RICARDO-AEA

# Air Quality Monitoring at Stansted Airport – Annual Report for 2014

Report for Stansted Airport Ltd

ED57706

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# Executive summary

This report provides details of air quality monitoring conducted around Stansted Airport during 2014. The work, carried out by Ricardo-AEA 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); $PM_{10}$ particulate matter was monitored at Stansted 3 only. Measured $PM_{10}$ 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.

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 90% was achieved for all the pollutants (NOx and $PM_{10}$) at Stansted 3 and Stansted 4.

The UK AQS hourly mean objective for $NO_2$ is 200 µg $m^{-3}$, with no more than 18 exceedances allowed each year. (Where data capture is below 90%, the 99.8$^{th}$ percentile of hourly means must be within 200 µg $m^{-3}$). Stansted 3 and Stansted 4 met this objective, with no hourly means recorded above the objective.

The annual mean AQS objective for $NO_2$ is 40 µg $m^{-3}$. This was also met at Stansted 3, Stansted 4, and at all five of the diffusion tube monitoring sites.

$PM_{10}$ 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 $PM_{10}$ is 40 µg $m^{-3}$. These objectives were met at Stansted 3, with only five instances of concentrations exceeding the 24-hour mean value.

Wind speed and direction data provided by Stansted Airport Ltd were used to produce bivariate plots showing hourly mean pollutant concentrations against the corresponding weather conditions. The bivariate plots for NO and $NO_2$ for Stansted 3 show elevated concentrations when wind speeds are low, prevailing from the west, indicating sources are close possibly being attributed to airport activity and the A120 road. The bivariate plot for $PM_{10}$ at Stansted 3 showed a source to the east of the site, possibly arising from agricultural activities as well as an elevated source from the west when wind speeds are moderate, indicating a potential source from the M11 motorway. The bivariate plots for NO and $NO_2$ at Stansted 4 generally show elevated concentrations when wind speeds are calm to moderate and prevailing from the south and south east, indicating sources being attributed to airport activity and the A120 road.

Several episodes of high concentrations for NOx and $PM_{10}$ occurred during 2014. At Stansted 3, particularly high concentrations of NOx and $PM_{10}$ were recorded in March (13$^{th}$, 14$^{th}$, 29$^{th}$) and April (2$^{nd}$,3$^{rd}$). Local emissions, combined with trans-boundary atmospheric transport of dust from the Sahara and emissions from continental Europe, in conjunction with anti-cyclonic weather conditions are the origin of this high concentration episodes.

Average $NO_2$ concentrations are broadly similar to those from comparable urban background monitoring sites and have remained lower than those for London Heathrow Airport. $PM_{10}$ levels at Stansted 3 have declined from a peak in 2006 and are also lower than those recorded at London Heathrow Airport.

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# 1 Introduction

## 1.1 Background

Stansted Airport is London's third busiest international airport, handling approximately 19 million passengers a year. The airport is situated approximately 40 miles north of London, in north east Hertfordshire. 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-AEA was contracted by Stansted Airport Ltd to carry out the required programme of air pollution measurements during 2014, the ninth 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 2.4 about VCM correction of the $PM_{10}$ data). Data in the annual report have been processed according to the rigorous quality assurance and quality control procedures used by Ricardo-AEA. These ensure the data are reliable, accurate and traceable to UK national measurement standards.

This report covers the period 1st January to 31st December 2014.

## 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 $NO_2$), using automatic techniques at two locations: Stansted 3 (High House) and Stansted 4 (Runway).

• Particulate matter ($PM_{10}$) at Stansted 3.

The automatic monitoring was supplemented by indicative monitoring of $NO_2$ 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 Europe[1], 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 2007[2], and the currently applicable air quality objectives are summarised in Appendix 1 of this report.

# 2 Air quality monitoring

## 2.1 Pollutants monitored

### 2.1.1 Nitrogen Oxides (NOx)

Combustion processes emit a mixture of oxides of nitrogen – NO and $NO_2$ - collectively termed NOx.

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 $NO_2$.

ii) $NO_2$ 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.

Of the NOx emissions (including $NO_2$) 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 NOx 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 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[4].

### 2.1.2 Particulate Matter ($PM_{10}$)

Airborne particulate matter varies widely in its physical and chemical composition, source and particle size. The term $PM_{10}$ 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 2011 National Atmospheric Emissions Inventory (NAEI) data, 0.07% of UK total $PM_{10}$ emissions were believed to originate from civil aircraft taking off and landing[5].

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 $PM_{10}$ [4].

## 2.2 Monitoring sites and Methods

### 2.2.1 Sites locations

Automatic monitoring was carried out at two sites during 2014. 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(09)[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*").

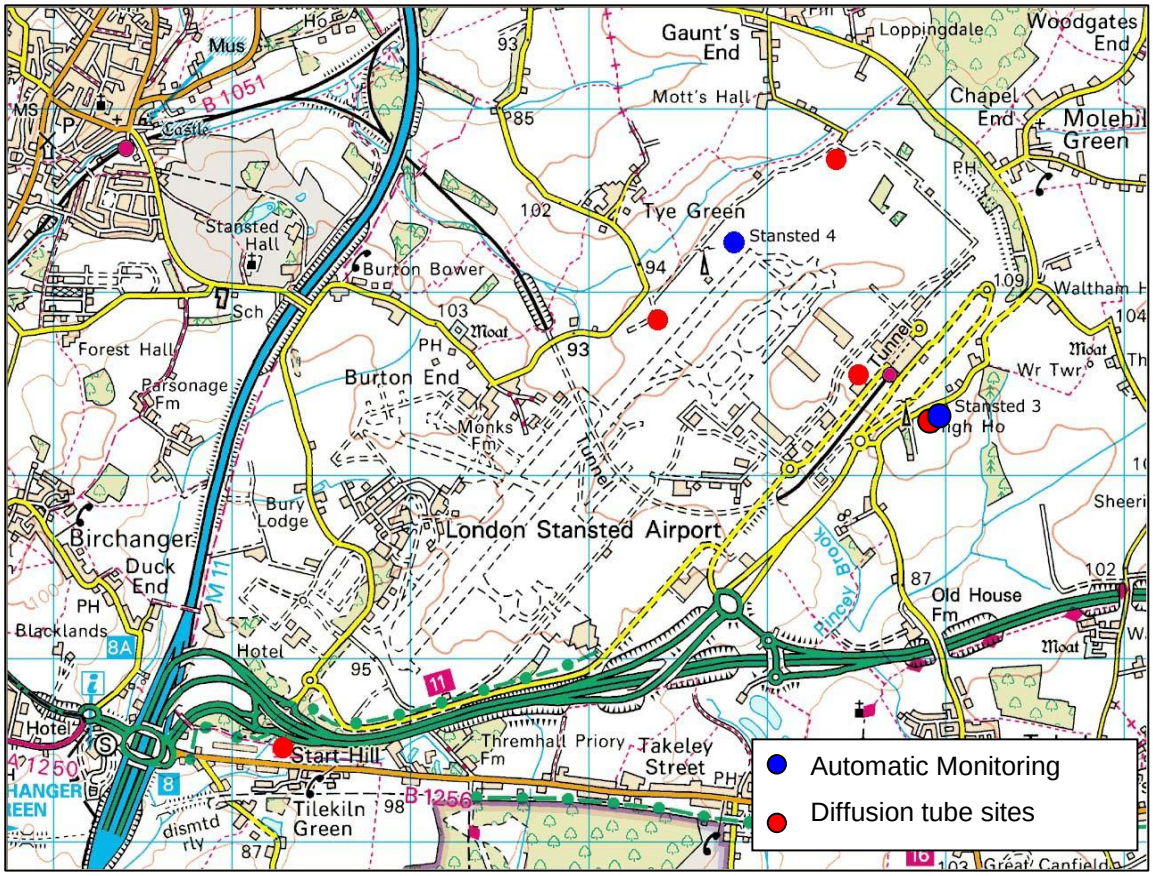
These two automatic sites were supplemented by five sites at which diffusion tubes were used to monitor $NO_2$ on a monthly basis. These were located at the Stansted 3 automatic site, and four sites to the north, east, south and west of the airport.

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 NOx and $PM_{10}$.<br>Diffusion tube monitoring of $NO_2$ monthly (co-located). | TL 558 233 |
| Stansted 4 | Grass area near runway | Automatic monitoring of NOx. | 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-AEA. 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 NOx (i.e. NO and $NO_2$) and $PM_{10}$:

•$PM_{10}$ - Tapered element oscillating microbalance (TEOM).

•NO, $NO_2$ - 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-AEA. Data are downloaded hourly. The data are converted to concentration units at Ricardo-AEA 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 $PM_{10}$ such as ammonium nitrate[6].

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 Model[7] (VCM), which allows TEOM $PM_{10}$ 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 $PM_{10}$. 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 $PM_{10}$ 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 $PM_{10}$ data is presented in Appendix 2 of this report.

### 2.2.4 Diffusive samplers

Diffusion tubes were used for additional indicative monitoring of $NO_2$. These are "passive" samplers which work by absorbing the pollutants direct from the surrounding air and need no power supply.

Diffusion tubes for $NO_2$ 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 $NO_2$. 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.

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 %. |

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

When using diffusion tubes for indicative $NO_2$ monitoring, the LAQM Technical Guidance LAQM.TG(09)[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 NOx 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 $NO_2$. The limits of detection vary from month to month, but typically equate to 0.4 µg $m^{-3}$ for $NO_2$. 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 90 % is recommended in the European Commission Air Quality Directive[1] and Defra Technical Guidance LAQM.TG (09)[4].

**Table 3.2** – Data capture statistics 2014.

| Sites | NOx | $NO_2$ | $PM_{10}$ |
|---|---|---|---|
| Stansted 3 | 95.3 % | 95.3% | 96.8% |
| Stansted 4 | 93.6% | 93.6% | N/A |

The 90 % 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 2014.

| Site | Pollutant | Start date | End date | No. of days | Reason | Comments |
|---|---|---|---|---|---|---|
| Stansted 3 | $NO_2$ | 16/01/2014 | 17/01/2014 | 1.1 | Service | Routine service |
| Stansted 4 | $NO_2$ | 16/01/2014 | 17/01/2014 | 1.0 | Service | Routine service |
| Stansted 3 | $PM_{10}$ | 29/01/2014 | 29/01/2014 | 0.4 | Communications | Communication Issue |
| Stansted 3 | $PM_{10}$ | 14/02/2014 | 15/02/2014 | 0.3 | Communications | Communication Issue |
| Stansted 3 | $PM_{10}$ | 09/05/2014 | 10/05/2014 | 0.7 | Communications | Communication Issue |
| Stansted 3 | $PM_{10}$ | 14/07/2014 | 15/07/2014 | 1.0 | Service | Routine service |
| Stansted 3 | $NO_2$ | 14/07/2014 | 16/07/2014 | 2.1 | Service | Routine service |
| Stansted 4 | $NO_2$ | 14/07/2014 | 18/07/2014 | 4.2 | Service | Routine service |
| Stansted 3 | $NO_2$ | 09/08/2014 | 13/08/2014 | 4.0 | Flat response | NOx flat data |
| Stansted 3 | $PM_{10}$ | 17/09/2014 | 18/09/2014 | 1.2 | Flat response | Flow warning filter changed |
| Stansted 3 | $PM_{10}$ | 07/11/2014 | 12/11/2014 | 5.6 | Power cut | NOx pump tripped site power supply |
| Stansted 3 | $NO_2$ | 07/11/2014 | 14/11/2014 | 7.0 | Power cut | Replaced pump |
| Stansted 3 | $NO_2$ | 16/12/2014 | 17/12/2014 | 1.0 | Service | Routine service |
| Stansted 4 | $NO_2$ | 16/12/2014 | 31/12/2014 | 15.5 | Analyser | Engineer called out |

