RICARDO-AEA

Air Quality Monitoring at Heathrow Airport – Annual Report for 2014

Report for Heathrow Airport Ltd

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Executive summary

This report provides details of air quality monitoring conducted around Heathrow Airport during 2014. The work, carried out by Ricardo-AEA on behalf of Heathrow Airport Ltd, is a continuation of monitoring undertaken at Heathrow Airport since 1993. The aims of the programme are to monitor air pollution around the airport, to assess compliance with relevant national air quality objectives, and to investigate changes in air pollutant concentrations over time.

Automatic continuous monitoring was carried out at four locations, referred to as LHR2, London Harlington, Green Gates and Oaks Road. LHR2 is located on the northern apron, between the airport boundary and the northern runway, London Harlington is located at the Imperial College Sports Ground, 1 km north of LHR2, Green Gates was located near the north western airport perimeter and Oaks road, on a residential location to the south west.

All sites monitored oxides of nitrogen (nitric oxide and nitrogen dioxide) and Particulate Matter (PM_{10} and $PM_{2.5}$). The PM_{10} data recorded for LHR2,Green Gates and Oaks Road during the interval (1st of January - 23rd of June) was measured using a Tapered Element Oscillating Microbalance (TEOM) particulate monitor, and therefore were adjusted using the King's College London Volatile Correction Model to correct for potential losses of volatile and semi-volatile components. PM_{10} and $PM_{2.5}$ instruments at all four stations were upgraded to FIDAS instruments in June 2014. All old TEOM instruments were removed. London Harlington is affiliated in the Defra AURN network therefore the equivalent TEOM FDMS instruments remain on site until the FIDAS instruments complete equivalence performance tests trials. Ozone measurements were undertaken at London Harlington and Black Carbon (BC) monitoring was undertaken for the first time at LHR2 and Oaks Road using Aethalometer instruments.

In addition to automatic monitoring, indicative passive monitoring of VOC's was carried out at Heathrow LHR2 using diffusion tubes from January to April 2014.

The minimum applicable data capture target of 90% (from the European Commission Air Quality Directive[3]) was achieved for all the station NO_x and BC instruments. PM_{10} and O_3 data capture target was not achieved at Harlington (87.7 and 84.3% respectively). $PM_{2.5}$ data capture was not achieved at the LHR2 site (62%), the LHR2 site $PM_{2.5}$ instrument incurred a critical fault, it was decided the PM instruments were to be replaced and upgraded therefore the decision was made not to fund repairs for the older TEOM.

The UK AQS hourly mean objective for NO_2 is 200 $\mu g\ m^{-3}$, with no more than 18 exceedances allowed each year. All the sites met this objective, with no hourly means recorded above this value.

The annual mean AQS objective for NO_2 is 40 $\mu g\ m^{-3}$. This was met at Harlington, Green Gates and Oaks Road. At LHR2, an annual mean of 46 $\mu g\ m^{-3}$ was registered, however, the AQS objectives and EU limit values do not apply for this site. LHR2 is located within the airport premises, where members of the public do not have access.

PM_{10} may exceed the 24-hour mean limit of 50 $\mu g\ m^{-3}$ no more than 35 times per year to meet the AQS objective. During 2014, 5 to 7 exceedances to the limit value were registered at each site. This AQS objective was therefore met for all sites. The annual mean AQS for PM_{10} is 40 $\mu g\ m^{-3}$. This objective was met at all the monitoring stations.

The Harlington station met the AQS objective for ozone in 2014.

Table ES-1 shows an overall summary of the AQS objective and data capture statistics recorded in 2014 at the Heathrow network, green shaded cells demonstrate the objective or requirement has been met whilst red shaded cells show failure to meet requirements.

Table ES-1- Summary of AQS Objective Compliance and Data Capture

Site name	Grid reference	Data Capture (%)	Annual Mean (µg m^{-3})	Hourly (NO_2), Running 8 Hour (O_3), Daily (PM_{10}) Objective Exceedances
LHR2 NO_2	508400	95.3	46	0
LHR2 PM_{10}	176750	95.2	19	7
LHR2 $PM_{2.5}$	-	62.4	10	N/A
Harlington NO_2	508299	95.2	36	0
Harlington PM_{10}	177809	87.7	20	5
Harlington $PM_{2.5}$	-	96.4	14	N/A
Harlington O_3	-	84.3	39	8
Green Gates NO_2	505630	96.7	35	0
Green Gates PM_{10}	176930	98.5	17	5
Green Gates $PM_{2.5}$	-	99.1	10	N/A
Oaks Road NO_2	505740	99.3	33	0
Oaks Road PM_{10}	174500	96.9	18	7
Oaks Road $PM_{2.5}$	-	97.4	10	N/A

Average concentrations of NO, NO_2, PM_{10}, $PM_{2.5}$ and ozone at the Heathrow sites were generally comparable to those measured at urban background air pollution monitoring sites in London.

Black Carbon data collected for the first time at LHR2 and Oaks Road shows good agreement with comparable stations in London.

The pattern of monthly averaged concentrations throughout the year showed that concentrations of the primary pollutant NO were typically highest in the winter months. NO_2, which has both primary and secondary components, showed a similar pattern. PM_{10} and $PM_{2.5}$ showed a much less pronounced seasonal pattern, which is quite common for particulates in urban areas. Ozone (measured at Harlington only) showed higher concentrations in the spring and summer. This is a typical seasonal pattern for ozone, which is formed from other pollutants in the presence of sunlight.

Modelled wind speed and wind direction data from the London Harlington location were used to investigate there effects on pollutant concentrations and potential sources. Bivariate plots of pollutant concentration indicated that nearby sources, such as the perimeter road, were probably the main source of NO. There were also high NO concentrations at greater wind speeds from the south west and north east. With regards to NO_2, there also appeared to be a contribution from the south west at higher wind speeds, possibly indicating a major source further away. In this direction are the Terminal 5, the Central Terminal Area (CTA) and the M25. For both PM_{10} and $PM_{2.5}$, concentrations were high under calm conditions but (particularly for PM_{10}) there also appeared to be contributions from the north west and south west at a range of wind speeds. Ozone measured at Harlington registers low levels near the site and high levels far away from the site, for higher wind speeds. Bivariate plots of Black Carbon data indicate readings were higher under calmer conditions suggesting local emission sources were probably the main source.

Several high pollution episodes occurred during 2014. At all sites, particularly high concentrations of PM_{10} were recorded in March (13th, 14th and 28th, 29th) and April (2nd, 3rd). 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.

In the long term, annual mean concentrations of total oxides of nitrogen and NO appear to show a general decrease over the past decade at LHR (although there is considerable year-to-year fluctuation). The trend for NO_2 is less clear, the proportion of NO_x measured as NO_2 has increased over the last decade, but have stabilised since 2011. The annual mean concentrations of PM_{10} have decreased for all sites in 2014 this is thought to have been partly due to the change in instrumentation from TEOM to FIDAS from June 2014 onwards. Decreases in long terms trends can be seen when installing new instruments techniques due to general improvements in measurement performance. Annual means are generally consistent with those measured at other sites in London. There is a slight increase of ozone (monitored at Harlington only), following a trend started in 2012.

Although the airport is a material contributor to local air pollutant concentrations, there appears to be no relationship between air traffic movements and ambient pollutant concentrations, either on a seasonal or long-term basis. This indicates that variations in ambient concentration are mainly driven by other factors (such as variations in meteorological conditions and emissions from non-airport sources such as road transport and stationary combustion processes). Air quality in the wider region can also be significantly influenced by long-range trans-boundary air pollution.

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1 Introduction

1.1 Background

Heathrow Airport is the world's busiest 2 runway international airport, handling approximately 73.4 million passengers in 2014. The airport is situated approximately 12 miles to the west of London, but within the general urbanised area of Greater London.

Airports are potentially significant sources of many air pollutants. Aircraft jet engines emit pollutants including oxides of nitrogen (NOx), carbon monoxide (CO), oxides of sulphur (SOx), particulate matter, hydrocarbons from partially combusted fuel, and other trace compounds. There are also pollutant emissions from the airside vehicles, and from the large number of road vehicles travelling to and from the airport each day. Also, Heathrow Airport is situated in an urban area, containing many domestic, commercial and industrial sources of pollution.

