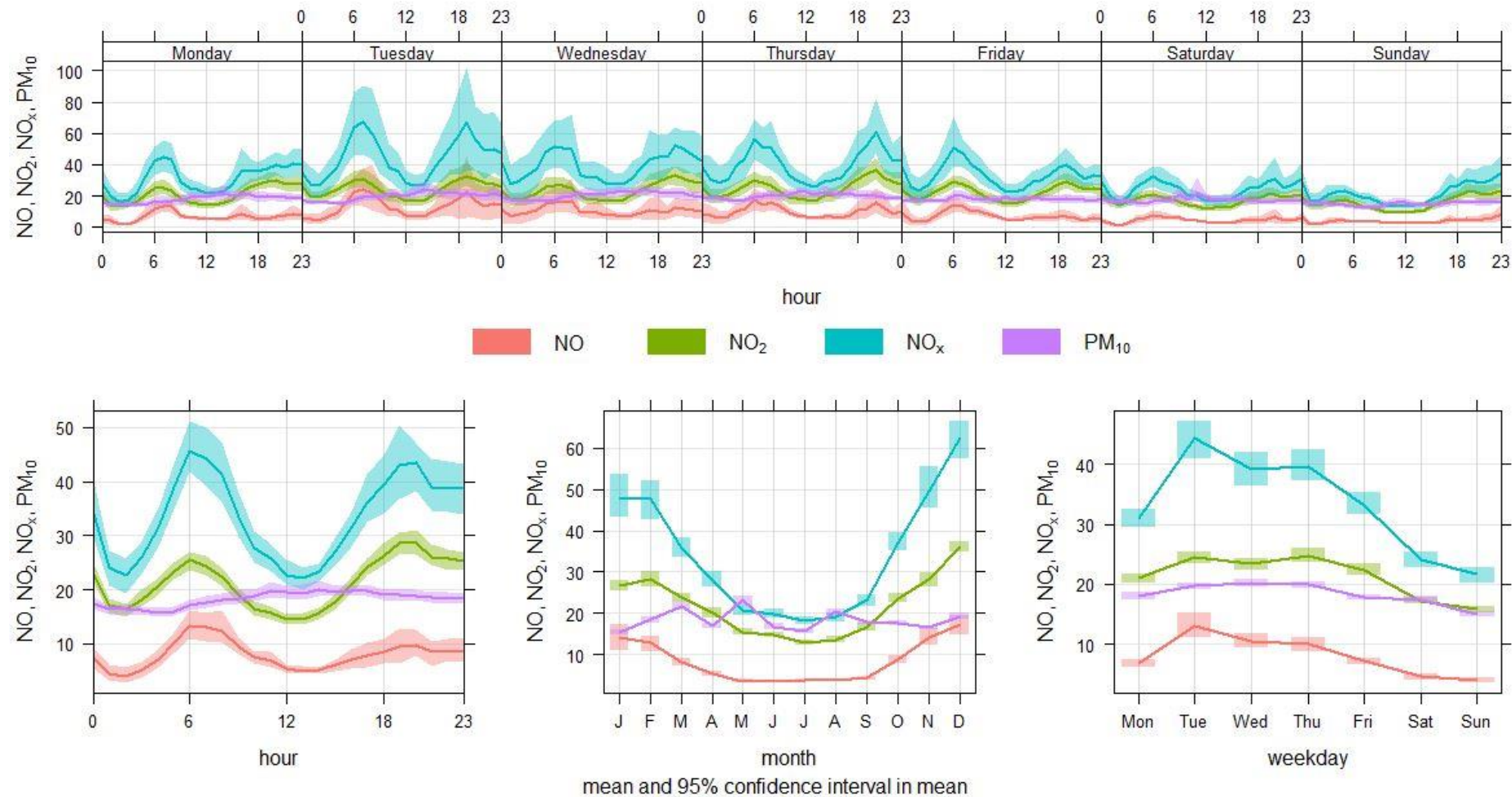


Figure 4.4 – Average NO_x , NO , NO_2 concentrations for each hour on a given day (top), any hour (bottom left), each month (bottom centre) and any day (bottom right) at Stansted 4, 2016.