# 4 Results and discussion

## 4.1 Automatic monitoring data

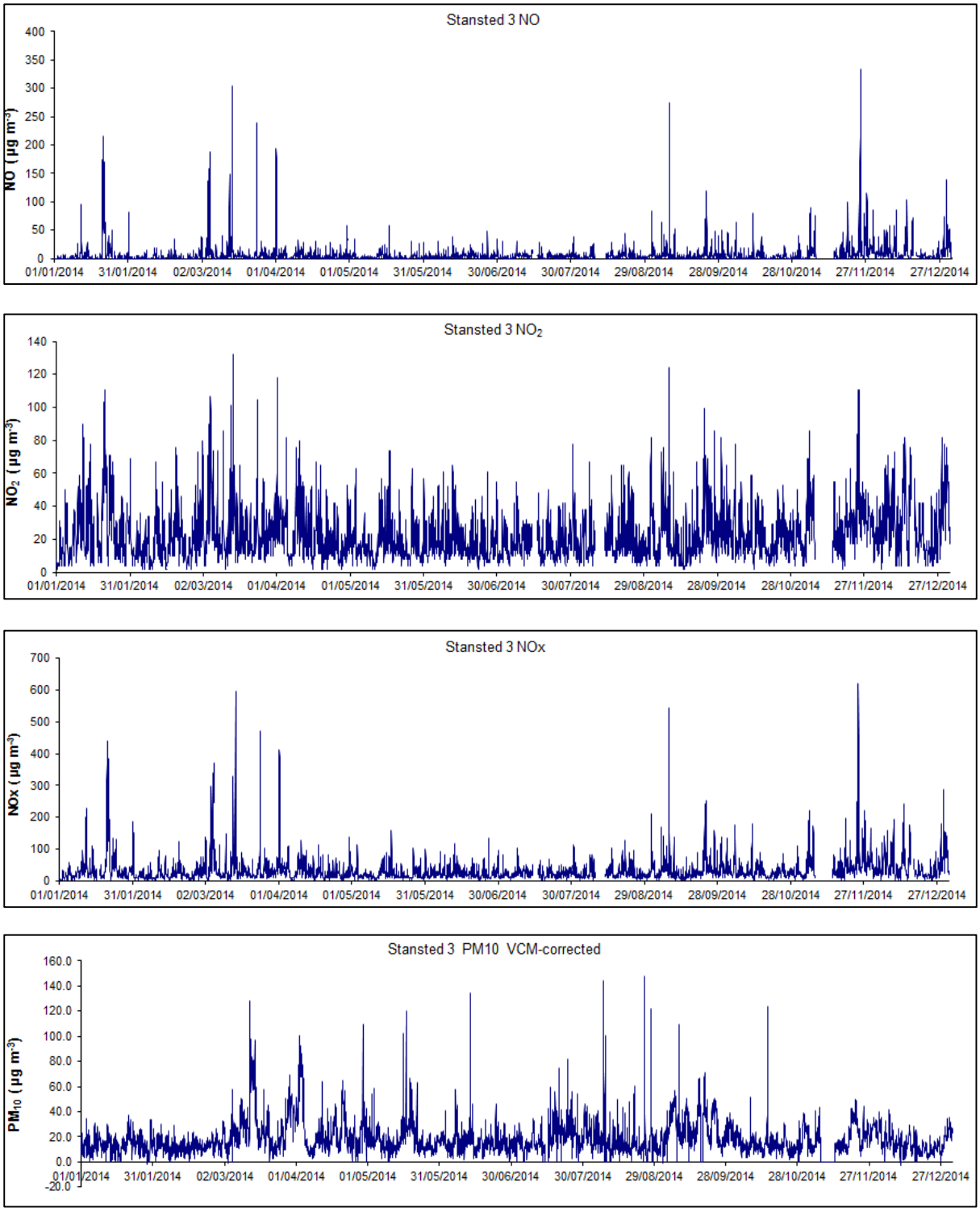
The summary statistics for 2014 are given in Table 4.1, and the time series of data for the full year, as measured by the automatic monitoring sites, are shown in Figure 4.1 and Figure 4.2.

**Table 4.1** – Air pollution statistics for Stansted 3, from 1st January to 31st December 2014.

| Stansted 3 | NO (µg $m^{-3}$) | $NO_2$ (µg $m^{-3}$) | NOx (µg $m^{-3}$) | $PM_{10}$ as measured (µg $m^{-3}$) | $PM_{10}$ VCM corrected (µg $m^{-3}$) |
|---|---|---|---|---|---|
| Maximum 15 minute mean | 393 | 172 | 728 | 382 | - |
| Maximum hourly mean | 334 | 132 | 621 | 150 | 148 |
| Maximum running 8 hour mean | 193 | 92 | 382 | 57 | - |
| Maximum running 24 hour mean | 107 | 76 | 240 | 44 | - |
| Maximum daily mean | 87 | 73 | 205 | 39 | 72 |
| Average | 6 | 22 | 32 | 15 | 19 |
| Data capture | 95.3 % | 95.3 % | 95.3 % | 96.8 % | 96.8 % |
| **Stansted 4** | **NO (µg $m^{-3}$)** | **$NO_2$ (µg $m^{-3}$)** | **NOx (µg $m^{-3}$)** | **$PM_{10}$ as measured (µg $m^{-3}$)** | **$PM_{10}$ VCM corrected (µg $m^{-3}$)** |
| Maximum 15 minute mean | 225 | 306 | 586 | - | - |
| Maximum hourly mean | 150 | 96 | 300 | - | - |
| Maximum running 8 hour mean | 97 | 66 | 204 | - | - |
| Maximum running 24 hour mean | 68 | 61 | 154 | - | - |
| Maximum daily mean | 55 | 54 | 130 | - | - |
| Average | 6 | 17 | 26 | - | - |
| Data capture | 93.6 % | 93.6 % | 93.6 % | - | - |

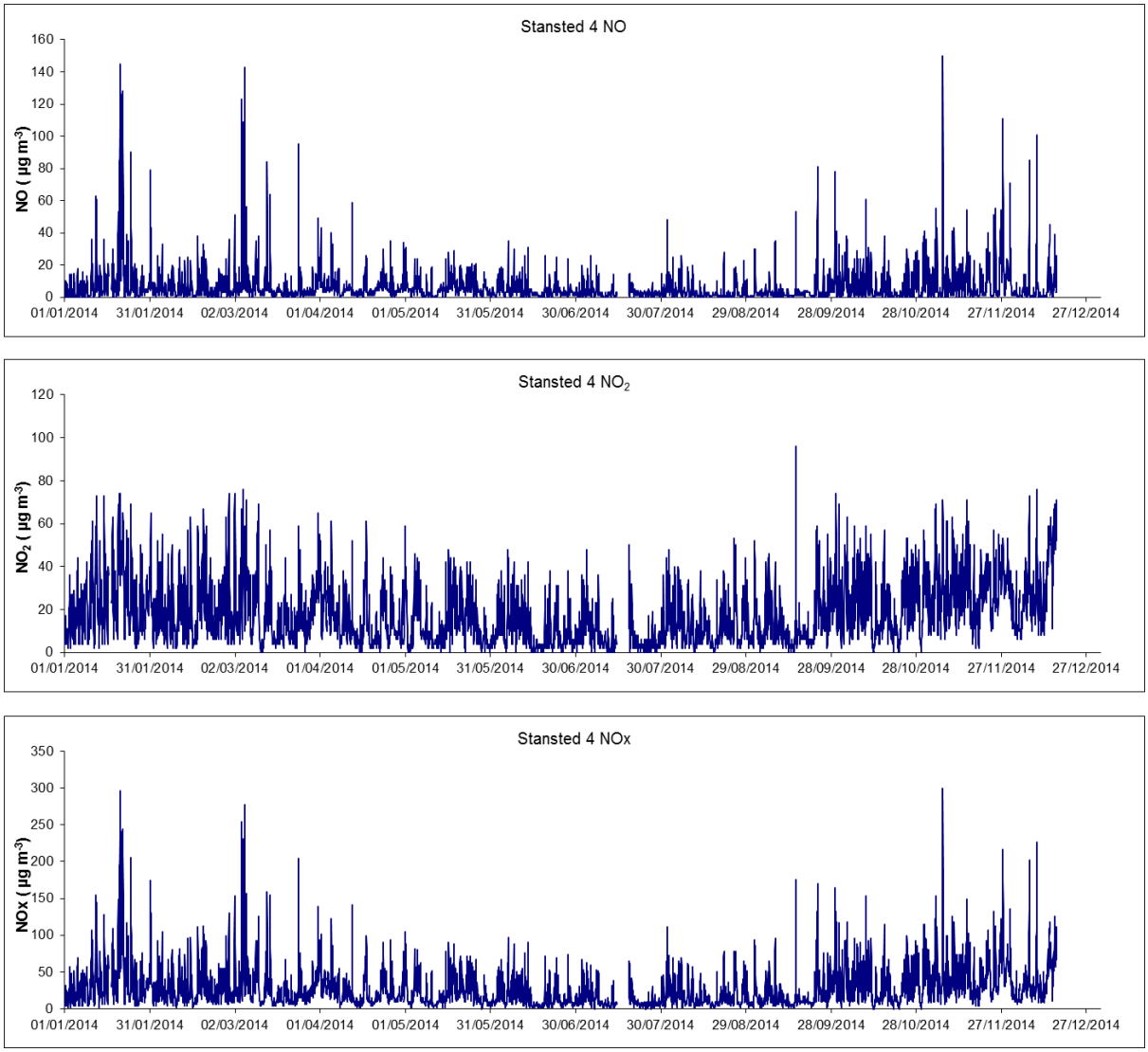
In this report $PM_{10}$ measured using the TEOM instrument were converted to gravimetric equivalent using the King's College London Volatile Correction Model[7] where appropriate. See section 2.2.3 for an explanation of this.

**Figure 4.1** – Time series of hourly averaged concentrations at Stansted 3 – 2014.




At Stansted 3, the biggest concentration of high hourly average $PM_{10}$ was recorded in March/April and September 2014. The explanation for this fact is described on the sub chapter 4.4 of the report. The highest $NO_2$ hourly mean registered for the year of 2014 was of 148 µg $m^{-3}$.

**Figure 4.2** – Time series of hourly averaged concentrations at Stansted 4 – 2014.




At Stansted 4, it is clearly visible the typical seasonal variation of NO and $NO_2$. The highest concentrations of NO and $NO_2$ 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 $NO_2$ is registered on the 15th of September, with a concentration of 96 µgmm$^3$. Although it appears to be an elevated spike in the chart, this value still continues to be way below the hourly mean $NO_2$ concentrations exceedance of 200 µg m$^{-3}$, which is the AQS objective for hourly mean $NO_2$.

## 4.2 Diffusion tube data

Table 4.2 shows the $NO_2$ diffusion tube results for 2014. 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** – $NO_2$ diffusion tube results 2014 (µg $m^{-3}$).

| Start date | End Date | Stansted North | Stansted East | Stansted South | Stansted West | Stansted 3 |
|---|---|---|---|---|---|---|
| 31/12/2013 | 05/02/2014 | 26.7 | 29.4 | 24.0 | 23.9 | 21.8 |
| 05/02/2014 | 05/03/2014 | 27.2 | 30.4 | 26.9 | 22.6 | 21.4 |
| 05/03/2014 | 03/04/2014 | 23.0 | 34.1 | 32.8 | 24.8 | 24.5 |
| 03/04/2014 | 30/04/2014 | 15.2 | 26.3 | 27.2 | 17.2 | 21.9 |
| 30/04/2014 | 28/05/2014 | 14.6 | 25.3 | 20.5 | 17.7 | 19.4 |
| 28/05/2014 | 02/07/2014 | 12.9 | 20.7 | 21.0 | 13.3 | 20.9 |
| 02/07/2014 | 30/07/2014 | 11.3 | 23.6 | 23.1 | 10.9 | 23.1 |
| 30/07/2014 | 27/08/2014 | 15.2 | 26.2 | 22.6 | 12.8 | 20.7 |
| 27/08/2014 | 01/10/2014 | 14.9 | 28.9 | 29.9 | 14.1 | 22.7 |
| 01/10/2014 | 29/10/2014 | 34.4 | 32.5 | 27.3 | 21.8 | 27.4 |
| 29/10/2014 | 03/12/2014 | 26.0 | 28.0 | 26.2 | 24.7 | 21.7 |
| 03/12/2014 | 07/01/2015 | 27.0 | 46.1 | 31.0 | 20.4 | 29.9 |
| **Mean** | - | 20.7 | 29.3 | 26.0 | 18.7 | 23.0 |
| **Bias adjusted** | - | 20.3 | 28.7 | 25.48 | 18.3 | 22.5 |

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

**Table 4.3** – Details of $NO_2$ diffusion tube result rejected.

| Site | Month | Tube number | [$NO_2$] (µg $m^{-3}$) | Reason for rejection |
|---|---|---|---|---|
| Stansted East | July 2014 | 1 | 17.72 | Low outlier in triplet |
| Stansted West | October 2014 | 2 | 14.93 | Low outlier in triplet |
| Stansted East | December 2014 | 3 | 35.6 | Low outlier in triplet |

Across the five sites, annual mean $NO_2$ concentrations measured with diffusion tubes ranged from 18 to 29 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 µg $m^{-3}$. This was in line with the annual mean of 22 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 $NO_2$ 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 0.98.