Heathrow Airport Ltd therefore carries out monitoring of ambient air quality at four sites around the airport: on the northern apron near the perimeter and northern runway (site LHR2), and outside the airport boundary at Harlington, Green Gates and Oaks Road.

The pollutants monitored at these sites:

- Oxides of nitrogen (nitric oxide (NO) and nitrogen dioxide (NO_2));
- Particulate matter (PM_{10} and $PM_{2.5}$ fractions);
- Ozone (O_3);
- Volatile organic compounds (VOCs) – benzene, toluene, ethylbenzene and xylenes;
- Black Carbon (BC).

Ricardo-AEA was contracted by Heathrow Airport Ltd (HAL) to carry out the required programme of air pollution measurements during 2014, the 22nd continuous year of monitoring, and this report presents and summarises the fully validated and quality controlled dataset for the period 1st January to 31st December 2014.

In addition to this report, HAL has daily access to provisional data from its monitoring sites via their own Heathrow Airwatch website[1] and data from the UK's national air quality monitoring network, through the Defra UK Air Information Resource (UK-AIR) [2].

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.

1.2 Aims and Objectives

The aim of this monitoring programme is to monitor concentrations of several important air pollutants around the airport. The results of the monitoring are used to assess whether applicable national air quality objectives have been met, and how pollutant concentrations in the area have changed over time. Additionally, meteorological data were used to investigate the importance of various sources of pollution.

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

Monitoring data collected at Heathrow 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.

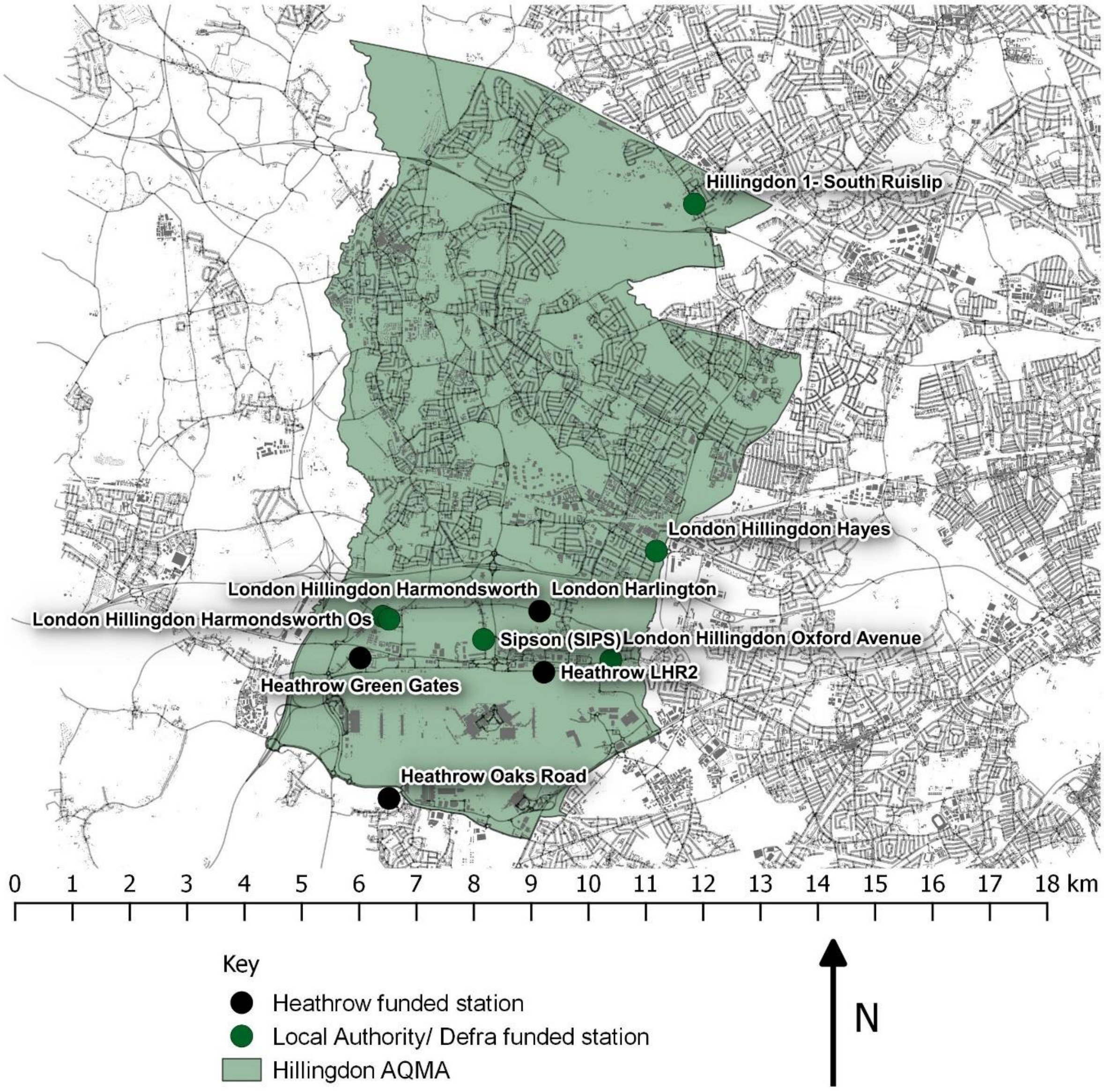
In addition, periods of relatively high pollutant concentrations are examined in more detail.

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[3], 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[4], and the currently applicable air quality objectives are summarised in Appendix 1 of this report. Figure 1.1 shows a map of Hillingdon AQMA.

Figure 1.1 – Map of Hillingdon AQMA



2 Air quality monitoring

2.1 Pollutants monitored

2.1.1 Nitrogen Oxides (NO_x)

Combustion processes emit a mixture of oxides of nitrogen – NO and NO_2 - 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 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 NO_x 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) [5] has stated that: "*Around a third of all NO_x emissions from the aircraft (including ground-level emissions from auxiliary power units, engine testing etc., as well as take-off and landing) occur below 100 m in height. The remaining two-thirds occur between 100 m and 1000 m and contribute little to ground-level concentrations. Receptor modelling studies show the impact of airport activities on ground-level NO_2 concentrations. Studies have shown that although emissions associated with road traffic are smaller than those associated with aircraft, their impact on population exposure at locations around the airport are larger*". Previous rounds of review and assessment within the 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[5].

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

Airborne particulate matter varies widely in its physical and chemical composition, source and particle size. The terms PM_{10} and $PM_{2.5}$ is used to describe particles with an effective size less than 10 and 2.5 µm respectively. 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[6].

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}.

2.1.3 Volatile Organic Compounds (VOC's)

Volatile organic compounds (VOCs) include a wide range of carbon-based chemical species. These can be present either in the gaseous phase, or carried by particulate matter. The main UK sources of volatile organic compounds are solvent use, and the extraction and distribution of fossil fuels[3]. VOCs are also emitted from incomplete combustion of fuels in vehicles and other combustion processes.

It is not easy to measure all of these hydrocarbon species (particularly the most volatile) without expensive continuous monitoring systems. However, there are four moderately volatile species, all of which may be associated with fuels and vehicle emissions, which are easy to monitor using passive samplers. These are benzene, toluene, ethylbenzene and xylenes. They are not the largest constituents of vehicle emissions, but due to their moderate volatility they can be monitored using simple diffusive samplers.

(i) Benzene

Of the above four hydrocarbons, benzene is of greatest concern, as it is a known human carcinogen. The major source of benzene in ambient air is the evaporation and combustion of petroleum-based fuels. Data from the NAEI[6] for 2011 indicate that civil aircraft taking off and landing are estimated to make a negligible contribution to total UK benzene emissions. Benzene is the only one of the above compounds for which there are mandatory limit values or objectives for ambient concentrations.

(ii) Toluene

The main use of toluene is as a solvent in paints and inks. It also occurs in petrol in small concentrations. Toluene has been found to adversely affect human health, and there are occupational limits for workplace exposure, but no mandatory limits on outdoor ambient concentrations.