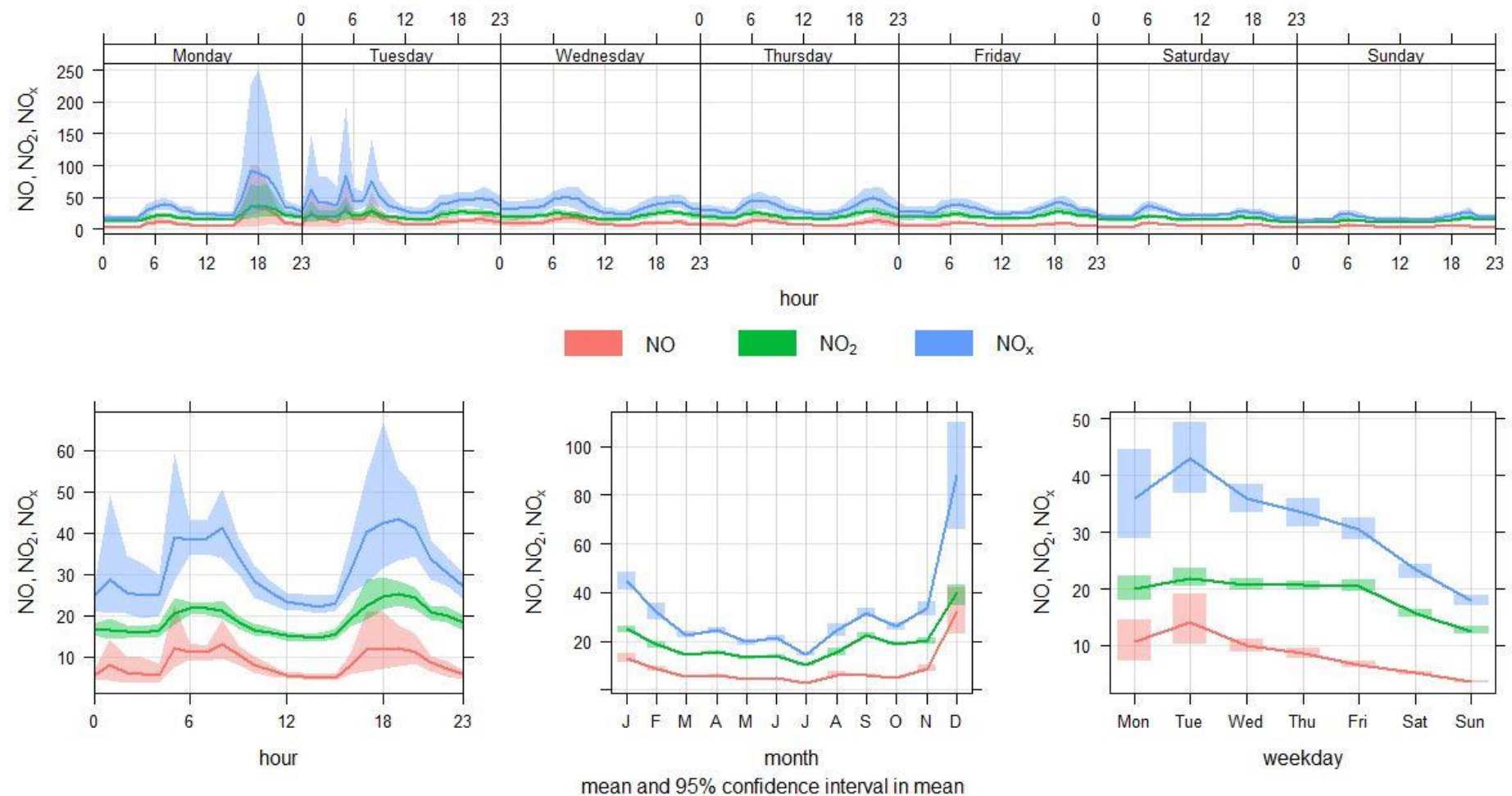


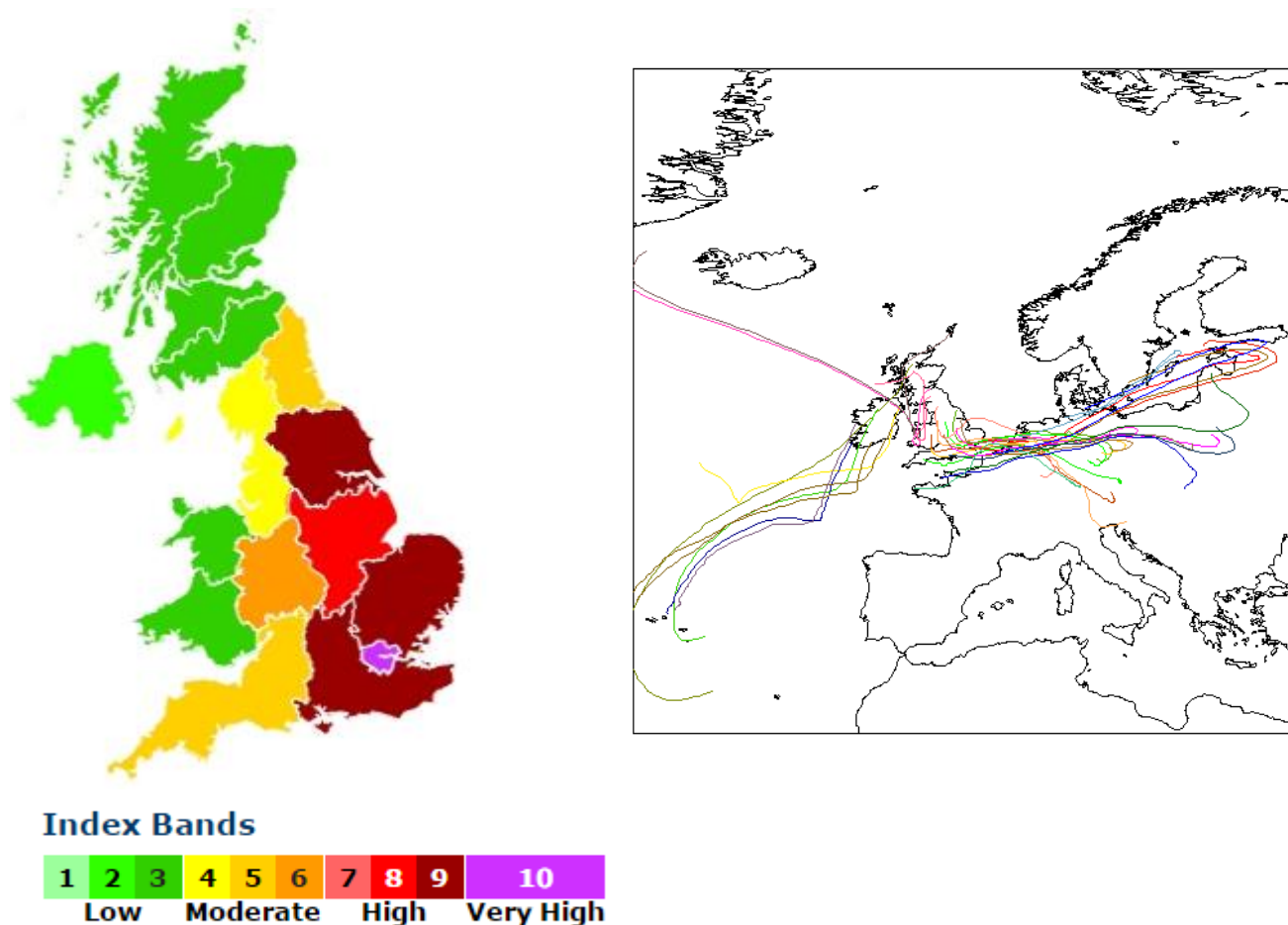
Figure 4.5 - Air quality Index and air mass back trajectories calculated for the 12th March 2016

Figure 4.5 shows an example of one of these high air pollution episodes. The region of Greater London has an index band of 10 (Very High), with surrounding regions showing index bands of 9 (High). The air mass trajectories calculated using the Hybrid Single Particle Lagrangian Integrated Trajectory Model (HYSPLIT)¹² for the same day, clearly show the displacement of air masses from Eastern Europe towards the U.K.

4.4.1 Diurnal variation

Bottom left graphs in figures 4.3 and 4.4 show diurnal variation in pollutant concentrations, as measured at Stansted 3 and Stansted 4.

Both sites showed typical urban area daily patterns for NO and NO₂. Pronounced peaks can be seen for these pollutants during the mornings, corresponding to rush hour traffic at around 06:00. Concentrations tend to decrease during the middle of the day, with a broader evening rush-hour peak in NO₂ building up from early afternoon. At Stansted 4 the afternoon peak in NO₂ was of the same order of magnitude compared to the morning peak and then stayed at elevated levels for much of the night. NO showed a much smaller peak in the afternoons. This is to be expected as concentrations of oxidising agents in the atmosphere (e.g. ozone) tend to increase in the afternoon, leading to enhanced oxidation of NO to NO₂. NO at Stansted 3 followed a similar pattern to that of Stansted 4, however NO₂ at Stansted 3 was of a much higher order of magnitude in the afternoons, staying at increased levels for much of the night.

PM₁₀ was only measured at Stansted 3. There was a steady increase in average PM₁₀ concentrations throughout the day, similar to the pattern observed in 2015. This can be attributed to two factors, the first being emissions of primary particulate matter. The second relates to the emissions of sulphur dioxide and NO_x that can react with other chemicals in the atmosphere to form secondary sulphate and nitrate particles, resulting in elevated levels of PM₁₀.

4.4.2 Weekly Variation

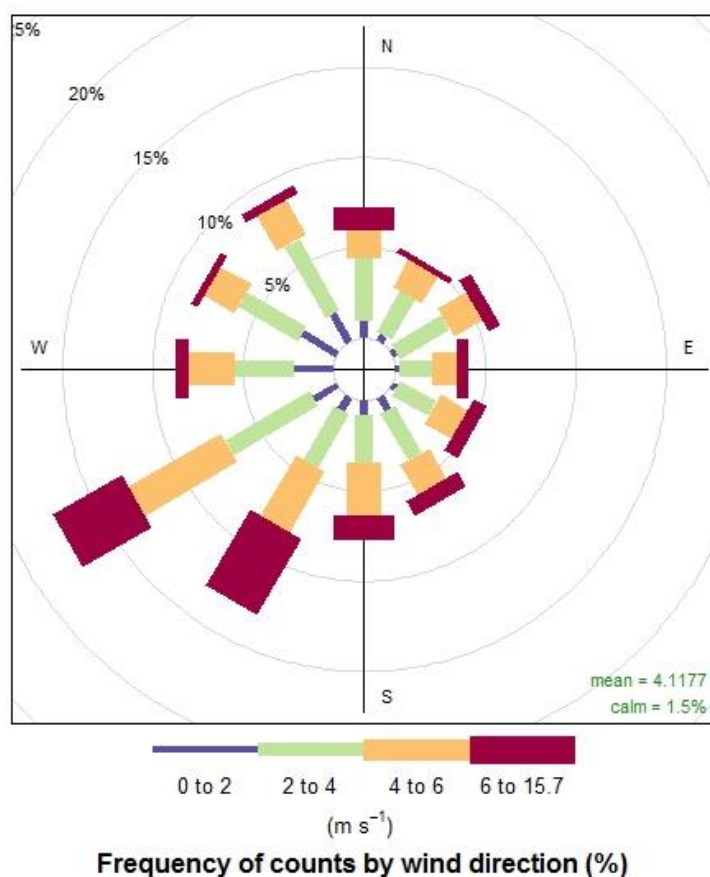
Analysis of each pollutant across weekly variation show similar diurnal trends occur across each week day. Early morning and late afternoon NO₂ peaks coincide with rush hour traffic and in general are much more elongated on the earlier days of the week (Monday and Tuesday), and show a quicker peak and drop of NO₂ during later week days and weekends. PM shows a similar (yet less pronounced) trend of increasing steadily during week days and decreasing towards the later week and during weekends.