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 objectives

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

The AQS objective for hourly mean $NO_2$ concentration is 200 µg $m^{-3}$ which may be exceeded up to 18 times per calendar year. At both Stansted 3 and Stansted 4 sites, there were no recorded hourly mean $NO_2$ concentrations in excess of the hourly mean AQS objective of 200 µg $m^{-3}$, the sites therefore met the AQS objective for this pollutant.

The annual mean $NO_2$ concentrations measured at Stansted 3 and Stansted 4 during 2014 were 22 µg$m^{-3}$ and 17 µg $m^{-3}$ respectively. Both automatic sites were therefore within the annual mean AQS objective for $NO_2$ 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 $NO_2$ concentrations measured at the five diffusion tube sites were all well within the AQS objective of 40 µg $m^{-3}$.

$PM_{10}$ 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 five. This is well within the maximum permitted number of exceedances (35), so this site met the AQS objective for 24-hour mean $PM_{10}$.

## 4.4 Temporal variation in pollutant concentrations

### 4.4.1 Seasonal variation

Figure 4.3 and Figure 4.4 show the variation of monthly averaged NO and $NO_2$ concentrations during 2014 at Stansted 3 and Stansted 4.

**Figure 4.3** - Seasonal variation of pollutant concentrations at Stansted 3, 2014.

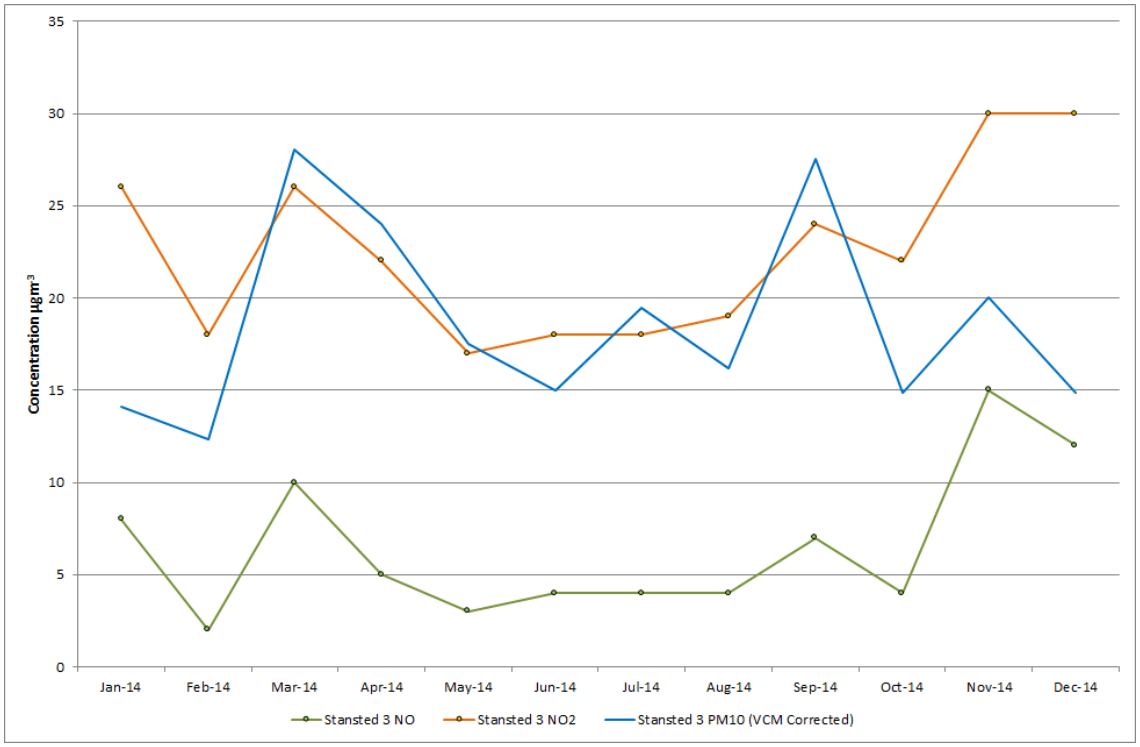



Figure 4.3 shows monthly averages of NO, $NO_2$ and $PM_{10}$ recorded at Stansted 3. This graph shows elevated concentration peaks for all 3 pollutants for the months of March/April and September. NO and $NO_2$ also both showed increases in winter, a pattern that would be expected during periods of cold weather and relatively low wind speeds.

**Figure 4.4** – Seasonal variation of pollutant concentrations at Stansted 4, 2014.

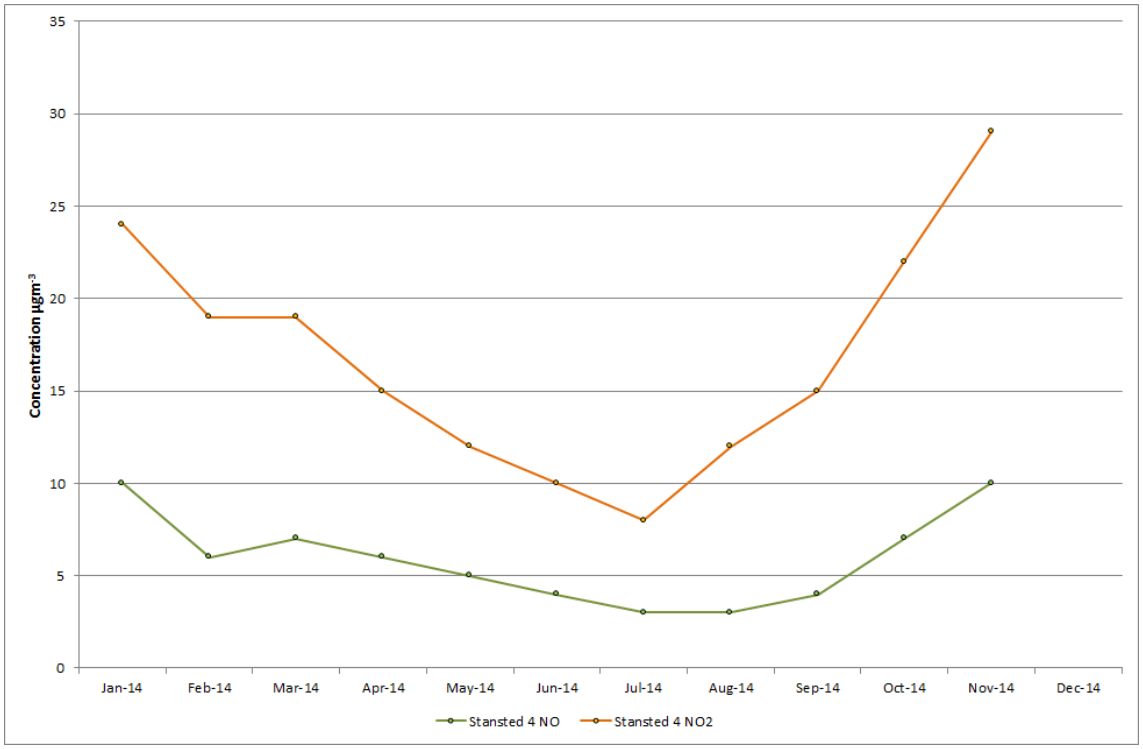



Figure 4.4 shows monthly averages of NO and recorded at Stansted 4. This graph shows increases in winter, a pattern that would be expected during periods of cold weather and relatively low wind speeds. The elevated periods seen at Stansted 3 in the March/April and September months are less pronounced at Stansted 4, possibly due to its location being exposed, having greater influence from wind speed / direction changes). 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 website[9] show air quality index bands that go from 4 (Moderate) to 10 (Very high) for most of the UK regions during 5 days in March (13th,14th,28th,29th and 30th), 2 days in April (2nd,3rd) and 4 days in September (16th to 19th). March/April and September 2014 also appear to be months where the monthly means (hourly measured) for $PM_{10}$ are higher in most of the monitoring stations across the UK[10].

According to a study from the Public Health England (PHE) [11], two outbreaks of high air pollution were identified in 2014, and they both have occurred during the same period of days mentioned above (for March and April).

The study states that: "Local emissions, combined with trans-boundary atmospheric transport of dust from the Sahara and emissions from continental Europe, in conjunction with anti-cyclonic weather conditions led to several days during this period with high to very high levels of particulate air pollution across most of the UK."

**Figure 4.5** - Air quality Index and air mass back trajectories calculated for the 29th March 2014.

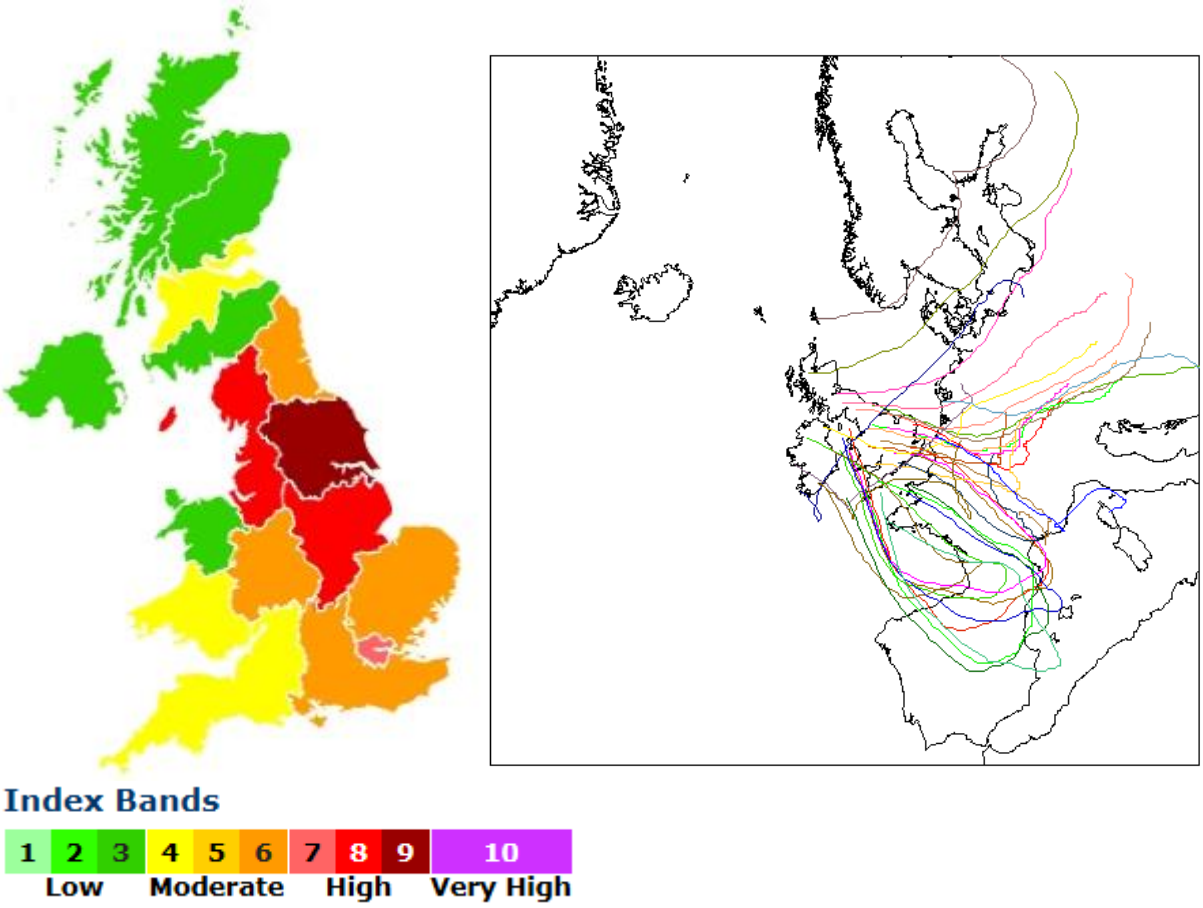



Figure 4.5 shows an example of one of these high air pollution episodes. The region of Greater London as an index band of 10 (Very High). The air mass trajectories calculated using the Hybrid Single Particle Lagrangian Integrated Trajectory Model (HYSPLIT) [12] for the same day, clearly show the displacement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

NO and $NO_2$ data for December 2014 was not included in Figure 4.4, since an instrument failure has occurred on the NOx chemiluminescence analyser. Data was not available from the 16th to the 31st of December 2014 (15.5 days).