(iii) Ethylbenzene

Again, there are no limits for ambient concentration of ethylbenzene. Although there are occupational limits relating to workplace exposure, these are several orders of magnitude higher than typical outdoor ambient concentrations.

(iv) Xylenes

Xylene exists in ortho (o), para (p) and meta (m) isomers. There are no limits for ambient concentration of xylenes, although (as in the case of toluene and ethylbenzene) there are occupational limits relating to workplace exposure. Xylene is used as a solvent, and can cause odour nuisance near processes which use it (such as vehicle paint spraying).

2.1.4 Ozone (O_3)

Ozone (O_3) is not emitted directly into the atmosphere in significant quantities, but is a secondary pollutant produced by reaction between nitrogen dioxide (NO_2) and hydrocarbons, in the presence of sunlight. Whereas nitrogen dioxide (NO_2) contributes to ozone formation, nitrogen oxide (NO) destroys ozone and therefore acts as a local sink. For this reason, ozone levels are not as high in urban areas (where NO is emitted from vehicles) as in rural areas. Ozone levels are usually highest in rural areas, particularly in hot, still, sunny weather conditions giving rise to "summer smog".

2.1.5 Black Carbon (BC)

Black Carbon (BC) is the strongest light-absorbing component of particulate matter. It is a primary aerosol, emitted directly at the source, as a result of incomplete combustion of fossil fuels (automobile exhaust, industrial and power plant exhaust, aircraft emissions, etc.) and biomass burning (burning of agricultural wastes, forest fires).Therefore, much of atmospheric BC is of anthropogenic origin. Exposure to BC is of great concern with regard to human health, since it's linked to health impacts such as cardiopulmonary morbidity and mortality, cancer and respiratory diseases. Reductions in exposure to particles containing BC will consequently reduce such adverse health impacts.

2.2 Monitoring sites and Methods

2.2.1 Sites locations

Automatic monitoring was carried out at four sites during 2014. These are referred to as LHR2, London Harlington, Green Gates and Oaks Road (the numbering of the sites continues the sequence used for previous short-term sites in earlier monitoring studies). The location descriptions of the sites fall into the category "other" as defined by the Defra Technical Guidance on air quality monitoring LAQM.TG(09)[7], (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*").

The pollutants that were monitored at each monitoring site are shown in Table 2.1. The LHR2 site has been in operation since 1993; the Harlington site commenced in 2003. The Green Gates and Oaks Road sites were originally set up for monitoring in connection with the Terminal 5 Construction Impact

Assessment in 2001, but were retained as part of the ongoing monitoring programme from 2007 onwards. Figure 2.1 shows a map of the locations of all monitoring sites used in this study.

Table 2.1 - Description of air quality monitoring sites at Heathrow

Site name	Description	Grid Reference	Pollutant	Date pollutant started
LHR2	Old northern apron	508400 176750	NO_x PM_{10} $PM_{2.5}$ BC MET (WS and WD)*	01/01/1993 16/11/1994 09/12/2009 01/01/2014 01/01/1993
Harlington	Imperial College Sports Ground, 1 km North of LHR2	508299 177809	NO_x O_3 PM_{10} $PM_{2.5}$	01/01/2004 01/01/2004 01/01/2004 16/09/2008
Heathrow Green Gates	Bath Road, close to north west of airport	505630 176930	NO_x PM_{10} $PM_{2.5}$	01/07/2001 04/05/2001 19/04/2002
Heathrow Oaks Road	Residential area to South West of airport	505740 174500	NO_x PM_{10} $PM_{2.5}$ BC	01/07/2001 04/05/2001 19/04/2002 01/01/2014

*On the 23rd of February 2015, a new Lufft WS600 meteorological sensor was installed at the LHR2 site. This sensor provides records of wind direction, pressure, temperature, relative humidity and precipitation, and has replaced the previous one that was broken and beyond economic repair and thus why modelled data was used for this 2014 report.

Figure 2.1 - Map of air quality monitoring sites at Heathrow

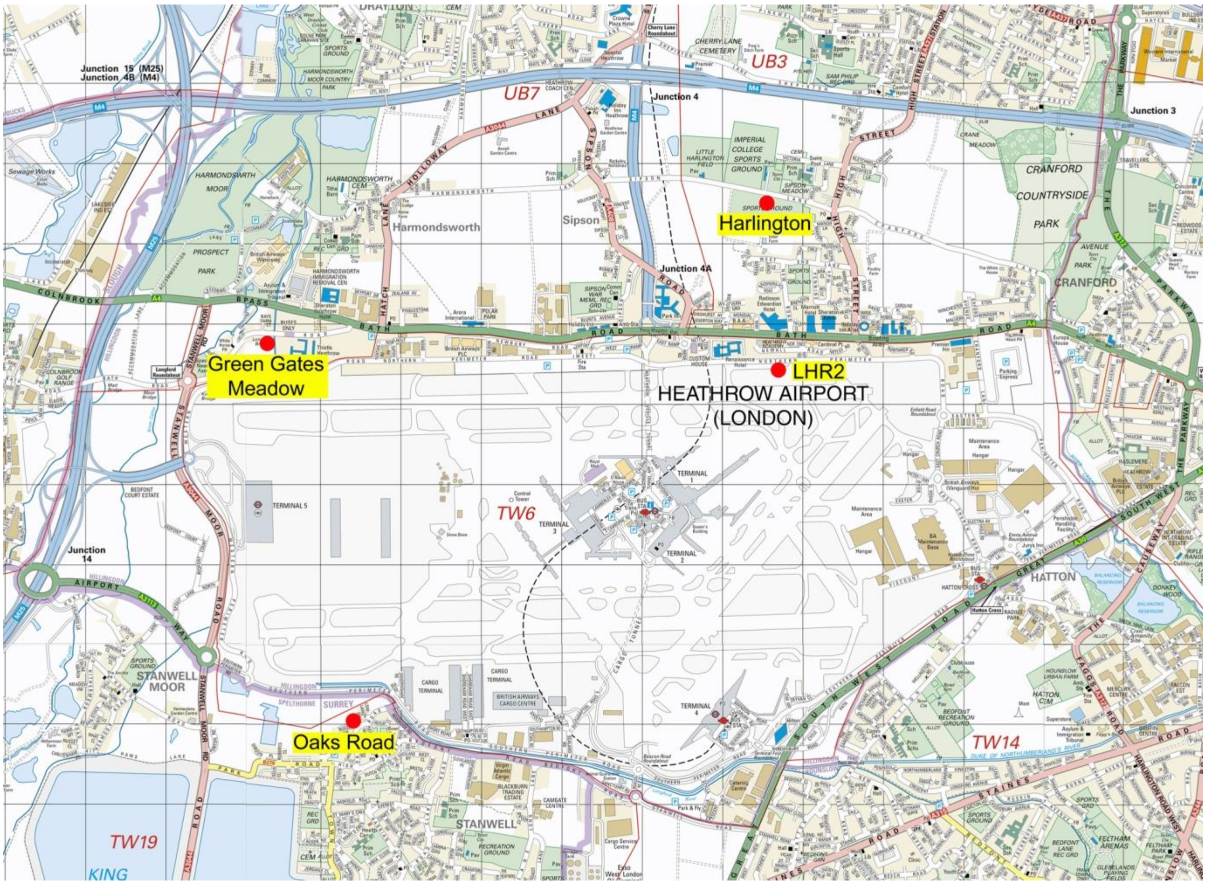


Figure 2.2 shows the LHR2 monitoring site. This is located on an area of the old apron between the northern runway and the northern perimeter road, 14.5 m from the kerb and 179 m from the runway centre. The prevailing wind direction is from the south west and hence this site, situated to the north east of the airport, was selected to monitor air pollutants arising from the airport area. The EU limit values and AQS objectives only apply to locations where public exposure may occur. As LHR2 is located within the airport premises, where members of the public do not have access, these limits do not strictly apply.