4.5 Source investigation

In order to investigate the possible sources of air pollution that were monitored at Stansted airport, meteorological data were used to add a directional component to the air pollutant concentrations. Wind speed and direction data was gathered using data gathered from the National Oceanic and Atmospheric Administration (NOAA) meteorological database. The QA/QC procedures for checking of these data are not known.

Figure 4.6 shows the 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 direction was 195 ° to 230 °, what shows that the prevailing wind direction was clearly from the south west. Each “spoke” is divided into coloured sections representing wind speed intervals of 2 m s⁻¹ as shown by the scale bar in the plot, followed by a final interval of 9.7 m s⁻¹. The mean wind speed was 4.12 m s⁻¹. The maximum measured wind speed was 15.7 m s⁻¹. Some of the highest wind speeds occurred during February and March 2016.

Figure 4.6 - Wind rose showing the wind speeds and directions from the on-airfield anemometer at Stansted Airport in 2016.



Figures 4.7 to 4.11 show bivariate plots of hourly mean concentrations of NO, NO₂, PM₁₀ at Stansted 3 and Stansted 4, against the corresponding wind speed and wind direction. These plots should be interpreted as follows.

- The wind direction is indicated as in the wind rose above (north, south, east and west are indicated).
- The wind speed is indicated by the distance from the centre of the plot: the concentric circles indicate wind speeds in intervals of 5 ms⁻¹.
- The pollutant concentration is indicated by the colour (as shown in the scale bars).

These plots therefore show how pollutant concentration varies with wind direction and wind speed. They do not depict distance from the monitoring location. They are best interpreted with reference to the map in Figure 2.1.

Figure 4.7 – Pollution rose for NO at Stansted 3 in 2016.

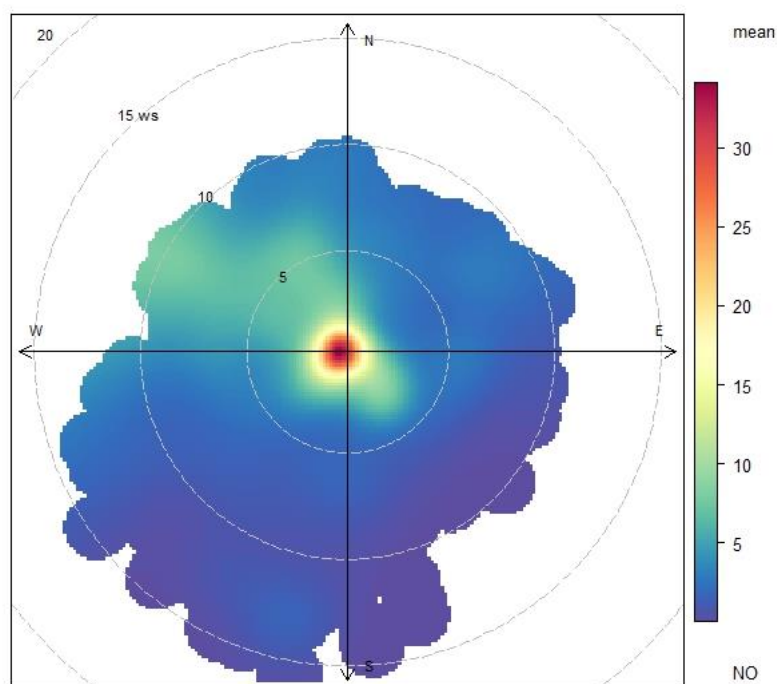


Figure 4.7 shows, as in previous years, that the highest NO concentrations at Stansted 3 were recorded at very low wind speeds. In the case of primary pollutants such as NO, this typically suggests that the site was dominated by emission sources close by. However, minor sources can also be detected to the north west of the monitoring location at higher wind speeds, indicated by the paler blue traces between 270 ° and 300 °. NO concentrations caught at higher wind speeds, usually suggest that main pollution sources are located further away.

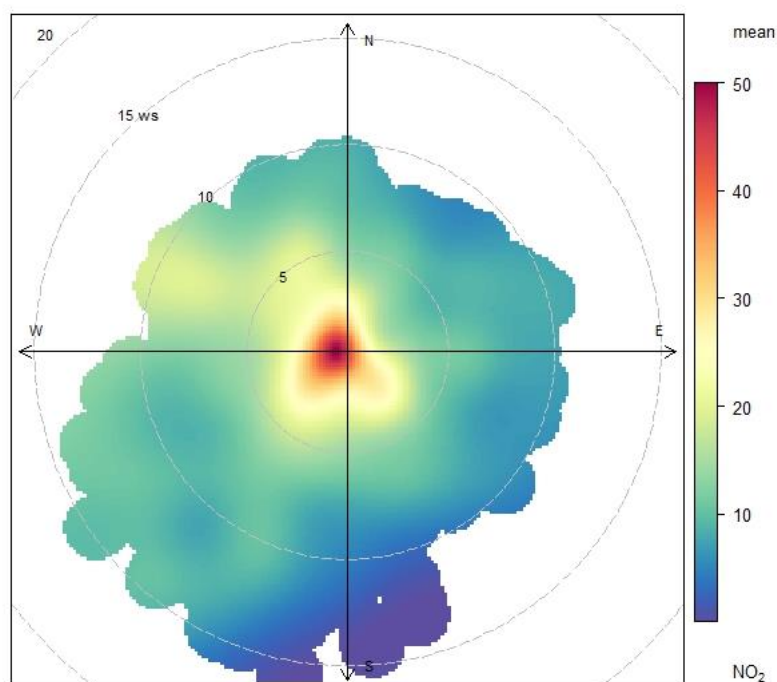
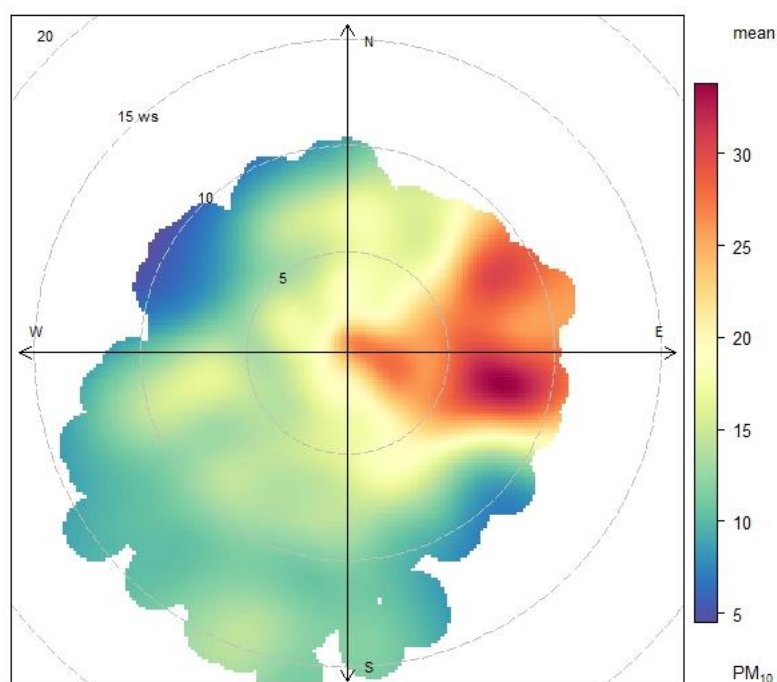
Figure 4.8 – Pollution rose for NO₂ at Stansted 3 in 2016.

Figure 4.8 shows the main source of NO₂ to appear close to the monitoring site, with the highest concentrations occurring at low wind speeds. At higher wind speeds, one main source seems to emerge, from North West of the monitoring location, these occurring at low and moderate wind speeds (around 5-10 m s⁻¹). These might be the result of activities around the airport terminal buildings. A source at increased wind speeds (around 10-15 m s⁻¹) also lies to the south-west. This may be due to emissions from roads such as the A120 which lies in a south/south-west direction of the site. Part of this NO₂ may be created by the reaction between local emissions of NO with ozone, travelling at increased wind speeds to create a faster reaction.