### 4.4.2 Diurnal variation

Figure 4.6 and Figure 4.7 show diurnal variation in pollutant concentrations, as measured at Stansted 3 and Stansted 4.

**Figure 4.6** - Diurnal variation of pollutant concentrations at Stansted 3, 2014 (times in GMT).

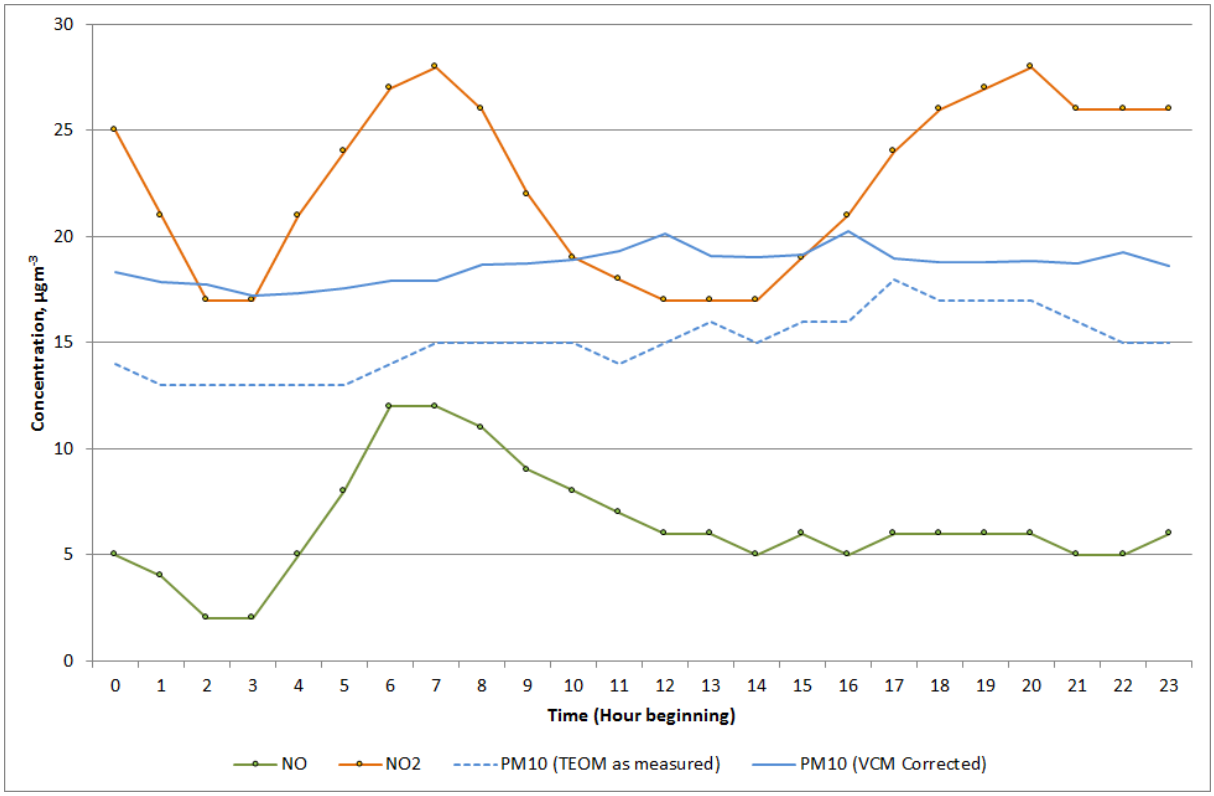
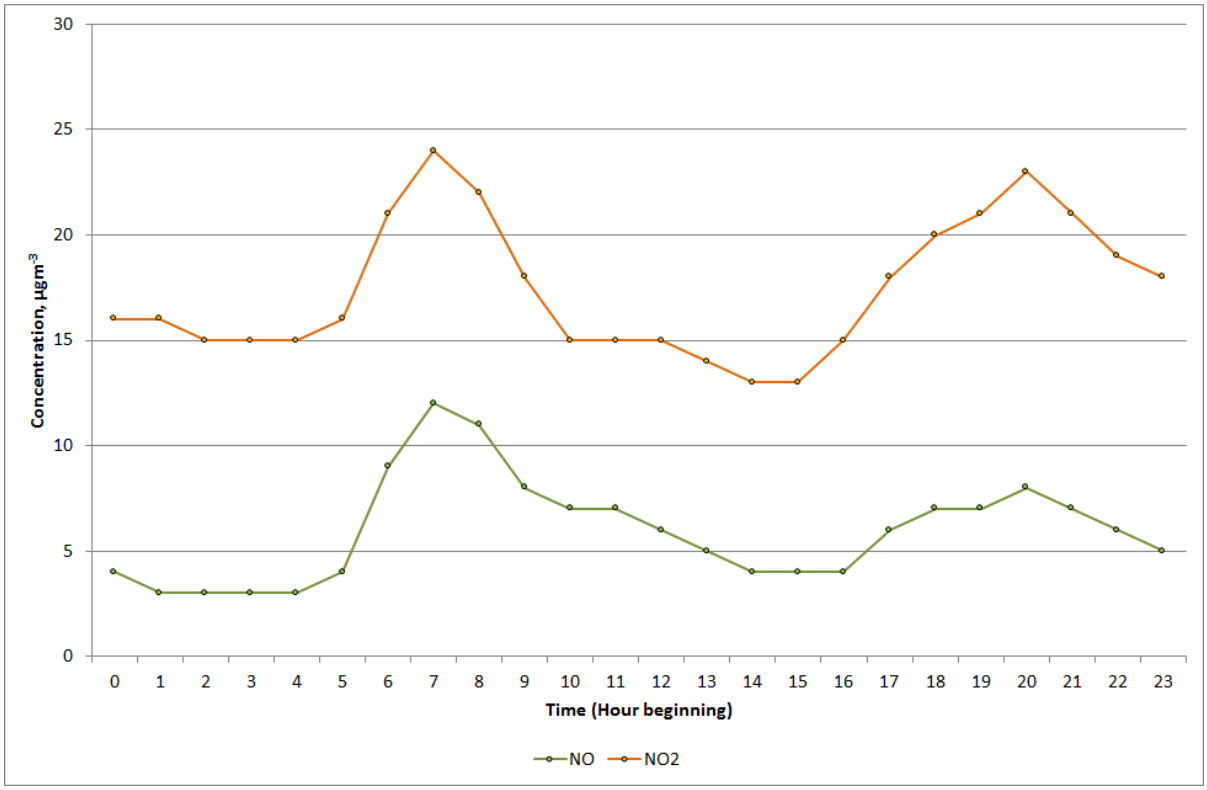



**Figure 4.7** – Diurnal variation of pollutant concentrations at Stansted 4, 2014 (times in GMT).




Both sites showed typical urban area daily patterns for NO and $NO_2$. Pronounced peaks can be seen for this pollutants during the mornings, corresponding to rush hour traffic at around 07:00. Concentrations decreased during the middle of the day, with a much broader evening rush-hour peak

in $NO_2$ building up from early afternoon. At Stansted 3 the afternoon peak in $NO_2$ was of the same order of magnitude than the morning peak and then stayed high 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 $NO_2$.

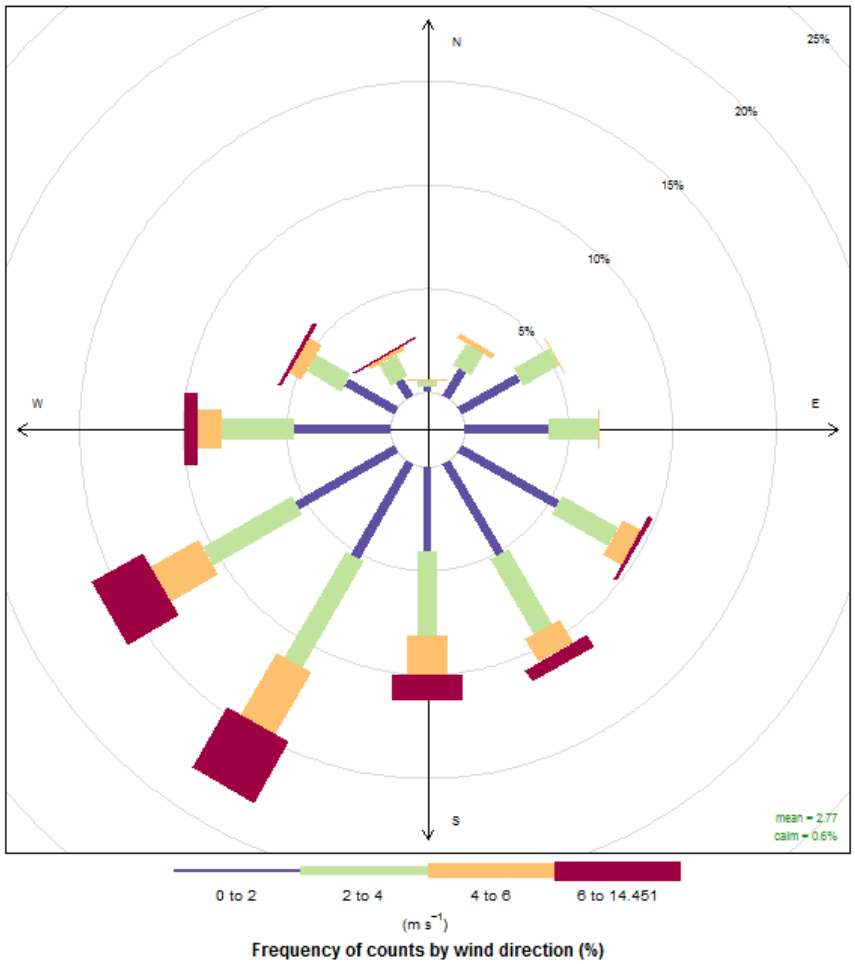
$PM_{10}$ was only measured at Stansted 3. As it can be seen in Figure 4.5, $PM_{10}$ concentration levels slightly increase after applying the king's college London volatile correction model. There was a steady increase in average $PM_{10}$ concentrations throughout the day. This is similar to the pattern observed in 2013. Emissions of sulphur dioxide and NOx can react with other chemicals in the atmosphere to form secondary sulphate and nitrate particles, resulting in elevated levels of $PM_{10}$.

## 4.5 Source investigation

In order to investigate the possible sources of air pollution that were monitored at Stansted airport, meteorological data (kindly supplied by Stansted Airport Ltd) were used to add a directional component to the air pollutant concentrations. The meteorological data used here are as received from Stansted Airport Ltd. The QA/QC procedures for checking of these data are not known.