Figure 2.3 shows the Harlington site. This was established to measure air pollution concentrations in residential areas close to the airport. The site is located in the grounds of the Imperial College Sports Ground, approximately 1 km north of LHR2 and 300 m from the western edge of Harlington. Since 1st January 2004, the site has been part of the Defra Automatic Urban and Rural Network (AURN), and meets the Air Quality Directive siting criteria. Because the site is part of the national network, it is classified according to the site types defined in the Air Quality Directive: its classification of “Urban Industrial” reflects the presence of the airport.

Figure 2.4 shows the Green Gates site. This site is close to Bath Road, which runs along the northern perimeter of the airport.

Figure 2.5 shows the Heathrow Oaks Road site. This site is located in a residential area near to the south western boundary of the airport and is classified as an urban background site. Both Green Gates and Oaks Road meet the Directive criteria for urban background sites.

Figure 2.2 – Heathrow LHR2 air quality monitoring site

Figure 2.3 – London Harlington air quality monitoring site

Figure 2.4 - Green Gates air quality monitoring site

Figure 2.5 - Oaks Road air quality monitoring site

2.2.2 Automatic monitoring

The following techniques were used for the automatic monitoring of NO_x (i.e. NO and NO_2), PM, O_3 and Black Carbon (BC):

•PM_{10} and $PM_{2.5}$ - Tapered Element Oscillating Microbalance (TEOM), Filter Dynamics Measurement Systems (FDMS) and Fine dust Analysis Systems (FIDAS);

•NO, NO_2 – Chemiluminescence;

•O_3 – UV absorption analyser;

•BC – Aethalometer.

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[8].

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[9] (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 indicative monitoring of four volatile organic compounds - benzene, toluene, ethylbenzene and xylenes. These are "passive" samplers which work by absorbing the pollutants direct from the surrounding air and need no power supply. Hydrocarbon diffusion tubes of this type are referred to as “BTEX” tubes – an acronym comprising the initials of the four compounds they measure.

BTEX diffusion tubes consist of a small metal tube, approximately 9 cm long, and fitted at both ends with brass Swagelok fittings. They are packed with an absorbent material which traps the hydrocarbons to be monitored. A separate “diffusion cap” is supplied. Immediately before exposure, one Swagelok end fitting is replaced with the diffusion cap, which allows gases to diffuse into the tube but keeps the absorbent in place. The tube is then mounted vertically at the monitoring site, with the diffusion cap at the bottom. Hydrocarbons diffuse up the tube during exposure. At the end of the exposure period, the diffusion cap is removed and the tube re-sealed using the Swagelok fitting. The tube is then returned to the laboratory for analysis. 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) [10], full intercalibration audits of the HAL 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 Heathrow 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 %
O_3	± 3.0	± 15 %
PM_{10}, $PM_{2.5}$	± 4	TEOM: ± 30 % or better (estimated*) VCM-corrected TEOM data : ± 25 % (estimated*) FDMS : ± 25 % (estimated*) FIDAS : ± 25 % (estimated*)

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

Diffusion tubes for VOC should be treated as an indicative technique, with greater uncertainty than most automatic methods. Additional uncertainties arise from the exposure phase so it is usually estimated that the overall uncertainty on diffusion tube measurements is approximately ± 25% for BTEX hydrocarbons.

The limits of detection depend partly on analytical factors and partly on the exposure time. They therefore vary to some extent from month to month. During 2014 the limit of detection (LoD) varied was reported to be 5 ng (total mass on tube). Results below 10 x the limit of detection have a higher level of uncertainty.

3.2 Data capture

Data capture statistics for the four monitoring sites are given in Table 3.2. A data capture target of 90% is recommended in the European Commission Air Quality Directive[3] and Defra Technical Guidance LAQM.TG (09)[7].This is particularly important at Harlington, as data from this site feeds into the Automatic Urban and Rural Network (AURN), the UK's main network used for compliance reporting against the Ambient Air Quality Directives.

Data capture for NO_2, the main pollutant of concern, was above 90% at all locations

Table 3.2 – Data capture statistics (%) for Heathrow, 2014

Sites	NO_x	NO_2	PM_{10}	$PM_{2.5}$	BC	O_3
LHR2	95.3	95.3	95.2	62.4	93.2	-
Harlington	95.2	95.2	87.7	96.4	-	84.3
Heathrow Green Gates	96.7	96.7	98.5	99.1	-	-
Heathrow Oaks Road	99.3	99.3	96.9	97.4	91.9	-

The 90 % data capture target was therefore achieved for all the analysed pollutants at Green Gates and Oaks Road. However, data capture was below the 90 % target for $PM_{2.5}$ at LHR2 and for PM_{10} and O_3 at Harlington. Table 3.3 shows the significant gaps in data capture that occurred for all sites during the year of 2014. The programme for replacing all site analysers caused some data capture disruptions to the HAL network, this was especially the case with the $PM_{2.5}$ monitoring at LHR2 where the old TEOM incurred a critical fault a few months before the analyser replacement programme was confirmed, therefore it did not make sense to fund a costly repair on the old instrument causing a sizable data gap.

Table 3.3 – Significant data gaps (Periods > 24h) occurred at Heathrow during 2014

Site	Pollutant	Start date	End date	No. of days	Reason	Comments
Green Gates	NO_x	09/03/2014	11/03/2014	2	Analyser	Motherboard Fault
Green Gates	NO_x	13/03/2014	14/03/2014	1	Analyser	Motherboard Fault
Green Gates	NO_x	16/03/2014	21/03/2014	5	Analyser	Motherboard Fault
Green Gates	NO_x	13/05/2014	15/05/2014	2	Analyser lost configuration	Ricardo-AEA Spare analyser installed
Green Gates	PM_{10} and $PM_{2.5}$	01/08/2014	02/08/2014	1	Web logger issue	No data collected from the web logger
LHR2	NO_x	15/03/2014	21/03/2014	6	Low Voltage Power supply faulty	5 V DC power supply faulty
LHR2	NO_x	26/03/2014	27/03/2014	1	Analyser lost its settings	Ricardo-AEA Spare analyser installed

LHR2	NO$_x$	25/04/2014	28/04/2014	3	Analyser fault	Ricardo-AEA Spare analyser installed
LHR2	NO$_x$	07/05/2014	08/05/2014	1	Analyser fault	Ricardo-AEA Spare analyser installed
LHR2	NO$_x$	17/11/2014	19/11/2014	2	Analyser fault	Ricardo-AEA Spare analyser installed
LHR2	PM$_{10}$ and PM$_{2.5}$	06/09/2014	12/09/2014	6	Flat Data	Intermittent Flat Data
LHR2	PM$_{10}$ and PM$_{2.5}$	16/09/2014	26/09/2014	10	Flat Data	Analyser removed for repair till 26th
LHR2	PM$_{2.5}$	27/01/2014	12/02/2014	16	Data rejected	BC Analyser causing problems with settings
LHR2	PM$_{2.5}$	07/03/2014	19/06/2014	105	Analyser faulty	HAL decided not to repair analyser due to FIDAS being installed
LHR2	PM$_{2.5}$	01/08/2014	02/08/2014	1	Data collection issue	No data collected from the web logger
LHR2	BC	20/01/2014	29/01/2014	9	Analyser fault	Tape issue
LHR2	BC	08/02/2014	18/02/2014	10	Analyser fault	Tape issue
LHR2	BC	06/04/2014	08/04/2014	2	Tape issue	Tape needed replacing at LSO visit
Oaks Road	NO$_x$	02/01/2014	03/01/2014	1	Service	Install new NO$_x$ analyser
Oaks Road	PM$_{10}$ and PM$_{2.5}$	28/06/2014	01/07/2014	3	No mV	Data collection issue from FIDAS