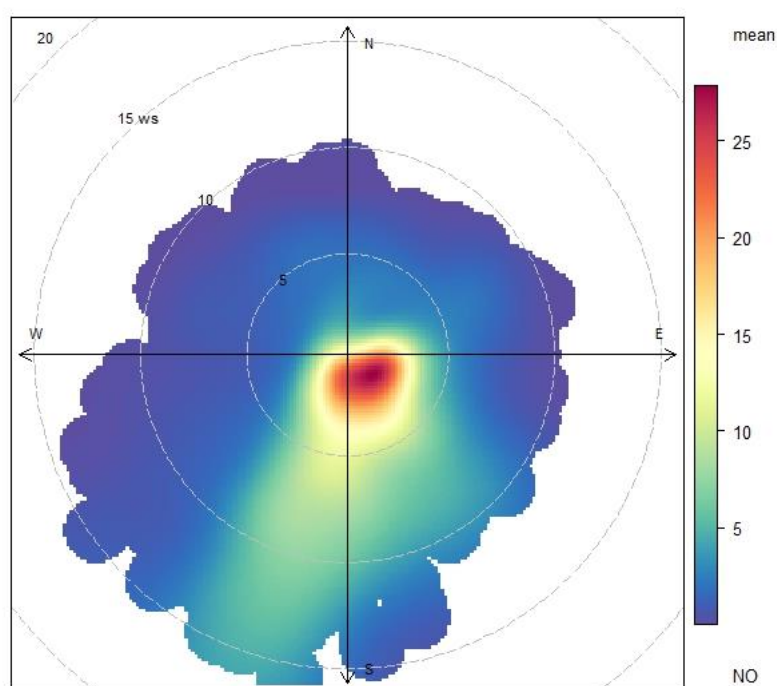
Figure 4.9 - Pollution rose for VCM-corrected PM₁₀ at Stansted 3 in 2016.

PM₁₀ concentrations follow a similar pattern in relation to last year. In both 2015 and 2016, PM₁₀ highest concentrations seem to be associated to higher wind speeds.

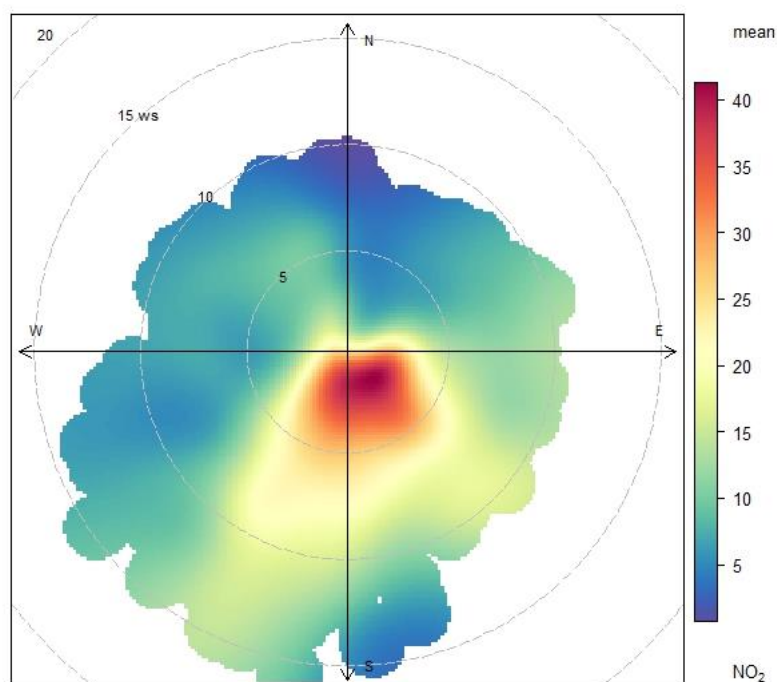
High PM₁₀ concentrations occurred under unsettled conditions (wind speeds above 5 m s⁻¹) further from the monitoring station to the east possibly due to agricultural activity. Figure 4.9 show that higher concentrations originate at higher wind speeds to the east of the monitoring location, much alike 2015. Moderate PM₁₀ concentrations were found close to the monitoring site under low to moderate wind speeds (0-5 m s⁻¹) for wind directions between 0-180°, and at higher wind speeds (10-15 m s⁻¹) to the South-West. These could be related to a source from the M11 motorway, airport and surrounding roads.

The UK-wide pollution/trans-boundary episodes associated previously mentioned on this report and some agricultural activity related to harvesting may help explain high PM₁₀ concentrations at higher wind speeds coming from several wind directions. This is further supported by the only daily exceedance in PM₁₀ originating from the 12th March 2016, which coincided with the previously mentioned UK-wide pollution event over this day.

Figure 4.10- Pollution rose for NO at Stansted 4 in 2016.



As for Stansted 3, Stansted 4 pollution rose for NO shows that the highest concentrations also occurred at low wind speeds, indicating that the main pollution sources were close to the monitoring site. It can also be clearly seen, as in previous years, the contribution of airport's runway and main terminal (coming from the South-West) to the increase of the registered NO concentrations.

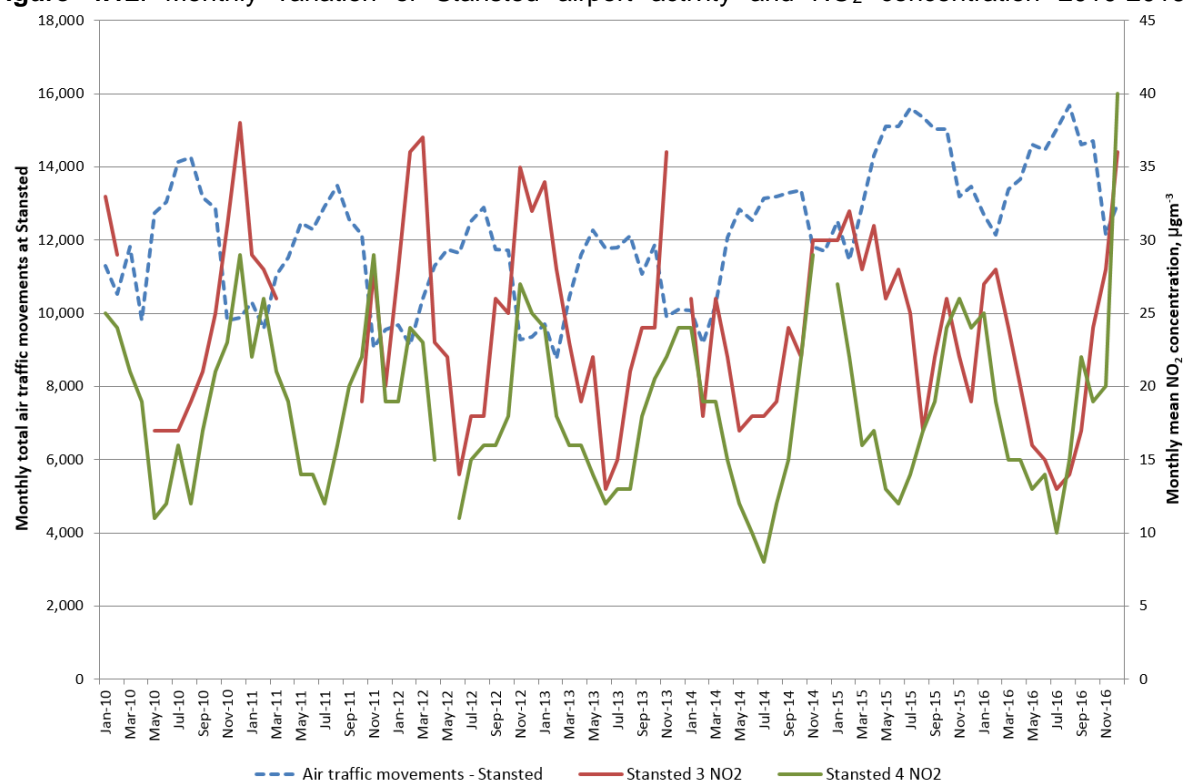
Figure 4.11- Pollution rose for NO₂ at Stansted 4 in 2016.

The NO₂ pollution rose (Figure 4.11) also shows evidence of sources close to the monitoring site. However, at higher wind speeds there is a stronger signature from the south east and south west – the direction of the main airport terminal, runway and surrounding access roads.