Figure 4.8 shows the wind speed and direction data, as supplied by Stansted Airport Ltd. 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 255 °, 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. The mean wind speed was 2.77 m $s^{-1}$. The maximum measured wind speed was 14.45 m $s^{-1}$. Some of the highest wind speeds occurred during January and February 2014.

**Figure 4.*8*** - Wind rose showing the wind speeds and directions at Stansted 3 in 2014.

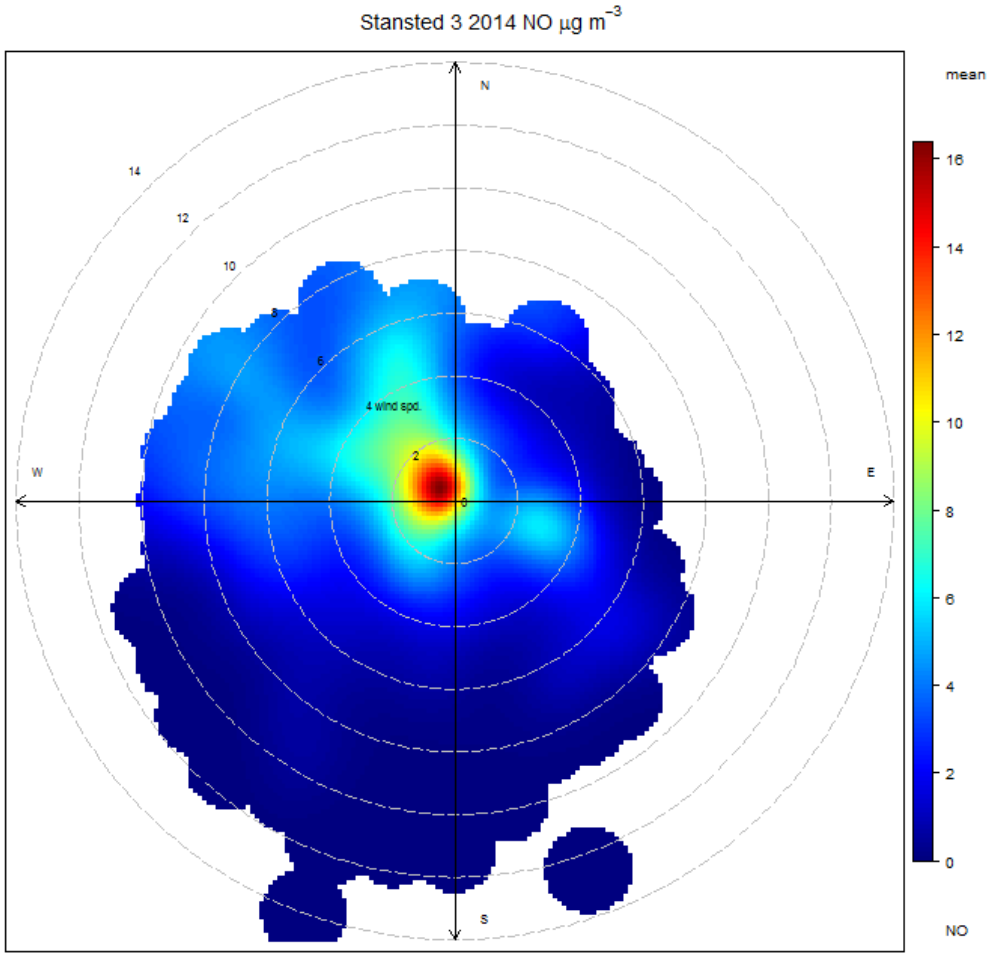


Figures 4.9 to 4.13 show bivariate plots of hourly mean concentrations of NO, $NO_2$, $PM_{10}$ and $PM_{2.5}$ at Stansted 3 and Stansted 4, against the corresponding wind speed and wind direction. These plots should be interpreted as follows.

- 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 2 $ms^{-1}$.
- The pollutant concentration is indicated by the colour (as shown in the scale bars).

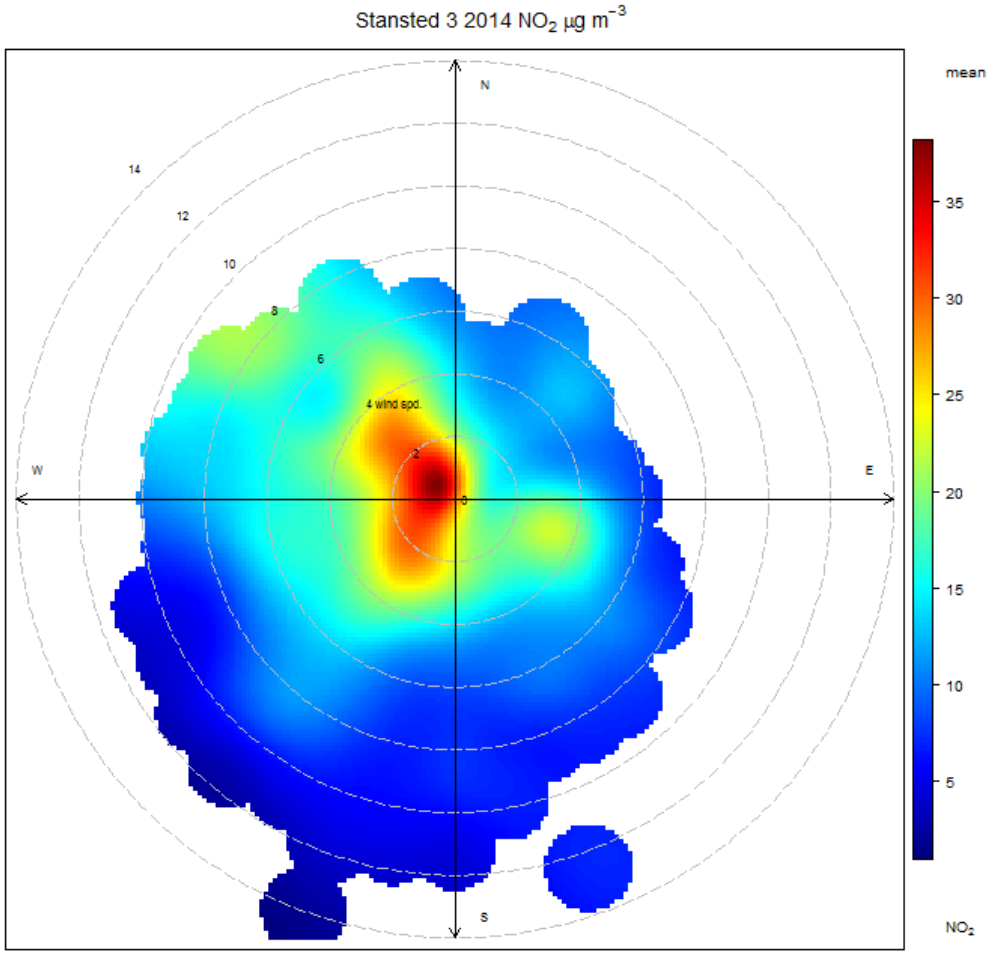
These plots therefore show how pollutant concentration varies with wind direction and wind speed. They do not depict distance from the monitoring location. They are best interpreted with reference to the map in Figure 2.1.

**Figure 4.*9*** – Pollution rose for NO at Stansted 3 in 2014.



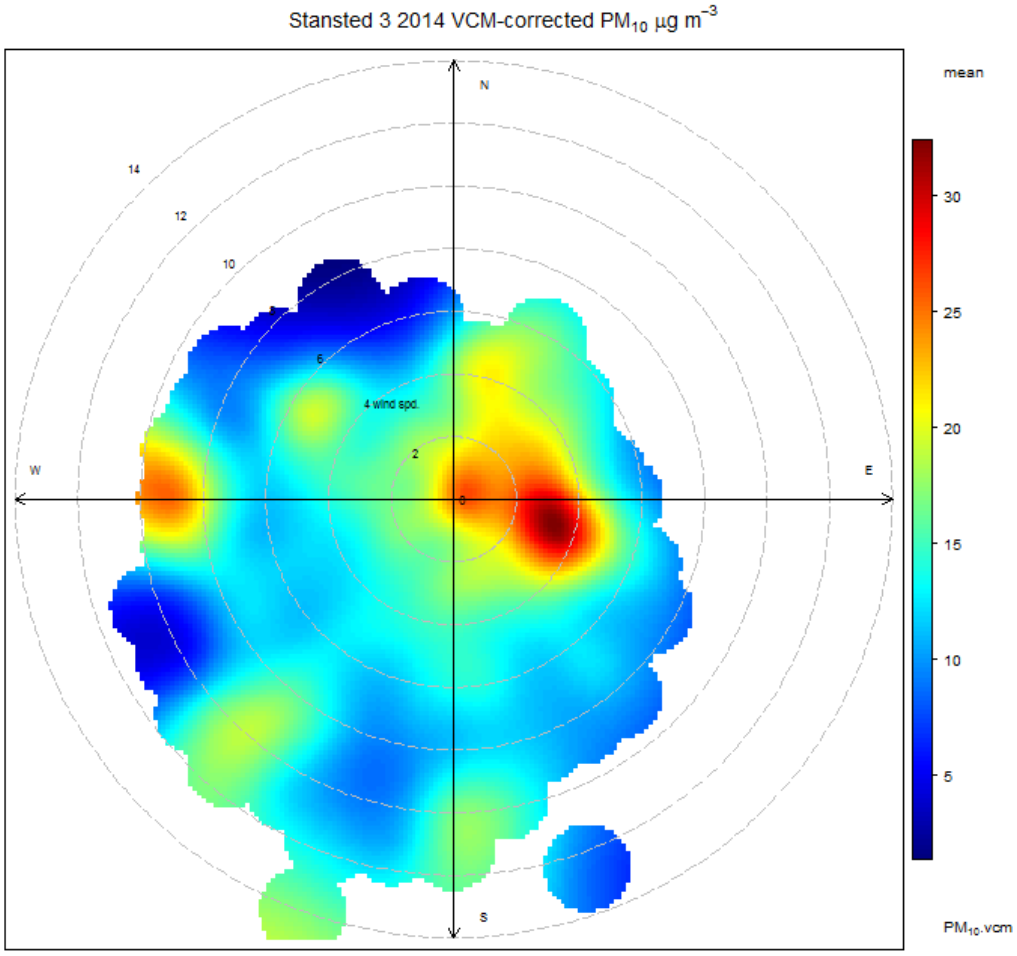

The highest NO concentrations at Stansted 3 were recorded at very low wind speeds. In the case of primary pollutants such as NO, this typically suggests that the site was dominated by emission sources close by. However, minor sources can also be detected to the north west of the monitoring location at higher wind speeds, indicated by the paler blue traces between 270 ° and 360 °. NO concentrations caught at higher wind speeds, usually suggest that main pollution sources are located further away.

**Figure 4.10 –** Pollution rose for $NO_2$ at Stansted 3 in 2014.




As in previous years, the main source of $NO_2$ appeared to be 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 to moderate wind speeds (around 6-8 m $s^{-1}$). These might be the result of activities around the airport terminal buildings and emissions from roads such as the A120 which lies to the south of the airport.