Oaks Road	PM_{10} and $PM_{2.5}$	05/07/2014	10/07/2014	4	No mV	Data collection issue from FIDAS
Oaks Road	PM_{10} and $PM_{2.5}$	15/07/2014	17/07/2014	2	No mV	Data collection issue from FIDAS
Oaks Road	PM_{10} and $PM_{2.5}$	29/07/2014	31/07/2014	2	No mV	Data collection issue from FIDAS
Oaks Road	PM_{10} and $PM_{2.5}$	02/08/2014	05/08/2014	4	No mV	Data collection issue from FIDAS
Oaks Road	PM_{10} and $PM_{2.5}$	10/08/2014	11/08/2014	1	No mV	Data collection issue from FIDAS
Oaks Road	PM_{10} and $PM_{2.5}$	14/08/2014	19/08/2014	5	Service	No data collected from the web logger
Oaks Road	PM_{10} and $PM_{2.5}$	26/08/2014	16/09/2014	21	No mV	Data collection issue from FIDAS
Oaks Road	PM_{10} and $PM_{2.5}$	21/09/2014	22/09/2014	1	No mV	Data collection issue from FIDAS
Oaks Road	PM_{10} and $PM_{2.5}$	25/09/2014	26/09/2014	1	No mV	Data collection issue from FIDAS
Oaks Road	PM_{10} and $PM_{2.5}$	27/09/2014	29/09/2014	2	No mV	Data collection issue from FIDAS.
Oaks Road	PM_{10} and $PM_{2.5}$	05/10/2014	06/10/2014	1	Web logger issue	No data collected from the web logger
Oaks Road	PM_{10} and $PM_{2.5}$	07/10/2014	10/10/2014	4	Web logger issue	No data collected from the web logger

Oaks Road	PM_{10} and $PM_{2.5}$	16/10/2014	17/10/2014	1	Web logger issue	No data collected from the web logger
Oaks Road	BC	28/03/2014	03/04/2014	6	Analyser fault	Tape issue
Oaks Road	BC	17/04/2014	29/04/2014	12	Analyser fault	Tape issue
Oaks Road	BC	14/08/2014	19/08/2014	5	Analyser issue	Resolved at service on 19th August
Harlington	NO_x	03/06/2014	05/06/2014	2	Analyser fault	Removed for repair on 3rd June returned on 5th June
Harlington	O_3	27/10/2014	13/11/2014	17	Analyser fault	Analyser removed for repair
Harlington	O_3	19/11/2014	05/12/2014	15	Analyser fault	Analyser removed for repair
Harlington	PM_{10}	01/01/2014	07/01/2014	7	Noise	Volatile data not being in acceptable limits
Harlington	$PM_{2.5}$	03/01/2014	07/01/2014	4	Noise	Volatile data not being in acceptable limits
Harlington	PM_{10}	15/03/2014	27/03/2014	12	Noise	Volatile data not being in acceptable limits
Harlington	PM_{10}	6/04/2014	23/04/2014	17	Noise	Volatile data not being in acceptable limits
Harlington	PM_{10} and $PM_{2.5}$	31/07/2014	05/082014	6	Zero Test	HEPA filters were put on the inlets

4 Results and discussion

4.1 Automatic monitoring data

The summary statistics for 2014 are presented in Table 4.1 and Table 4.2. The time series of data for the full year, as measured by the automatic monitoring sites, are shown in Figure 4.1, 4.2, 4.3 and 4.4. Figure 4.5 shows the hourly averages for BC at LHR2 and Oaks road sites.

Table 4.1 – Air pollution statistics for LHR2 and Harlington, from 1st January to 31st December 2014

LHR2	NO (µg m^{-3})	NO$_2$ (µg m^{-3})	NO$_x$ (µg m^{-3})	PM$_{2.5}$ (µg m^{-3})	PM$_{10}$ (µg m^{-3})	BC (µg m^{-3})
Maximum 15 minute mean	684	212	1238	89	-	-
Maximum hourly mean	650	199	1192	83	132	20
Maximum running 8 hour mean	460	155	857	55	-	-
Maximum running 24 hour mean	325	129	626	39	91	12
Maximum daily mean	299	128	585	36	88	10
Average	37	46	102	10*	19	3
Data capture	95.3%	95.3%	95.3%	62.4%	95.2%	93.2%
Harlington	**NO (µg m^{-3})**	**NO$_2$ (µg m^{-3})**	**NO$_x$ (µg m^{-3})**	**PM$_{2.5}$ (µg m^{-3})**	**PM$_{10}$ (µg m^{-3})**	**O$_3$ (µg m^{-3})**
Maximum 15 minute mean	682	205	1207	-	-	128
Maximum hourly mean	522	164	932	108	157	124
Maximum running 8 hour mean	352	125	637	78	93	115
Maximum running 24 hour mean	259	101	498	65	82	85
Maximum daily mean	231	99	453	61	72	76
Average	17	36	63	14	20	39
Data capture	95.2%	95.2%	95.2%	96.4%	87.7%	84.3%

*The PM$_{2.5}$ annual average at LHR2 has been calculated with data capture low at 62.4% this should be considered when quoting this statistic.

Table 4.2 – Air pollution statistics for Green Gates and Oaks Road, from 1st January to 31st December 2014

Heathrow Green Gates	NO (µg m^{-3})	NO_2 (µg m^{-3})	NO_x (µg m^{-3})	$PM_{2.5}$ (µg m^{-3})	PM_{10} (µg m^{-3})	-
Maximum 15 minute mean	609	160	1077	66	-	-
Maximum hourly mean	545	143	976	61	100	-
Maximum running 8 hour mean	366	103	657	48	-	-
Maximum running 24 hour mean	273	81	498	41	85	-
Maximum daily mean	253	80	464	36	72	-
Average	19	35	64	10	17	-
Data capture	96.7 %	96.7 %	96.7 %	99.1 %	98.5 %	-
Heathrow Oaks Road	NO (µg m^{-3})	NO_2 (µg m^{-3})	NO_x (µg m^{-3})	$PM_{2.5}$	PM_{10} (µg m^{-3})	BC (µg m^{-3})
Maximum 15 minute mean	503	151	915	153	-	-
Maximum hourly mean	459	132	821	99	104	16
Maximum running 8 hour mean	319	110	589	49	-	-
Maximum running 24 hour mean	203	97	391	42	88	9
Maximum daily mean	179	96	353	37	74	8
Average	17	33	58	10	18	2
Data capture	99.3 %	99.3 %	99.3 %	97.4 %	96.9 %	91.9%

Figure 4.1 – Time series of hourly averaged concentrations of NO_x and PM for LHR2 site, 2014