4.6 Relationship with airport activity

The data presented in the sections above suggest that the airport is a major source of oxides of nitrogen and, to a lesser degree, of PM₁₀. In this section, the potential for correlation between airport activity and pollutant concentrations is investigated by comparing pollutant concentrations with aircraft movements at Stansted.

Figure 4.12 shows monthly statistics for the number of air traffic movements (ATMs) during the years 2010 to 2016. Also shown (plotted against the secondary y-axis) are monthly mean NO₂ concentrations at Stansted 3 and Stansted 4.

Figure 4.12: Monthly variation of Stansted airport activity and NO₂ concentration 2010-2016.

As seen last year, there is a distinct seasonal pattern indicating high air traffic 'activity' in the summer months (July and August) and lower in the winter. Monthly mean NO₂ and NO concentrations showed the opposite seasonal pattern, being higher in the winter months rather than the summer. This is a typical seasonal pattern for an urban area.

The monthly peak at Stansted 4 in December 2016 is elevated due to the operation of the generator for 18 hours on the 5th/6th of December. If this data were to be discounted the monthly mean at this site would be 32µg m³ which is within the scope of the expected responses.

The emissions from the airport and its surrounding roads are a significant contributor to the ambient pollutant concentrations, as illustrated in the pollution rose plots in section 4.5. However, this simple analysis of air traffic movements indicates that seasonal variation in pollutant concentrations (i.e. the periods of high and low concentration) at Stansted are influenced to a greater extent by general meteorological factors than by air traffic movement.

4.7 Periods of elevated pollutant concentration

This section reviews the most significant periods of high air pollution concentrations for the whole year. It is important to stress that, despite there being some periods when pollutant concentrations exceeded the applicable air quality objectives, these were attributable to specific external sources.

As already explained in section 4.4.1, the historic Air Quality Index data presented at the Department of Environment, Food & Rural Affairs (Defra) UK-Air website⁹ shows air quality index bands that go from 2 (Low) to 10 (Very High) for most of the UK regions during 2 days in March (11th and 12th), November 30th and the 8th of May. These pollution episodes are consistent with the period of elevated PM and NO_x concentrations measured in the two monitoring stations at Stansted. Furthermore, Newspaper articles (ex: The Independent¹³ and The Guardian¹¹) corroborate these increased index readings on May 8th and : *"Strong south-easterly winds blowing in air from the continent could lead to moderate levels of pollution tomorrow and over the weekend in parts of England and Wales."*

Two other small regional pollution episodes were also widely identified in 2016. These help explain elevated measurements of NO_x and PM registered at the Stansted sites:

1- Period of 18th-19th January (NO_x and PM):

This event was mainly confined to the South-East and Midlands area. A local build-up of particulate and NO_x was recorded due to calm climatic conditions (corroborated by low wind speeds recorded from the onsite anemometer).

2- Period from 29th October to 30th October (PM):

The Air Quality Index data for the London region shows moderate/high Index bands during this period. Again, settled conditions coupled with winds coming from the continent allowed for a build-up of local particulates. This episode was further contributed by the Hindu Festival of Diwali and Guy Fawkes Night falling in close proximity, both of which involve fireworks and contain high amounts of particulates.

4.7.1 Nitrogen oxides (NO_x)

At Stansted 3, the highest hourly mean concentration of NO₂ was 129 µg m⁻³. There were no periods when hourly mean NO₂ concentrations exceeded 200 µg m⁻³, which is the AQS objective for hourly mean NO₂. The lower threshold of the Defra “Moderate” air quality band is 201 µg m⁻³ for hourly means. Therefore NO₂ levels at Stansted 3 stayed within the Defra “Low” band for the whole year and there were no periods of high NO₂ at Stansted 3.

At Stansted 4, there were ten hourly mean NO₂ concentrations exceeding 200 µg m⁻³. As previously explained in this report, these can all be attributed to the periods at the beginning on December (5th and 6th) when a generator was turned on. Therefore, excluding these explained readings and for the rest of the year, NO₂ levels at Stansted 4 also stayed within the Defra “Low” band.

4.7.2 Particulate matter (PM₁₀)

At Stansted 3, there was one day where daily mean PM₁₀ (after VCM correction) exceeded the AQS objective of 50 µg m⁻³.

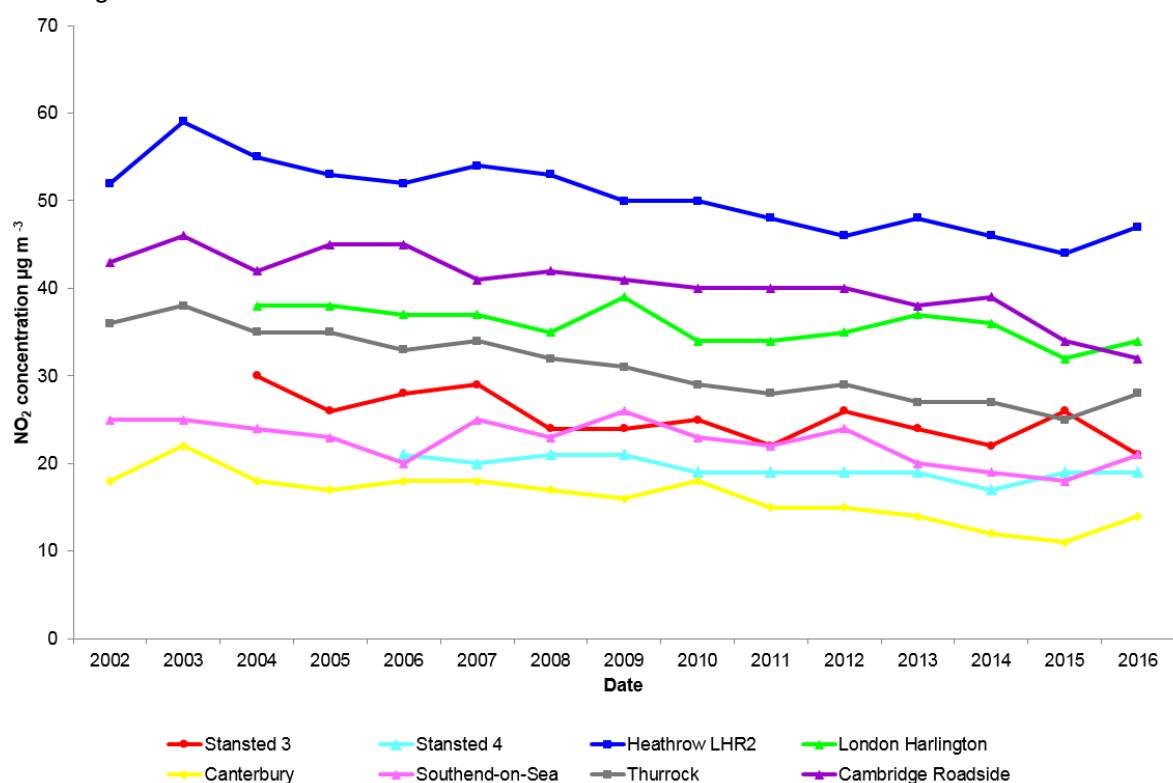
The daily mean PM₁₀ was exceeded on the 12th of March. This day was within the outbreak of high air pollution that has been previously mentioned and identified in 2016. Excluding this atypical high pollution episode, the registered PM₁₀ daily mean did not exceed the AQS objective of 50 µg m⁻³.

4.8 Comparison with other UK sites

Figure 4.14 provides a comparison between annual mean pollutant NO₂ levels at the Stansted sites and corresponding measurements made at six other monitoring stations (2001 to 2015). Five of these are other AURN monitoring sites in the south and east of England and the sixth is in the vicinity of a major airport. These sites are listed below.

- Canterbury – an urban background site approximately 1.5 kilometres from the centre of Canterbury.
- Thurrock – an urban background site in the town of Thurrock, Essex, approximately 35 metres from the kerb of a busy road.
- Cambridge Roadside – roadside site in the city of Cambridge, where vehicle emissions are the major pollution source.
- Southend-on-Sea – an urban background site situated in an urban public park in a residential area.
- London Harlington – a background monitoring station approximately 1 km north east of the perimeter of Heathrow airport.
- LHR2 – a long-term airside monitoring station at Heathrow, 180 metres north of runway 27R and north east of the central terminal area. This site is not part of the AURN, but data are made available to the public through the Heathrow Airwatch website¹⁴.