**Figure 4.11** - Pollution rose for VCM-corrected PM10 at Stansted 3 in 2014.



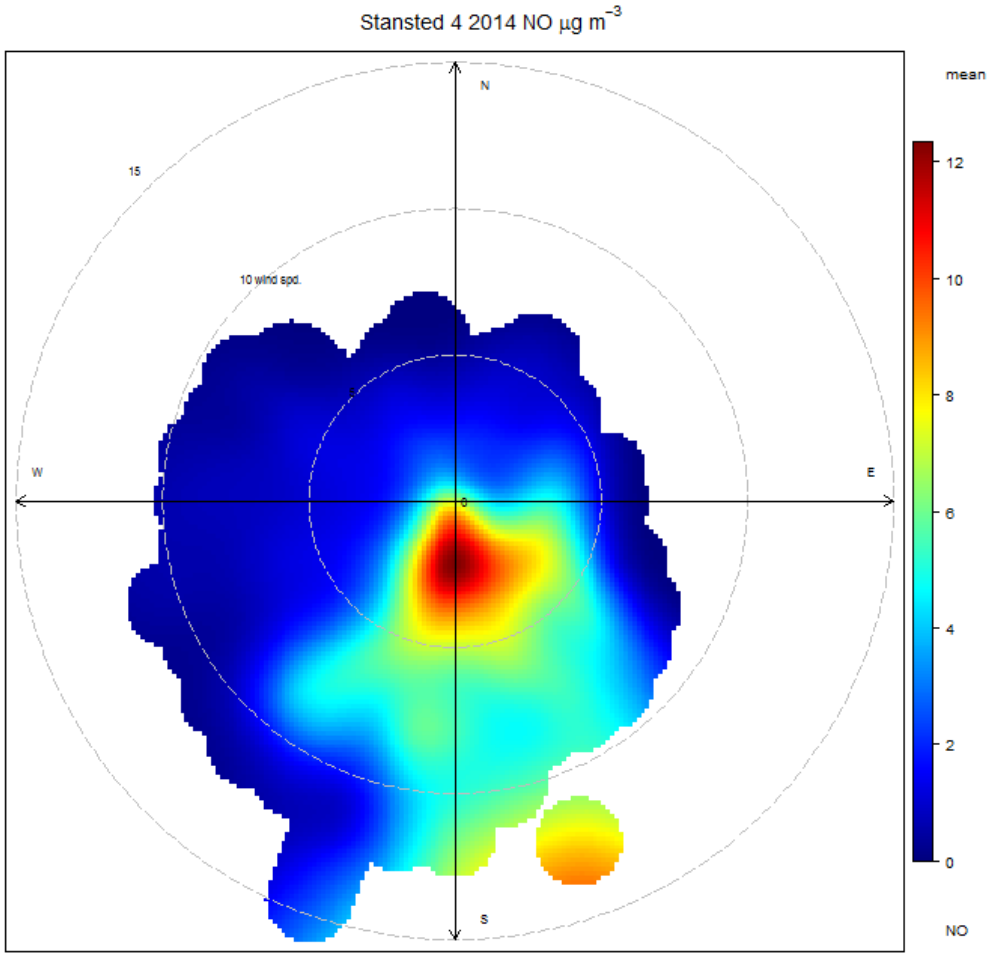

$PM_{10}$ concentrations didn't follow the same pattern in relation to last year. In 2014, $PM_{10}$ highest concentrations seem to be associated to both low and high wind speeds.

High $PM_{10}$ concentrations occurred under calm conditions (wind speeds between 0-5 $ms^{-1}$) very close to the monitoring station to the east possibly due to agricultural activity, and for higher wind speeds (8-10 $ms^{-1}$) to the West possibly a source from the M11 motorway, airport and surrounding roads.

Moderate $PM_{10}$ concentrations were found close to the monitoring site under low to moderate wind speeds (4-6 $ms^{-1}$) for wind directions between 270-360º and at higher wind speeds (8-12 $ms^{-1}$) to the South and South-West.

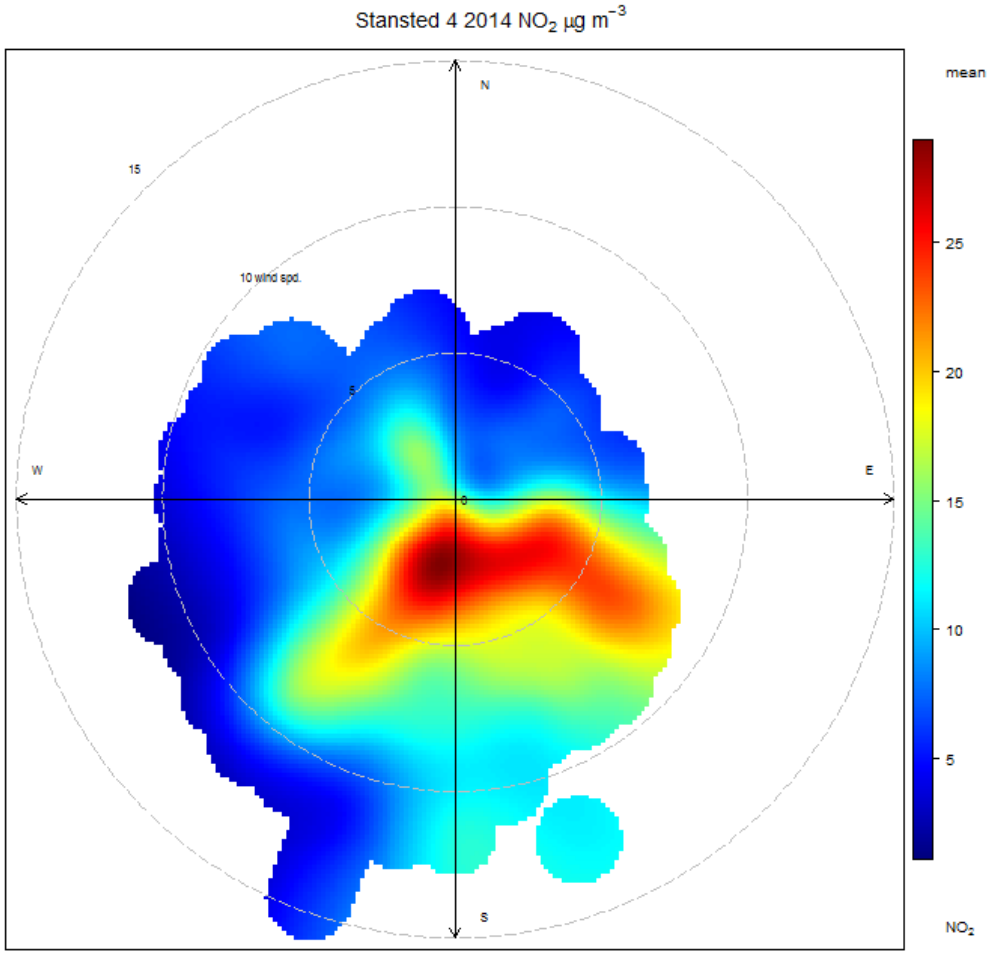
The UK-wide pollution/trans-boundary episodes associated previously mentioned on this report and some agricultural activity related to harvesting may help explain high PM10 concentrations at higher wind speeds coming from several wind directions.

**Figure 4.12-** Pollution rose for NO at Stansted 4 in 2014.




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-East) to the increase of the registered NO concentrations.

**Figure 4.13** - Pollution rose for $NO_2$ at Stansted 4 in 2014.



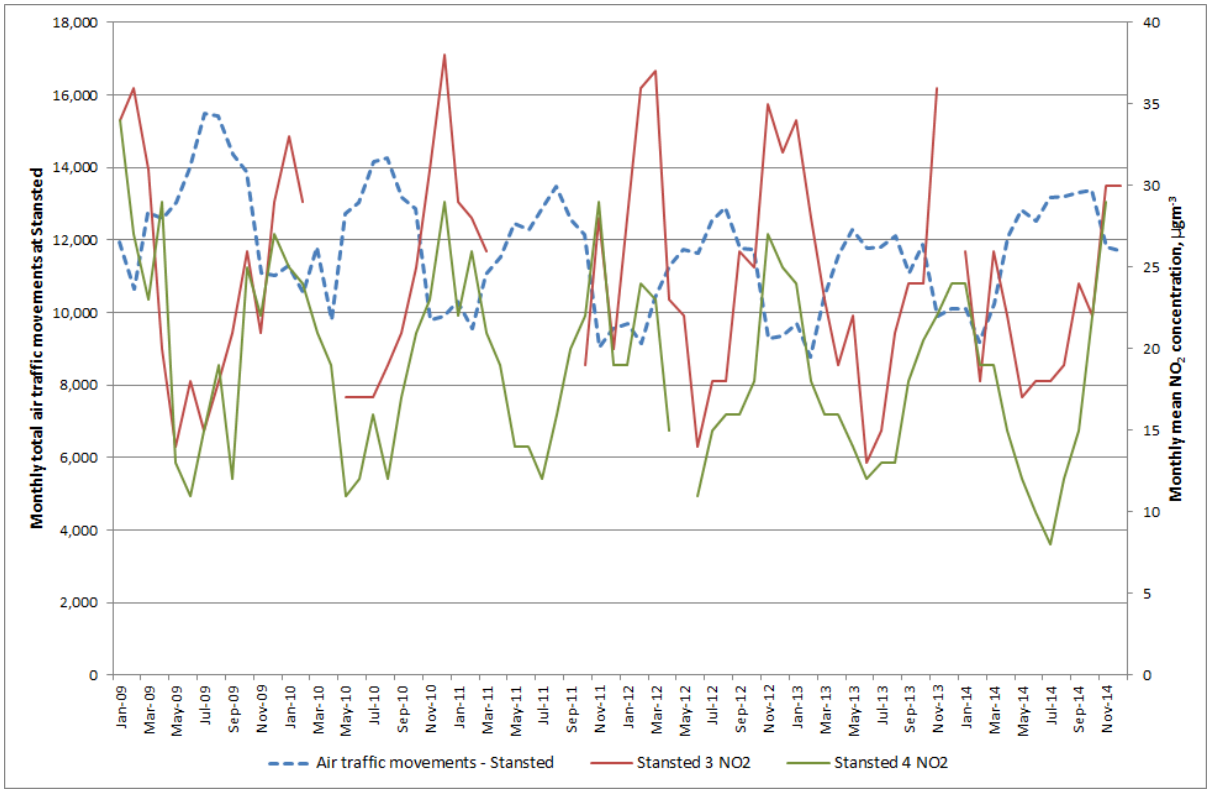

The $NO_2$ pollution rose (Figure 4.13) also shows evidence of sources close to the monitoring site. However, at higher wind speeds there is a stronger signature from the south east – the direction of the main airport terminal and surrounding access roads.

## 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 $PM_{10}$. 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 4.14 shows monthly statistics for the number of air traffic movements (ATMs) during the years 2009 to 2014. Also shown (plotted against the secondary y-axis) are monthly mean $NO_2$ concentrations at Stansted 3 and Stansted 4.

**Figure 4.14**: Monthly variation of Stansted airport activity and $NO_2$ concentration 2009-2014.




As seen last year, there is a distinct seasonal pattern indicating high air traffic 'activity' in the summer months (July and August) and a lower in the winter. Monthly mean $NO_2$ 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 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 (mainly Figures 4.12 and 4.13). 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.

### 4.7.1 Nitrogen oxides (NOx)

At Stansted 3, the highest hourly mean concentration of $NO_2$ was 132 µg $m^{-3}$. There were no periods when hourly mean $NO_2$ concentrations exceeded 200 µg $m^{-3}$, which is the AQS objective for hourly mean $NO_2$. The lower threshold of the Defra "Moderate" air quality band is 201 µg $m^{-3}$ for hourly means. Therefore $NO_2$ levels at Stansted 3 stayed within the Defra "Low" band for the whole year and there were no periods of high $NO_2$ at Stansted 3.

At Stansted 4, there were no hourly mean $NO_2$ concentrations exceeding 200 µg $m^{-3}$. Therefore $NO_2$ levels at Stansted 4 also stayed within the Defra "Low" band for the whole year and there were no periods of high $NO_2$ at Stansted 4.

### 4.7.2 Particulate Matter ($PM_{10}$)

At Stansted 3, there were five days where daily mean $PM_{10}$ (after VCM correction) exceeded the AQS objective of 50 µg $m^{-3}$.