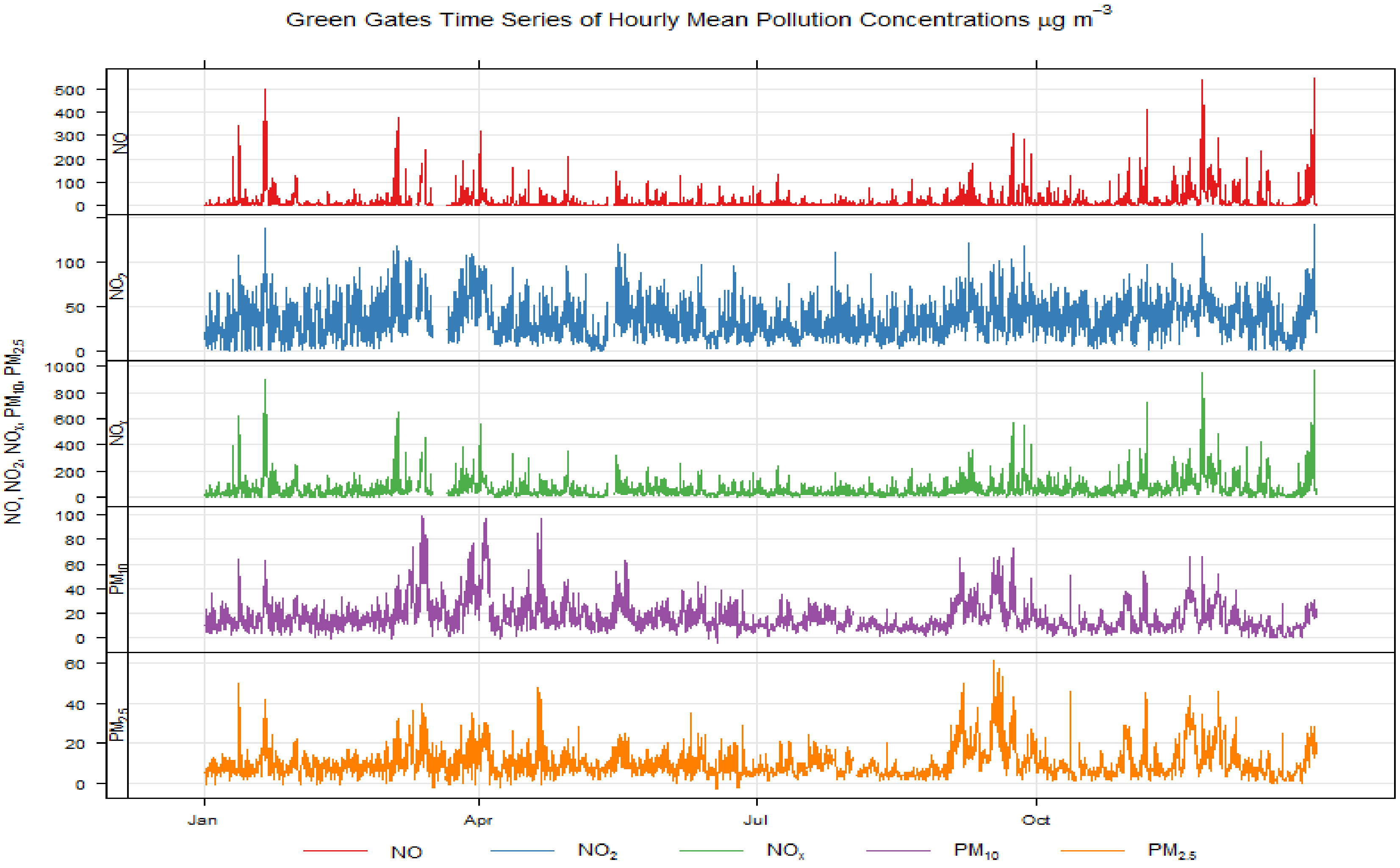


Figure 4.2 – Time series of hourly averaged concentrations of NO_x, PM and O_3 for Harlington site, 2014

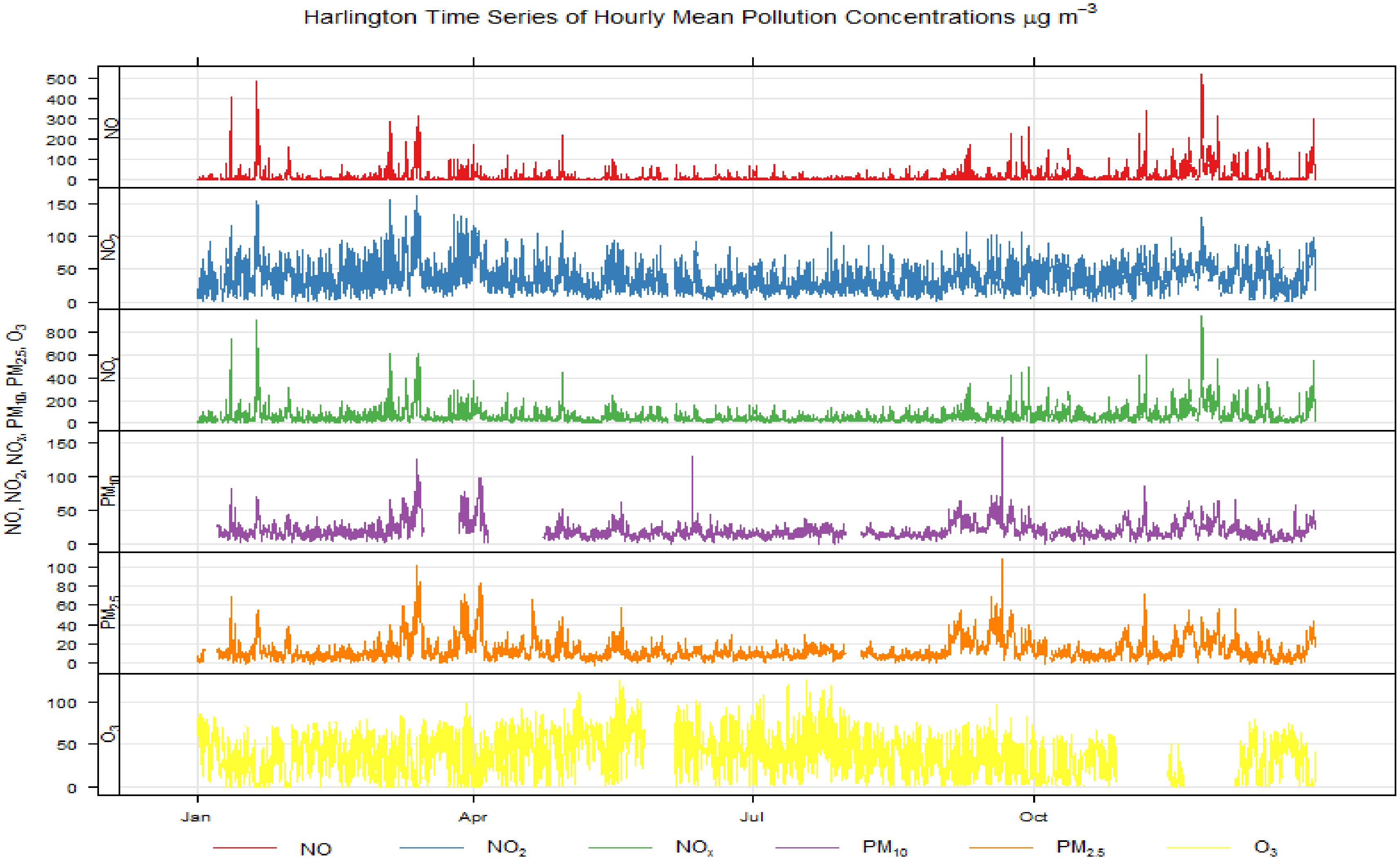


Figure 4.3 - Time series of hourly averaged concentrations of NOx and PM for Green Gates site, 2014