Figure 4.13: Annual mean trend NO₂ concentrations at Stansted 3, Stansted 4 and other regional monitoring sites.



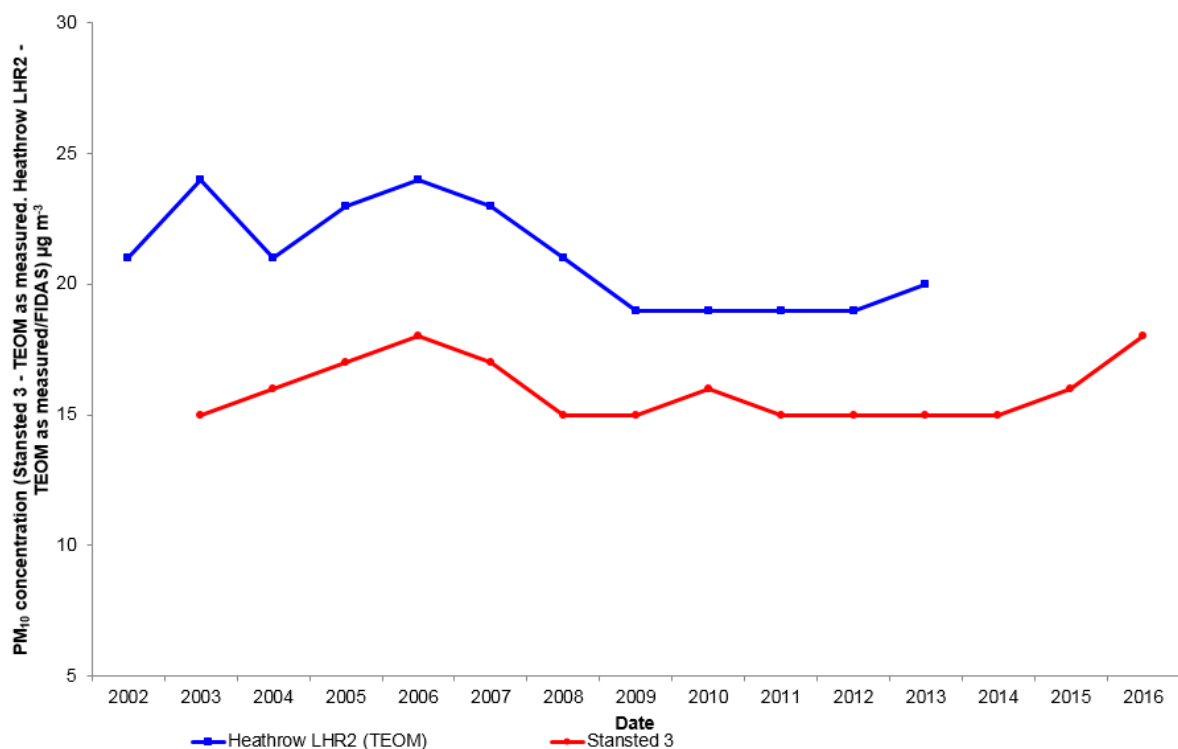
In recent years, annual mean concentrations of NO₂ at the Stansted sites have resembled urban background concentrations measured at similar sites. For example, the concentrations seen at Stansted 3 and Stansted 4 are comparable with those at Southend-on-Sea and Thurrock, although they are slightly higher than those reported from Canterbury.

Both Stansted sites have consistently reported lower concentrations than those recorded at London Harlington, Heathrow LHR2, and Cambridge Roadside. Annual mean NO₂ concentrations at Stansted 3 have exhibited a slight general decrease from 2004-2014, followed by a slight increase in 2015. In 2016 the annual mean concentrations at Stansted 3 have decreased considerably in relation to 2015, and have remained constant at Stansted 4 in comparison to 2015.

Cambridge Roadside, located at the kerb of a busy road in the nearby city of Cambridge, is included as an example of a site showing constant high annual mean NO₂ concentrations. The site (like many other urban roadside sites in the UK) has consistently recorded annual mean NO₂ concentrations in excess of 32 µg m⁻³, substantially higher than those observed at either of the Stansted sites.

The data collected in 2016 shows that there is a slight general increase of NO₂ concentrations in most of the analysed monitoring sites. Only Stansted 3, Stansted 4 and Cambridge Roadside seem to escape from this tendency, having registered a small decrease of NO₂ concentrations at Stansted 3 and Cambridge Roadside and been constant at Stansted4 in comparison with the results from 2015.

Figure 4.14 shows annual mean PM₁₀ concentrations at Stansted 3 and the London Heathrow site LHR2. These are “as measured” data without VCM correction.

Figure 4.14: Annual mean PM₁₀ concentrations at Stansted 3 and Heathrow LHR2.

Concentrations of PM₁₀ at Stansted 3 have risen in comparison to 2015, as was the case in 2015 compared to 2014. It is however, not possible to make a direct comparison between Stansted 3 and LHR2 for data from 2015-2016 due to different monitoring techniques. Since 2004, the two lines have shown a very similar pattern from one year to the next. Over the past three years this has been slightly different, with Heathrow having registered a decrease on PM₁₀ annual mean concentration, and in the past two years Stansted 3 registering an increase. PM₁₀ annual mean concentration at Stansted 3 continue to present similar values since 2007. It is however not possible to make direct comparisons between data for both sites from 2015 because a new PALAS Fidas PM instrument was installed at LHR2, the Fidas uses an optical light scattering technique. Although a Fidas instrument was installed at both Stansted 3 and Stansted 4 at the end of 2016, a direct comparison will only be able to be made following a whole annual average that will be received in 2017. This has meant comparisons would be made between two instruments for 2016 that have different measurement techniques.

5 Conclusions

The following conclusions have been drawn from the results of air quality monitoring at Stansted Airport during 2016.

1. The data capture target of least 85 % was achieved for all the measured pollutants at Stansted 3 and Stansted 4.
2. Stansted 3 and Stansted 4 met the AQS objectives for 1 hour mean NO₂ concentrations.
3. All five NO₂ diffusion tube sites met the AQS annual mean objective for this pollutant.
4. Stansted 3 met the AQS objectives for daily mean and annual mean PM₁₀ concentration.
5. NO and NO₂ concentrations were higher during the winter months at both Stansted 3 and Stansted 4. This is a typical pattern for urban sites. PM₁₀ levels showed a peak in March, May and December.
6. Concentrations of NO and NO₂ followed a characteristic diurnal pattern, with peaks coinciding with the morning and evening rush hour periods. PM₁₀ concentrations showed no marked diurnal variation.
7. Bivariate plots of pollutant concentrations against meteorological data indicated that sources of NO_x were located close to the monitoring sites and were probably associated with the airport. PM₁₀ analysis seems to indicate the presence of several sources for this pollutant (both local and regional), with peaks occurring at unsettled conditions, but show a similar trend to those in 2015.
8. Annual mean concentrations of NO₂ at Stansted 3 and Stansted 4 were similar to those measured at similar urban background sites such as Southend-on-Sea and Thurrock. Annual PM₁₀ means at Stansted 3 have slightly increased in comparison with last year's measurements, but present similar values since 2006.

6 Acknowledgements

Ricardo Energy & Environment would like to thank Stansted Airport Ltd, particularly Duncan Smith and Liz Brassington for assistance with this monitoring study.

7 References

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Appendices

Appendix 1: Air Quality objectives and index bands.

Appendix 2: Monitoring apparatus and techniques.

Appendix 3: Quality assurance and Quality control.

Appendix 4: NO₂ diffusion tubes (full dataset).

Appendix 1 - Air Quality objectives and index bands

Table A1.1: UK air quality objectives for protection of human health, July 2007.