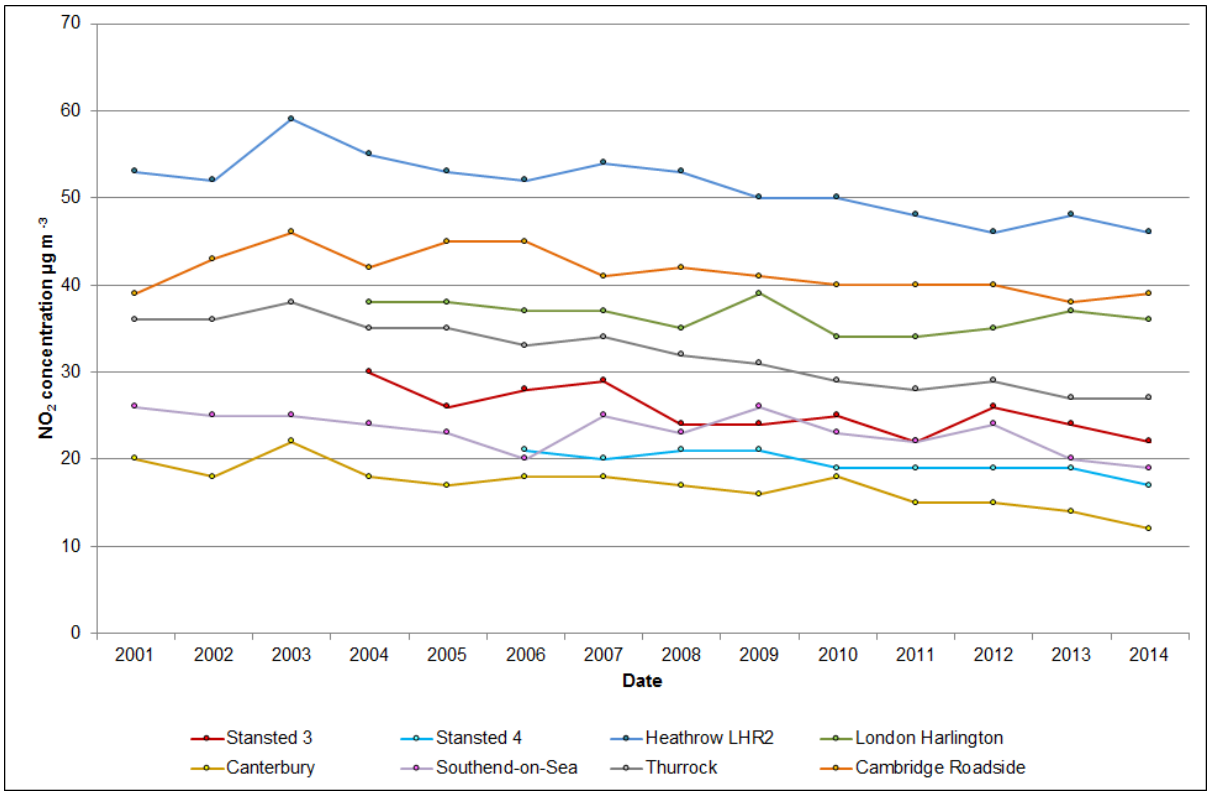
The daily mean $PM_{10}$ was exceeded on March 13th, 14th, 29th and on the 2nd and 3rd of April. All this days are within the two outbreaks of high air pollution that were previously mentioned and identified in 2014. Excluding this atypical high pollution episodes, registered $PM_{10}$ daily mean has recorded values always bellow 50 µg $m^{-3}$, the daily limit value for $PM_{10}$.

## 4.8 Comparison with other UK sites

Figure 4.15 provides a comparison between annual mean pollutant $NO_2$ levels at the Stansted sites and corresponding measurements made at six other monitoring stations (2001 to 2014). 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 website[13].

**Figure 4.15:** Annual mean trend $NO_2$ concentrations at Stansted 3, Stansted 4 and other regional monitoring sites.




In recent years, annual mean concentrations of $NO_2$ 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.

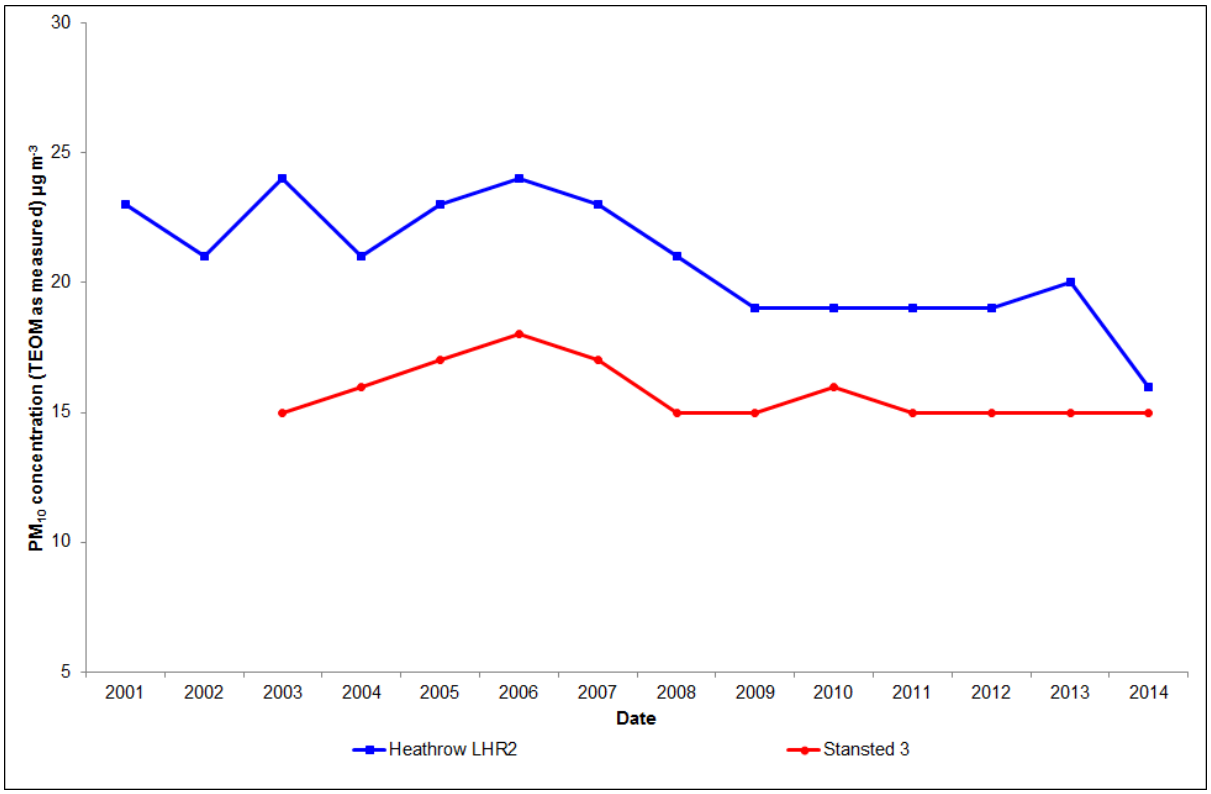
Both Stansted sites have consistently reported lower concentrations than those recorded at London Harlington, Heathrow LHR2, Thurrock, and Cambridge Roadside. Annual mean $NO_2$ concentrations at Stansted 3 have exhibited a slight general decrease since 2004, reducing the gap between this site and Stansted 4, which has stayed largely constant.

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 $NO_2$ concentrations. The site (like many other urban roadside sites in the UK) has consistently recorded annual mean $NO_2$ concentrations in excess of 38 µg $m^{-3}$, substantially higher than those observed at either of the Stansted sites.

The data collected in 2014 shows that there is a slight general decrease of $NO_2$ concentrations in most of the analysed monitoring sites. Only Thurrock and Cambridge roadside sites seem to escape from this tendency, having registered a small increase of $NO_2$ concentrations, in comparison with the results from 2013.

Figure 4.16 shows annual mean $PM_{10}$ concentrations at Stansted 3 and the London Heathrow site LHR2. These are "as measured" data without VCM correction.

**Figure 4.16**: Annual mean $PM_{10}$ concentrations at Stansted 3 and Heathrow LHR2.




Concentrations of $PM_{10}$ at Stansted 3 continue to be lower than those measured at LHR2. Since 2004, the two lines have been showing very similar patterns from one year to the next. This year was slightly different, with Heathrow having registered a decrease on $PM_{10}$ annual mean concentration. $PM_{10}$ annual mean concentration at Stansted 3 continues to present similar values since 2008.

# 5 Conclusions

The following conclusions have been drawn from the results of air quality monitoring at Stansted Airport during 2013.

1. The data capture target of least 90 % was achieved for all the measured pollutants in both sites (Stansted 3 and Stansted 4).

2. Stansted 3 and Stansted 4 met the AQS objectives for 1-hour mean $NO_2$ concentrations.

3. All five $NO_2$ 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 $PM_{10}$ concentration.

5. At Stansted 3, as mentioned above, unusual high levels of $PM_{10}$ were recorded over 5 days in March/April 2013. High concentrations were attributed to trans-boundary air pollution episodes.

6. NO and $NO_2$ concentrations were higher during the winter months at both Stansted 3 and Stansted 4. This is a typical pattern for urban sites. $PM_{10}$ levels showed a peak in March and September.

7. Concentrations of NO and $NO_2$ followed a characteristic diurnal pattern, with peaks coinciding with the morning and evening rush hour periods. $PM_{10}$ concentrations showed no marked diurnal variation.

8. Bivariate plots of pollutant concentrations against meteorological data indicated that sources of NOx were located close to the monitoring sites and were probably associated with the airport. $PM_{10}$ analysis seems to indicate the presence of several sources for this pollutant (both local and regional).

9. Annual mean concentrations of $NO_2$ at Stansted 3 and Stansted 4 were similar to those measured at similar urban background sites such as Canterbury, Southend-on-Sea and Thurrock. Annual $PM_{10}$ means at both sites have slightly decreased in comparison with last year's measurements. $PM_{10}$ concentrations (as measured) at Stansted 3 were slightly lower than those for London Heathrow Airport.

# 6 Acknowledgements

Ricardo-AEA would like to thank Stansted Airport Ltd, particularly Duncan Smith and Liz Brassington for assistance with this monitoring study

# 7 References

1- Directive 2008/50/EC of the European Parliament and of the Council of 21st May 2008 on ambient air quality and cleaner air for Europe [online]. Official Journal of the European Communities L152/1. Available at: http://ec.europa.eu/environment/air/quality/legislation/directive.htm [accessed 10th March 2015].

2- Department for Environment, Food and Rural Affairs (2007). The Air Quality Strategy for England, Scotland, Wales and Northern Ireland (Volume 1) [online]. London, UK: Department for Environment, Food and Rural Affairs in partnership with the Scottish Executive, Welsh Assembly Government and Department of the Environment Northern Ireland. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69336/pb12654-air-quality-strategy-vol1-070712.pdf [Accessed 10th March 2015]. Also original Air Quality Strategy published 2000 and addendum 2003.

3-Air Quality Expert Group (2004) **Nitrogen dioxide in the United Kingdom** [online]. London, UK: Department for Environment, Food and Rural Affairs. Available at: http://uk-air.defra.gov.uk/library/aqeg/publications [Accessed 10th March 2015].

4-Department for Environment, Food and Rural Affairs (2009). **Part IV of the Environment Act 1995. Local air quality management – Technical Guidance LAQM.TG (09)** [online]. London, UK: Department for Environment, Food and Rural Affairs in partnership with the Scottish Executive, Welsh Assembly Government and Department of the Environment Northern Ireland. Available at http://archive.defra.gov.uk/environment/quality/air/airquality/local/guidance/documents/tech-guidance-laqm-tg-09.pdf [Accessed 10th March 2015].

5-National Atmospheric Emissions Inventory (2013). NAEI UK National Atmospheric Emissions Inventory [online]. Available at http://naei.defra.gov.uk/ [Accessed 18th February 2014]

6 -Harrison D (2006). UK equivalence programme for monitoring of particulate matter [online]. London, UK:Bureau Veritas, BV/AQ/AD202209/DH/2396. Available at http://uk-air.defra.gov.uk/assets/documents/reports/cat05/0606130952_UKPMEquivalence.pdf [Accessed 10th March 2015].

7-King's College London (2012). Volatile Correction Model (VCM) [online]. Available at http://www.volatile-correction-model.info/Default.aspx [Accessed 10th March 2015].

8- Department for Environment, Food and Rural Affairs (2009). QA/QC procedures for the UK Automatic and Urban Rural Air Quality Monitoring Network (AURN) [online]. London, UK: Department for Environment, Food and Rural Affairs and the Devolved Administrations. Available at: http://uk-air.defra.gov.uk/reports/cat13/0910081142_AURN_QA_QC_Manual_Sep_09_FINAL.pdf [Accessed 6th March 2015].