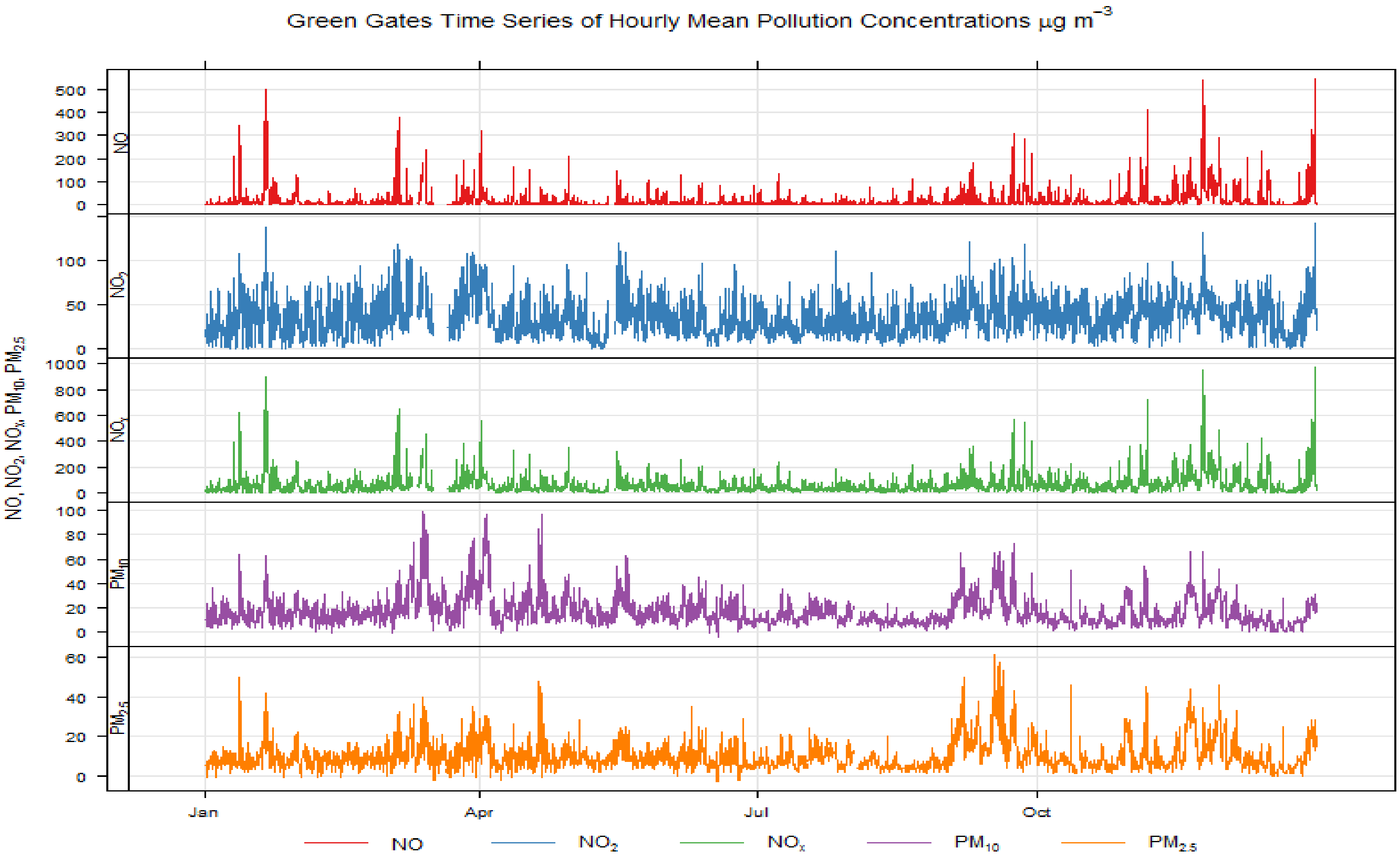


Figure 4.4: Time series of hourly averaged concentrations of NO_x and PM for Oaks Road site, 2014

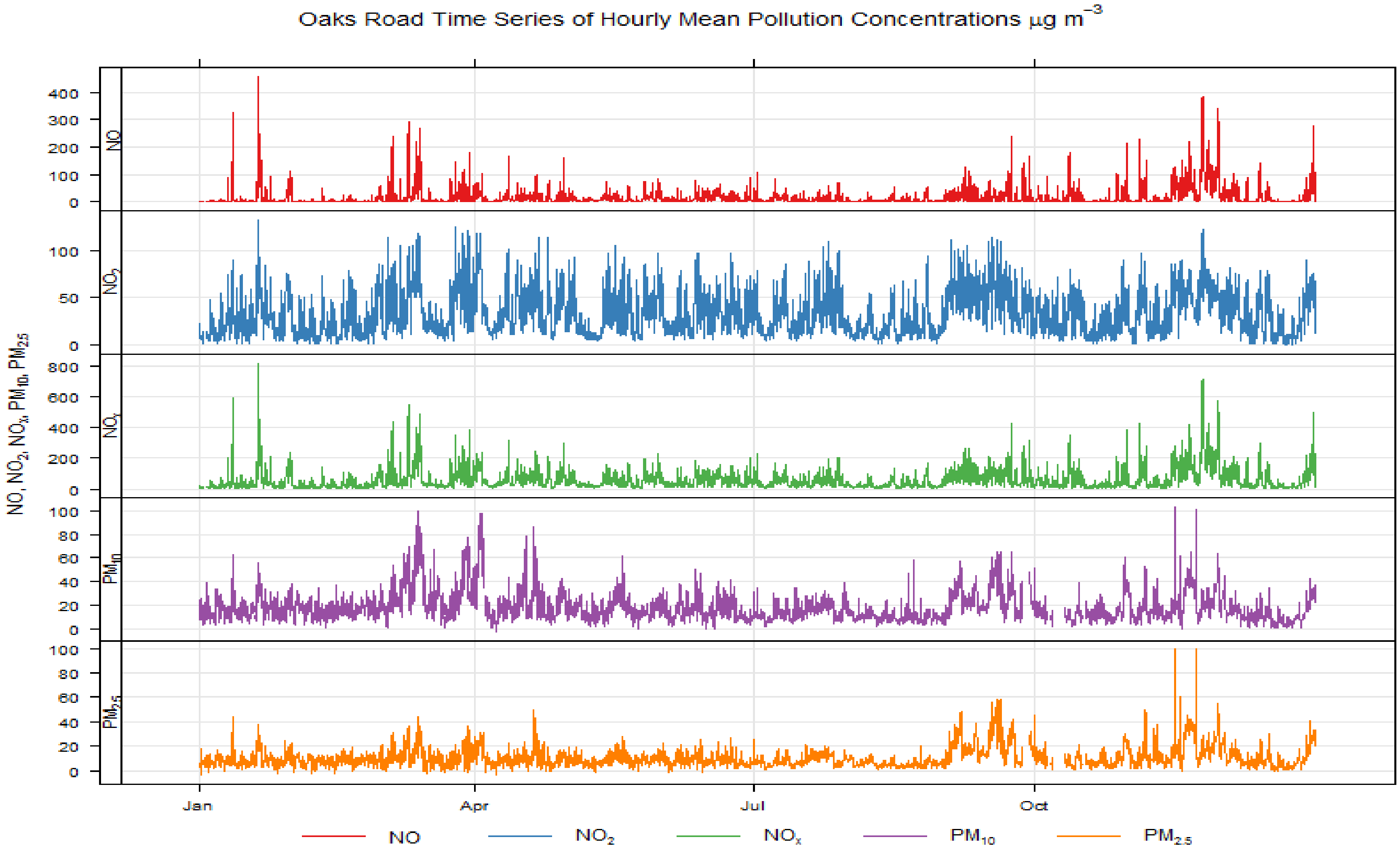
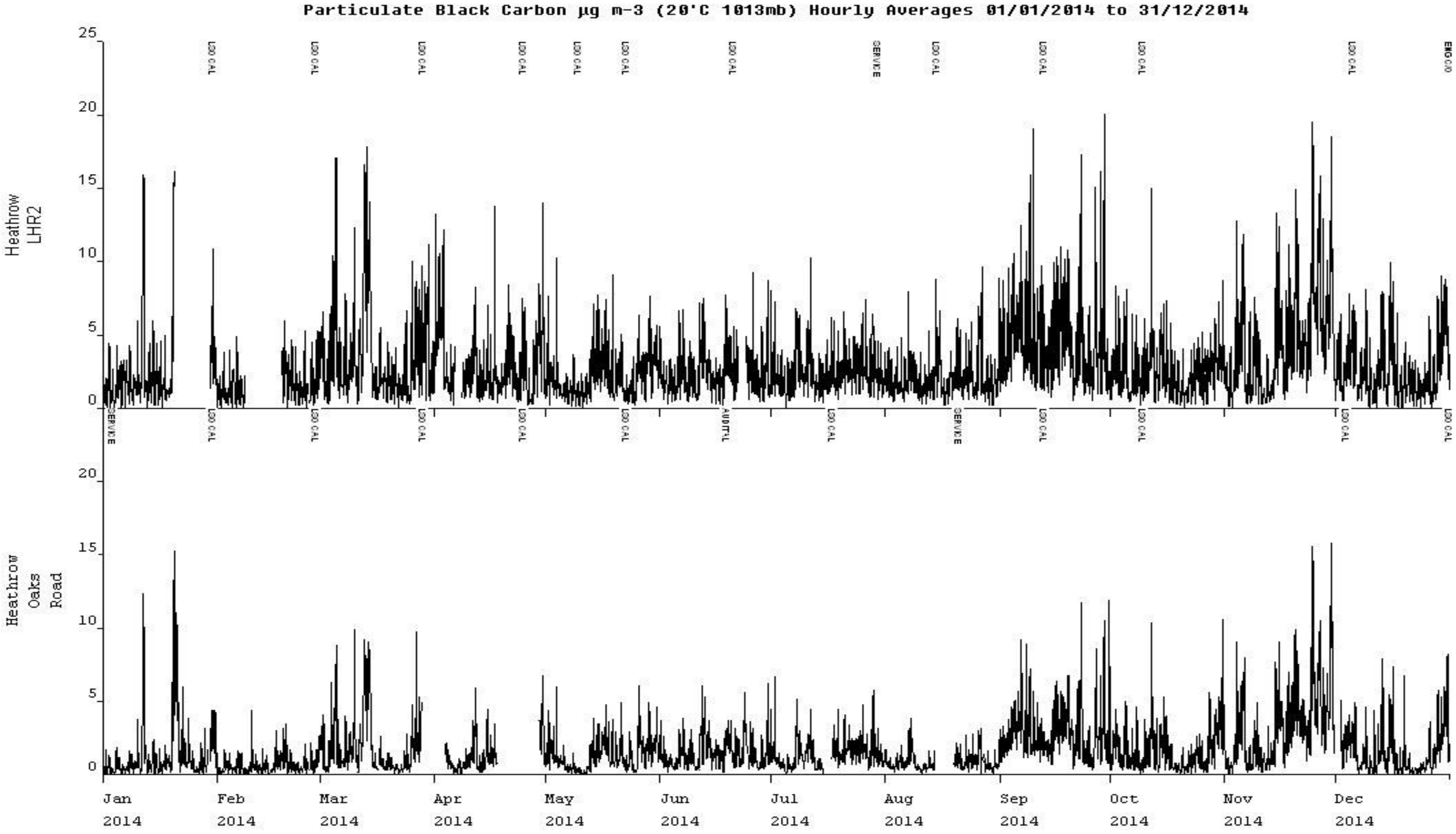