Pollutant	Air Quality objective		Date to be achieved by
	Concentration	Measured as	
Benzene All authorities	16.25 $\mu\text{g m}^{-3}$	Running annual mean	31/12/2003
England and Wales only	5.00 $\mu\text{g m}^{-3}$	Annual mean	31/12/2010
Scotland and Northern Ireland	3.25 $\mu\text{g m}^{-3}$	Running annual mean	31/12/2010
1,3-Butadiene	2.25 $\mu\text{g m}^{-3}$	Running annual mean	31/12/2003
Carbon monoxide England, Wales and Northern Ireland	10.0 mg m^{-3}	Maximum daily running 8-hour mean	31/12/2003
Scotland	10.0 mg m^{-3}	Running 8-hour mean	31/12/2003
Lead	0.5 $\mu\text{g m}^{-3}$	Annual mean	31/12/2004
	0.25 $\mu\text{g m}^{-3}$	Annual mean	31/12/2008
Nitrogen dioxide	200 $\mu\text{g m}^{-3}$ not to be exceeded more than 18 times a year	1-hour mean	31/12/2005
	40 $\mu\text{g m}^{-3}$	Annual mean	31/12/2005
Particles (PM₁₀) (gravimetric) All authorities	50 $\mu\text{g m}^{-3}$, not to be exceeded more than 35 times a year	24-hour mean	31/12/2004
	40 $\mu\text{g m}^{-3}$	Annual mean	31/12/2004
Scotland	50 $\mu\text{g m}^{-3}$, not to be exceeded more than 7 times a year	24-hour mean	31/12/2010
	18 $\mu\text{g m}^{-3}$	Annual mean	31/12/2010
Particles (PM_{2.5}) (gravimetric)* All authorities	25 $\mu\text{g m}^{-3}$ (target)	Annual mean	2020
	15% cut in urban background exposure	Annual mean	2010-2020
Scotland only	12 $\mu\text{g m}^{-3}$ (limit)	Annual mean	2020
Sulphur dioxide	350 $\mu\text{g m}^{-3}$, not to be exceeded more than 24 times a year	1-hour mean	31/12/2004

	125 $\mu\text{g m}^{-3}$, not to be exceeded more than 3 times a year	24-hour mean	31/12/2004
	266 $\mu\text{g m}^{-3}$, not to be exceeded more than 35 times a year	15-minute mean	31/12/2005
PAH*	0.25 ng m^{-3}	Annual mean	31/12/2010
Ozone*	100 $\mu\text{g m}^{-3}$ not to be exceeded more than 10 times a year	8-hour mean	31/12/2005

* Not included in regulations.

Table A1.2: UK air quality objectives for protection of vegetation and ecosystems, July 2007.

Pollutant	Air Quality objective		Date to be achieved by
	Concentration	Measured as	
Nitrogen oxides measured as NO_2	30 $\mu\text{g m}^{-3}$	Annual mean	31st December 2000
Sulphur dioxide	20 $\mu\text{g m}^{-3}$	Annual mean	31st December 2000
	20 $\mu\text{g m}^{-3}$	Winter average (October to March)	31st December 2000
Ozone	18 $\mu\text{g m}^{-3}$	AOT40 ⁺ , calculated from 1-hour values May to July. Mean of 5 years, starting 2010	1st January 2010

+ AOT40 is the sum of the differences between hourly concentrations greater than 80 $\mu\text{g m}^{-3}$ (= 40 ppb) and 80 $\mu\text{g m}^{-3}$ over a given period using only 1-hour averages measured between 08:00 and 20:00.

Defra Air Pollution bands and index values

Table A1.3: Air pollution bandings and descriptions.

Band	Index	Health descriptor
Low	1 to 3	Effects are unlikely to be noticed even by individuals who know they are sensitive to air pollutants.
Moderate	4 to 6	Mild effects, unlikely to require action, may be noticed amongst sensitive individuals.
High	7 to 9	Significant effects may be noticed by sensitive individuals and action to avoid or reduce these effects may be needed (e.g. reducing exposure by spending less time in polluted areas outdoors). Asthmatics will find that their 'reliever' inhaler is likely to reverse the effects on the lung.
Very High	10	The effects on sensitive individuals described for 'High' levels of pollution may worsen.

Table A1.4: Air pollution bandings and descriptions.

Band	Index	O ₃	NO ₂	SO ₂	PM _{2.5}	PM ₁₀
		Daily max 8-hour mean (µg m ⁻³)*	Hourly mean (µg m ⁻³)	15 minute mean (µg m ⁻³)	24 hour mean (µg m ⁻³)	24 hour mean (µg m ⁻³)
Low	1	0-33	0-67	0-88	0-11	0-16
	2	34-66	68-134	89-177	12-23	17-33
	3	67-100	135-200	178-266	24-35	34-50
Moderate	4	101-120	201-267	267-354	36-41	51-58
	5	121-140	268-334	355-443	42-47	59-66
	6	141-160	335-400	444-532	48-53	67-75
High	7	161-187	401-467	533-710	54-58	76-83
	8	188-213	468-534	711-887	59-64	84-91
	9	214-240	535-600	888-1064	65-70	92-100
Very High	10	241 or more	601 or more	1065 or more	71 or more	101 or more

Appendix 2 – Monitoring apparatus and techniques

Monitoring equipment

The following continuous monitoring methods were used at the Stansted air quality monitoring stations:

- NO, NO₂: chemiluminescence with ozone.
- PM₁₀: tapered element oscillating microbalance (TEOM) and Fine Dust Analysis Systems (FIDAS).

These methods were selected in order to provide real-time data. The chemiluminescence analyser is the European reference method for ambient NO₂ monitoring.

Each analyser provides a continuous output, proportional to the pollutant concentration. This output is recorded and stored every 10 seconds, and averaged to 15 minute average values by the on-site data logger. This logger is connected to a modem and interrogated twice daily, by telephone, to download the data to Ricardo Energy & Environment. The data are then converted to concentration units and averaged to hourly mean concentrations.

The chemiluminescence analysers for NO_x are equipped with an automatic calibration system, which is triggered daily under the control of the data logger. Fully certificated calibration gas cylinders are also used at each site for manual calibration.

The PM₁₀ TEOM analyser cannot be calibrated in the same way as the gas analysers and these data are scaled using the results of 6-monthly checks. In these checks, the flow rate through the analyser is measured and the mass determination checked with pre-weighed filters.

The PM₁₀ monitoring data recorded by TEOM monitors were corrected with the King's College Volatile Correction Model (VCM)⁷. This online tool allows TEOM measurements to be corrected for the loss of volatile components of particulate matter that occur due to the high sampling temperatures employed by this instrument. The resulting corrected measurements have been demonstrated as equivalent to the gravimetric reference equivalent.

The VCM works by using the volatile particulate matter measurements provided by nearby FDMS (Filter Dynamic Measurement System) instruments (within 130 km) to assess the loss of PM₁₀ from the TEOM; this value is then added back onto the TEOM measurements.

The FIDAS unit employs a white light LED light scatter method that offers additional information on both particle size distribution from 0.18 to 30 microns (PM₁, PM_{2.5}, PM₄, PM₁₀ and Total Suspended Particles (TSP)).

Method

The following data are required as inputs to the VCM:

- Daily or hourly average temperatures
- Daily or hourly pressures
- Daily or hourly TEOM concentrations (µg m⁻³)
- Daily or hourly FDMS purge measurements (µg m⁻³)

The correction generated by the VCM is specific to that geographical location, so an exact location of the TEOM instrument is therefore required.

All of the air quality monitoring equipment at both sites is housed in purpose-built enclosures.

The native units of the analysers are volumetric (e.g. ppb). Conversion factors from volumetric to mass concentration measurement for gaseous pollutants are provided below:

- NO 1 ppb = 1.25 µg m⁻³
- NO₂ 1 ppb = 1.91 µg m⁻³

In this report, the mass concentration of NO_x has been calculated as follows:

$$\text{NO}_x \text{ } \mu\text{g m}^{-3} = (\text{NO ppb} + \text{NO}_2 \text{ ppb}) \times 1.91.$$

This complies with the requirements of the Air Quality Directive¹ and is also the convention generally adopted in air quality modelling.

Appendix 3 – Quality assurance and quality control

Ricardo Energy & Environment operates air quality monitoring stations within a tightly controlled and documented quality assurance and quality control (QA/QC) system. These procedures are documented in the AURN QA/QC manual⁸.