9- Air Quality Index. UK-air Website [online]. Available at: http://uk-air.defra.gov.uk/latest/index?date=01%2F04%2F2014#summary [Accessed 16th March 2015].

10- Data archive (PM10 monthly means). UK-air website. [Online]. Available at: http://uk-air.defra.gov.uk/data/exceedence?f_exceedence_id=S6&f_year_start=2014&f_year_end=2014&f_group_id=4&f_region_reference_id=1&f_sub_region_id=9999&f_output=screen&f_parameter_id=GE10&action=exceedence3&go=Go [Accessed 16th March 2015].

11-Air Quality News [online]. Available at: http://www.airqualitynews.com/2015/03/09/significant-rise-in-doctor-visits-during-2014-pollution/ [Accessed 16th March 2015].

12- Air Resources Laboratory. NOOA website [online]. Available at http://ready.arl.noaa.gov/HYSPLIT.php [Accessed 16th March 2015].

13-Heathrow Airwatch (2014). **Air quality at Heathrow** [online]. Available at http://www.heathrowairwatch.org.uk/ [Accessed 13th March 2015].

# Appendices

Appendix 1: Air Quality objectives and index bands.

Appendix 2: Monitoring apparatus and techniques.

Appendix 3: Quality assurance and Quality control.

Appendix 4: $NO_2$ 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 do be achieved by |
|---|---|---|---|
| | Concentration | Measured as | |
| **Benzene**<br>All authorities | 16.25 µg $m^{-3}$ | Running annual mean | 31/12/2003 |
| England and Wales only | 5.00 µg $m^{-3}$ | Annual mean | 31/12/2010 |
| Scotland and Northern Ireland | 3.25 µg $m^{-3}$ | Running annual mean | 31/12/2010 |
| **1,3-Butadiene** | 2.25 µg $m^{-3}$ | Running annual mean | 31/12/2003 |
| **Carbon monoxide**<br>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 µg $m^{-3}$ | Annual mean | 31/12/2004 |
| | 0.25 µg $m^{-3}$ | Annual mean | 31/12/2008 |
| **Nitrogen dioxide** | 200 µg $m^{-3}$ not to be exceeded more than 18 times a year | 1-hour mean | 31/12/2005 |
| | 40 µg $m^{-3}$ | Annual mean | 31/12/2005 |
| **Particles ($PM_{10}$) (gravimetric)**<br>All authorities | 50 µg $m^{-3}$, not to be exceeded more than 35 times a year | 24-hour mean | 31/12/2004 |
| | 40 µg $m^{-3}$ | Annual mean | 31/12/2004 |
| Scotland | 50 µg $m^{-3}$, not to be exceeded more than 7 times a year | 24-hour mean | 31/12/2010 |
| | 18 µg $m^{-3}$ | Annual mean | 31/12/2010 |
| **Particles ($PM_{2.5}$) (gravimetric)***<br>All authorities | 25 µg $m^{-3}$ (target) | Annual mean | 2020 |
| | 15% cut in urban background exposure | Annual mean | 2010-2020 |
| Scotland only | 12 µg $m^{-3}$ (limit) | Annual mean | 2020 |

| | | | |
|---|---|---|---|
| **Sulphur dioxide** | 350 µg $m^{-3}$, not to be exceeded more than 24 times a year | 1-hour mean | 31/12/2004 |
| | 125 µg $m^{-3}$, not to be exceeded more than 3 times a year | 24-hour mean | 31/12/2004 |
| | 266 µg $m^{-3}$, 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 µg $m^{-3}$ 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 do be achieved by |
|---|---|---|---|
| | Concentration | Measured as | |
| Nitrogen oxides measured as $NO_2$ | 30 µg $m^{-3}$ | Annual mean | 31st December 2000 |
| Sulphur dioxide | 20 µg $m^{-3}$ | Annual mean | 31st December 2000 |
| | 20 µg $m^{-3}$ | Winter average (October to March) | 31st December 2000 |
| Ozone | 18 µg $m^{-3}$ | 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 µg $m^{-3}$ (= 40 ppb) and 80 µg $m^{-3}$ 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 | $O_3$ Daily max 8-hour mean (µg $m^{-3}$)* | $NO_2$ Hourly mean (µg $m^{-3}$) | $SO_2$ 15 minute mean (µg $m^{-3}$) | $PM_{2.5}$ 24 hour mean (µg $m^{-3}$) | $PM_{10}$ 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 | 888-1,064 | 65-70 | 92-100 |
| Very High | 10 | 241 or more | 601 or more | 1,065 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, $NO_2$: chemiluminescence with ozone.
- $PM_{10}$: tapered element oscillating microbalance (TEOM).

These methods were selected in order to provide real-time data. The chemiluminescence analyser is the European reference method for ambient $NO_2$ 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-AEA. The data are then converted to concentration units and averaged to hourly mean concentrations.

The chemiluminescence analysers for NOx 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 $PM_{10}$ 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 $PM_{10}$ 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 $PM_{10}$ from the TEOM; this value is then added back onto the TEOM measurements.

## 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 $m^{-3}$
- $NO_2$ 1 ppb = 1.91 µg $m^{-3}$

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

NOx µg $m^{-3}$ = (NO ppb + $NO_2$ ppb) *x* 1.91.

This complies with the requirements of the Air Quality Directive[1] and is also the convention generally adopted in air quality modelling.

# Appendix 3 – Quality assurance and quality control

Ricardo-AEA 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 manual[8].

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-AEA. 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-AEA'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 NOx monitor, the efficiency of the $NO_2$ 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-AEA. 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-AEA 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 %. |

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

# Appendix 4 – $NO_2$ 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 $NO_2$ 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 |
|---|---|---|---|---|---|
| 31/12/2013 | 22.46 | 20.03 | 22.90 | 21.80 | - |
| 05/02/2014 | 22.75 | 20.09 | 21.28 | 21.37 | - |
| 05/03/2014 | 24.28 | 24.78 | 24.37 | 24.48 | - |
| 03/04/2014 | 23.13 | 22.17 | 20.33 | 21.87 | - |
| 30/04/2014 | 19.61 | 18.61 | 19.91 | 19.38 | - |
| 28/05/2014 | 21.11 | 19.84 | 21.78 | 20.91 | - |
| 02/07/2014 | 22.36 | 24.03 | 22.86 | 23.08 | - |
| 30/07/2014 | 20.68 | 20.62 | 20.81 | 20.70 | - |
| 27/08/2014 | 21.90 | 21.79 | 24.53 | 22.74 | - |
| 01/10/2014 | 27.58 | 26.89 | 27.71 | 27.39 | - |
| 29/10/2014 | 21.12 | 23.12 | 20.77 | 21.67 | - |
| 03/12/2014 | 29.16 | 30.59 | 29.88 | 29.88 | - |

**Table A4.2:** Monthly mean $NO_2$ 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 |
|---|---|---|---|---|---|
| 31/12/2013 | 28.17 | 29.55 | 22.49 | 26.74 | - |
| 05/02/2014 | 24.75 | 29.54 | 27.33 | 27.21 | - |
| 05/03/2014 | 23.36 | 22.46 | 23.27 | 23.03 | - |
| 03/04/2014 | 14.33 | 14.90 | 16.26 | 15.16 | - |
| 30/04/2014 | 15.88 | 13.24 | 14.53 | 14.55 | - |
| 28/05/2014 | 13.32 | 12.28 | 13.21 | 12.94 | - |
| 02/07/2014 | 10.48 | 10.99 | 12.36 | 11.28 | - |
| 30/07/2014 | 16.55 | 15.20 | 13.83 | 15.19 | - |
| 27/08/2014 | 14.77 | 16.17 | 13.87 | 14.94 | - |
| 01/10/2014 | 33.28 | 38.52 | 31.53 | 34.44 | - |
| 29/10/2014 | 26.55 | 25.83 | 25.69 | 26.02 | - |

| | | | | | |
|---|---|---|---|---|---|
| 03/12/2014 | 29.14 | 26.02 | 25.89 | 27.02 | |

**Table A4.3:** Monthly mean $NO_2$ concentrations as measured by diffusion tubes, Stansted East (Enterprise House offices) (µg $m^{-3}$).

| Start date | Tube 1 | Tube 2 | Tube 3 | Mean | Comments |
|---|---|---|---|---|---|
| 31/12/2013 | 28.33 | 29.65 | 30.19 | 29.39 | - |
| 05/02/2014 | 31.48 | 29.86 | 29.88 | 30.41 | - |
| 05/03/2014 | 35.90 | 33.05 | 33.31 | 34.09 | - |
| 03/04/2014 | 25.22 | 26.19 | 27.56 | 26.32 | - |
| 30/04/2014 | 25.72 | 25.36 | 24.73 | 25.27 | - |
| 28/05/2014 | 20.89 | 18.84 | 22.31 | 20.68 | - |
| 02/07/2014 | Rejected | 23.15 | 23.99 | 23.57 | Low outlier of 17.72 µg $m^{-3}$ rejected |
| 30/07/2014 | 27.01 | 28.03 | 23.70 | 26.25 | - |
| 27/08/2014 | 26.89 | 30.56 | 29.35 | 28.93 | - |
| 01/10/2014 | 33.08 | 31.24 | 33.32 | 32.55 | - |
| 29/10/2014 | 24.26 | 28.59 | 31.23 | 28.03 | - |
| 03/12/2014 | 44.44 | 47.67 | Rejected | 46.06 | Low outlier of 35.57 µg $m^{-3}$ rejected |

**Table A4.4:** Monthly mean $NO_2$ 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 |
|---|---|---|---|---|---|
| 31/12/2013 | 23.19 | 24.98 | 23.97 | 24.05 | - |
| 05/02/2014 | 27.52 | 27.38 | 25.91 | 26.94 | - |
| 05/03/2014 | 33.94 | 32.21 | 32.25 | 32.80 | - |
| 03/04/2014 | 29.21 | 25.17 | 27.28 | 27.22 | - |
| 30/04/2014 | 20.30 | 19.66 | 21.39 | 20.45 | - |
| 28/05/2014 | 21.34 | 20.99 | 20.61 | 20.98 | - |
| 02/07/2014 | 23.56 | 22.40 | 23.26 | 23.07 | - |
| 30/07/2014 | 22.77 | 23.24 | 21.68 | 22.56 | - |
| 27/08/2014 | 29.18 | 30.36 | 30.13 | 29.89 | - |
| 01/10/2014 | 27.03 | 28.25 | 26.60 | 27.29 | - |
| 29/10/2014 | 24.76 | 29.77 | 24.11 | 26.21 | - |
| 03/12/2014 | 31.07 | 30.34 | 31.65 | 31.02 | - |

**Table A4.5:** Monthly mean $NO_2$ 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 |
|---|---|---|---|---|---|
| 31/12/2013 | 25.20 | 22.53 | 23.99 | 23.91 | - |
| 05/02/2014 | 22.50 | 22.53 | 22.75 | 22.59 | - |
| 05/03/2014 | 24.64 | 25.83 | 24.06 | 24.84 | - |
| 03/04/2014 | 18.48 | 15.63 | 17.36 | 17.15 | - |
| 30/04/2014 | 18.04 | 17.87 | 17.29 | 17.73 | - |
| 28/05/2014 | 12.40 | 13.97 | 13.46 | 13.28 | - |
| 02/07/2014 | 10.75 | 10.95 | 11.12 | 10.94 | - |
| 30/07/2014 | 12.06 | 12.96 | 13.44 | 12.82 | - |
| 27/08/2014 | 12.89 | 14.61 | 14.94 | 14.15 | - |
| 01/10/2014 | 22.11 | 20.15 | 23.05 | 21.77 | - |
| 29/10/2014 | 26.21 | Rejected | 23.13 | 24.67 | Low outlier of 14.93 µg $m^{-3}$ rejected |
| 03/12/2014 | 21.74 | 20.03 | 19.48 | 20.42 | - |

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