Elements covered within this system include: definition of monitoring objectives, equipment selection, site selection, protocols for instrument operation calibration, service and maintenance, integrity of calibration gas standards, data review, scrutiny and validation.

All gas calibration standards used for routine analyser calibration are certified against traceable primary gas calibration standards at the Gas Standards Calibration Laboratory at Ricardo Energy & Environment. The calibration laboratory operates within a specific and documented quality system and has UKAS accreditation for calibration of the gas standards used in this survey.

An important aspect of QA/QC procedures is the regular six-monthly intercalibration and audit check undertaken at every monitoring site. This audit has two principal functions: firstly to check the instruments and the site infrastructure, and secondly to recalibrate the transfer gas standards routinely used on-site, using standards recently checked in the calibration laboratory. Ricardo Energy & Environment's audit calibration procedures are UKAS accredited to ISO 17025.

In line with current operational procedures within the Defra AURN, full intercalibration audits take place at the end of winter and summer. At these visits, the essential functional parameters of the monitors such as noise, linearity and, for the NO_x monitor, the efficiency of the NO₂ to NO converter are fully tested. In addition, the on-site transfer calibration standards are checked and re-calibrated if necessary, the air intake sampling system is cleaned and checked and all other aspects of site infrastructure are checked.

All air pollution measurements are reviewed daily by experienced staff at Ricardo Energy & Environment. Data are compared with corresponding results from AURN monitoring stations and with expected air pollutant concentrations under the prevailing meteorological conditions. This review process rapidly highlights any unusual or unexpected measurements, which may require further investigation. When such data are identified, attempts are made to reconcile the data against known or possible local air pollution sources or local meteorology, and to confirm the correct operation of all monitors. In addition, the results of the daily automatic instrument calibrations (see Appendix 2) are examined to identify any possible instrument faults. Should any faults be identified or suspected, arrangements are made for Ricardo Energy & Environment personnel or equipment service contractors to visit the site as soon as possible.

At the end of every quarter, the data for that period are reviewed to check for any spurious values and to apply the best daily zero and sensitivity factors, and to account for information which only became available after the initial daily processing. At this time, any data gaps are filled with data from the data logger back-up memory to produce as complete a data record as possible.

Finally, the data are re-examined on an annual basis, when information from the six-monthly intercalibration audits can be incorporated. After completion of this process, the data are fully validated and finalised, for compilation in the annual report. Following these three-stage data checking and review procedures allows the overall accuracy and precision of the data to be calculated. The accuracy and precision figures for the pollutants monitored at Stansted are summarised in Table A3.1.

Table A3.1: Estimated accuracy and precision of the data presented.

Pollutant	Precision	Accuracy
NO	± 2.5	± 15 %
NO ₂	± 6.9	± 15 %
PM ₁₀	± 4	Estimated* accuracy of a TEOM ± 30 % or better. With VCM correction, estimated as ± 25 %. FIDAS: ±25% (estimated)

* Accuracy of particle measurements with a TEOM instrument cannot be reliably assessed.

Appendix 4 – NO₂ diffusion tubes (full dataset)

Results were reported to two decimal places by the analyst. However, given the uncertainty of diffusion tube measurements, in this report they have been rounded to one decimal place. In the main part of the report, diffusion tube results have been quoted to the nearest integer.

Table A4.1: Monthly mean NO₂ concentrations as measured by diffusion tubes, Stansted 3 (east of High House, µg m⁻³).

Start date	Tube 1	Tube 2	Tube 3	Mean	Comments
06/01/2016	24.73	25.32	26.89	25.65	-
03/02/2016	29.77	28.23	25.24	27.75	-
02/03/2016	21.83	21.92	25.10	22.95	-
30/03/2016	23.63	22.77	21.82	22.74	-
27/04/2016	18.27	17.57	15.44	17.09	-
24/05/2016	16.34	15.92	16.20	16.15	-
23/06/2016	18.68	17.89	18.82	18.46	-
27/07/2016	20.00	19.43	20.48	19.97	-
25/08/2016	23.56	22.56	22.53	22.88	-
28/09/2016	22.34	23.66	23.56	23.19	-
26/10/2016	25.66	28.16	28.77	27.53	-
30/11/2016	35.63	35.16	36.00	35.60	-

Table A4.2: Monthly mean NO₂ concentrations as measured by diffusion tubes, Stansted North (north lights, north end of runway, µg m⁻³).

Start date	Tube 1	Tube 2	Tube 3	Mean	Comments
06/01/2016	30.64	27.71	Rejected	29.18	Spider and web in tube
03/02/2016	21.81	24.18	27.06	24.35	-
02/03/2016	15.31	18.10	17.28	16.90	-
30/03/2016	15.95	16.76	18.10	16.94	-
27/04/2016	13.52	14.30	13.59	13.80	-
24/05/2016	10.53	13.36	12.89	12.26	-
23/06/2016	13.71	17.80	15.38	15.63	-
27/07/2016	14.02	17.04	15.97	15.68	-
25/08/2016	20.66	23.77	22.90	22.44	-
28/09/2016	15.20	18.95	17.18	17.11	-
26/10/2016	23.23	22.97	22.01	22.74	-
30/11/2016	40.21	42.40	35.67	39.43	-

Table A4.3: Monthly mean NO₂ concentrations as measured by diffusion tubes, Stansted East (Enterprise House offices, µg m⁻³).

Start date	Tube 1	Tube 2	Tube 3	Mean	Comments
06/01/2016	34.78	37.06	38.24	36.69	-
03/02/2016	34.40	34.67	35.30	34.79	-
02/03/2016	27.59	24.03	25.24	25.62	-
30/03/2016	31.44	29.15	34.25	31.61	-
27/04/2016	23.67	24.25	23.54	23.82	-
24/05/2016	20.40	22.88	20.26	21.18	-
23/06/2016	25.94	26.46	25.33	25.91	-
27/07/2016	26.63	29.83	27.26	27.91	-
25/08/2016	30.40	30.64	31.94	30.99	-
28/09/2016	28.96	30.24	29.90	29.70	-
26/10/2016	34.23	32.06	37.08	34.46	-
30/11/2016	45.80	46.43	45.33	45.85	-

Table A4.4: Monthly mean NO₂ concentrations as measured by diffusion tubes, Stansted South (balancing pond south of site, µg m⁻³).

Start date	Tube 1	Tube 2	Tube 3	Mean	Comments
06/01/2016	30.52	27.46	31.12	29.70	-
03/02/2016	30.09	34.70	32.81	32.53	-
02/03/2016	28.42	31.68	30.88	30.33	-
30/03/2016	31.53	30.03	30.86	30.81	-
27/04/2016	23.55	21.97	24.18	23.23	-
24/05/2016	20.97	21.64	20.77	21.13	-
23/06/2016	19.01	21.24	19.81	20.02	-
27/07/2016	22.44	23.57	23.83	23.28	-
25/08/2016	24.75	25.50	25.35	25.20	-
28/09/2016	31.26	32.15	30.20	31.20	-
26/10/2016	29.13	29.31	30.52	29.65	-
30/11/2016	36.81	39.77	37.65	38.08	-

Table A4.5: Monthly mean NO₂ concentrations as measured by diffusion tubes, Stansted West (radar tower, Burton End, µg m⁻³).

Start date	Tube 1	Tube 2	Tube 3	Mean	Comments
06/01/2016	21.37	23.29	24.16	22.94	-
03/02/2016	21.05	21.02	21.07	21.05	-
02/03/2016	14.53	13.14	14.10	13.92	-
30/03/2016	15.87	17.07	15.71	16.22	-
27/04/2016	13.75	13.70	13.98	13.81	-
24/05/2016	11.21	11.47	11.37	11.35	-
23/06/2016	12.19	12.10	11.82	12.04	-
27/07/2016	13.47	12.98	Rejected	13.23	Dirt in tube from earwig (live) inside.
25/08/2016	18.89	18.50	18.81	18.73	-
28/09/2016	15.73	15.84	16.07	15.88	-
26/10/2016	17.74	18.31	17.64	17.90	-
30/11/2016	29.13	28.47	28.55	28.72	-



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