Figure 4.5-Time series of hourly averaged concentrations of Black Carbon (BC) for Heathrow LHR2 and Oaks Road sites, 2014



All sites show similar peaks of PM_{10} and $PM_{2.5}$ during March/April and September. The origin of such elevated concentrations of PM are investigated later in the report. The elevated peaks of NO_x/NO_2 and BC appear to some extent during the same periods mentioned for PM. Others appear during winter month, this pollutants seem to follow a typical seasonal pattern.

4.2 Diffusion tube data

Table 4.3 shows the VOC diffusion tube results for 2014, the lab results were assessed every month from January to April. The results showed consistency along the 4 months. Low levels of VOC concentration were found during this period and in previous years of this monitoring study, with some periods under the limit of detection. It was decided by HAL following a discussion with Ricardo-AEA the passive VOC's tube monitoring would end after April 2014 due to long term low recorded measurements that were not at all close to breaching air quality limit values.

Table 4.3 – VOC diffusion tube results 2014 (µg m^{-3})

Start date	End Date	Benzene (µg m^{-3})	Toluene (µg m^{-3})	Ethyl benzene (µg m^{-3})	m, p-xylene (µg m^{-3})	o-xylene (µg m^{-3})
03-01-2014	29-01-2014	1.18	2.01	0.55	1.13	0.52
29-01-2014	26-02-2014	0.85	0.90	0.30	0.59	0.14
26-02-2014	27-03-2014	0.76	1.62	0.47	1.25	0.48
27-03-2014	23-04-2014	0.83	3.23	0.61	1.25	0.42
4 month mean		0.91	1.94	0.48	1.10	0.39

** Values < LoD shown as ½ LoD, in red. Averages in this table are calculated by treating < LoD values as ½ LoD.*

Due to the fact that the results were frequently close to the limit of detection (LoD), these data should be treated as indicative only. Values below the limit of detection (<LoD) are shown in red. In line with current guidance, when calculating the annual mean, values below the LoD have been treated as ½ LoD. For example, a value of <0.10 µg m^{-3} has been treated as 0.05 µg m^{-3} when calculating the annual means.

4.3 Comparison with air quality objectives

None of the annual, hourly or daily mean limits specified by Defra for all the analysed pollutants were exceeded at HAL monitoring locations in 2014.The Details of 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.

The highest hourly mean concentration of NO_2 was found at LHR2 recorded at 199 µg m^{-3}.There were no periods when hourly mean NO_2 concentrations exceeded 200 µg m^{-3} for all stations. The lower threshold of the Defra "Moderate" air quality band is 201 µg m^{-3} for hourly means. Therefore NO_2 levels at all sites stayed within the Defra "Low" band for the whole year and there were no hourly periods of high NO_2.

The annual mean AQS objective for NO_2 is 40 µg m^{-3}. This was met at Harlington, Green Gates and Oaks Road, but not at LHR2 site, where the calculated annual mean was of 46 µg m^{-3}. Although this value exceeds the AQS objective for NO_2, for this particular case it is not a problem. LHR2 falls into the category "other" as defined by the Defra Technical Guidance on air quality monitoring LAQM.TG (09)[7] : "Any special source-orientated or location category covering monitoring undertaken in relation to specific emission sources such as power stations, car-parks, airports or tunnels." The EU limit values and AQS objectives only apply to locations where public exposure may occur. As LHR2 is located within the airport premises, where members of the public do not have access, these limits do not strictly apply

The AQS objective for PM_{10} is a maximum of 50 µg m^{-3} for 24h mean periods, not to be exceeded more than 35 times a year. Data at Green Gates, Oaks Road and LHR2 up to 23/06/2014 inclusive was collected using TEOM instruments and has been VCM corrected. PM_{10} data from the 24th of June until the end of the year was collected using a FIDAS instrument, not requiring correction for volatiles. PM_{10} and $PM_{2.5}$ data from Harlington for this report was taken from the FDMS instruments requiring no correction.

Results show that some exceedances to the 50 µg m^{-3} 24h mean periods value were registered in all sites. At LHR2 and Oaks Road 7 exceedances were recorded. The range of these exceedances are between 50.9 to 86.7 µg m^{-3}. Green Gates and Harlington have registered 5 exceedances each, with values ranging from 53.0 to 72.3 µg m^{-3}. All sites are well within the yearly maximum permitted number of exceedances of 35 times, all meeting the AQS objective for 24-hour mean PM_{10}.

Because Harlington has a percentage of data capture below 90% for PM_{10}, the 90th percentile of hourly means must be within the limit value for this pollutant. This objective was met, since the 90th percentile value was 33 µg m^{-3}.

The annual mean AQS objective for PM_{10} is 40 µg m^{-3}. All sites registered average annual values ranging between 17 and 20 µg m^{-3}, this objective was therefore met

No AQS objective exists for $PM_{2.5}$, an annual mean objective exists of 25 µg m^{-3}, although this is a non-mandatory compliance target to be met by 2020. The highest annual mean for this pollutant was registered at Harlington at 14 µg m^{-3}. All the other sites have registered average values of 10 µg m^{-3}, almost half of the average concentration target limit for 2020.

Benzene was monitored indicatively at LHR2 using BTEX diffusion tubes, with exposure periods of nominally four weeks. Individual measurements ranged from 0.76 µg m^{-3} to 1.18 µg m^{-3}. The 4 month mean of benzene concentration recorded in 2014 was 0.91 µg m^{-3}. Although this value represents roughly 1/5 of the Benzene AQS objective of annual mean (5 µg m^{-3}), this values cannot be compared because they do not represent the same temporal interval.

O_3 was measured at Harlington only. The AQS objective for daily maximum on an 8 hour running mean is of 100 µg m^{-3} (not to be exceeded more than 10 days a year). Harlington exceeded the AQS objective for ozone in 8 days during 2014. The maximum concentration of ozone was registered on the 18th of May recorded at 115 µg m^{-3}. The site met the AQS objectives for this pollutant in 2014.

Black Carbon was measured at LHR2 and Oaks Road. The highest hourly mean registered was at 20 µg$m^{-3}$and 16 µgm^{-3} for LHR2 and Oaks Road respectively. The UK Government does not have specific policies to address black carbon and other short lived climate forcers, and therefore, no comparison to a limit can be made. As a large proportion of particulate matter is black carbon, action to reduce particle emissions will reduce this pollutant.

4.4 Temporal variation in pollutant concentrations

Figure 4.6, 4.7, 4.8 and 4.9 show the variation of monthly and daily averaged NO_x and PM concentrations during 2014 at LHR2, Harlington, Green Gates and Oaks Road respectively. Figure 4.7 stands for the Harlington site and also includes O_3. Figures 4.10 and 4.11 show monthly and diurnal variations of BC at LHR2 and Oaks Road.

Figure 4.6 - Time series of seasonal and diurnal variations of NO_x and PM for the LHR2 site, 2014

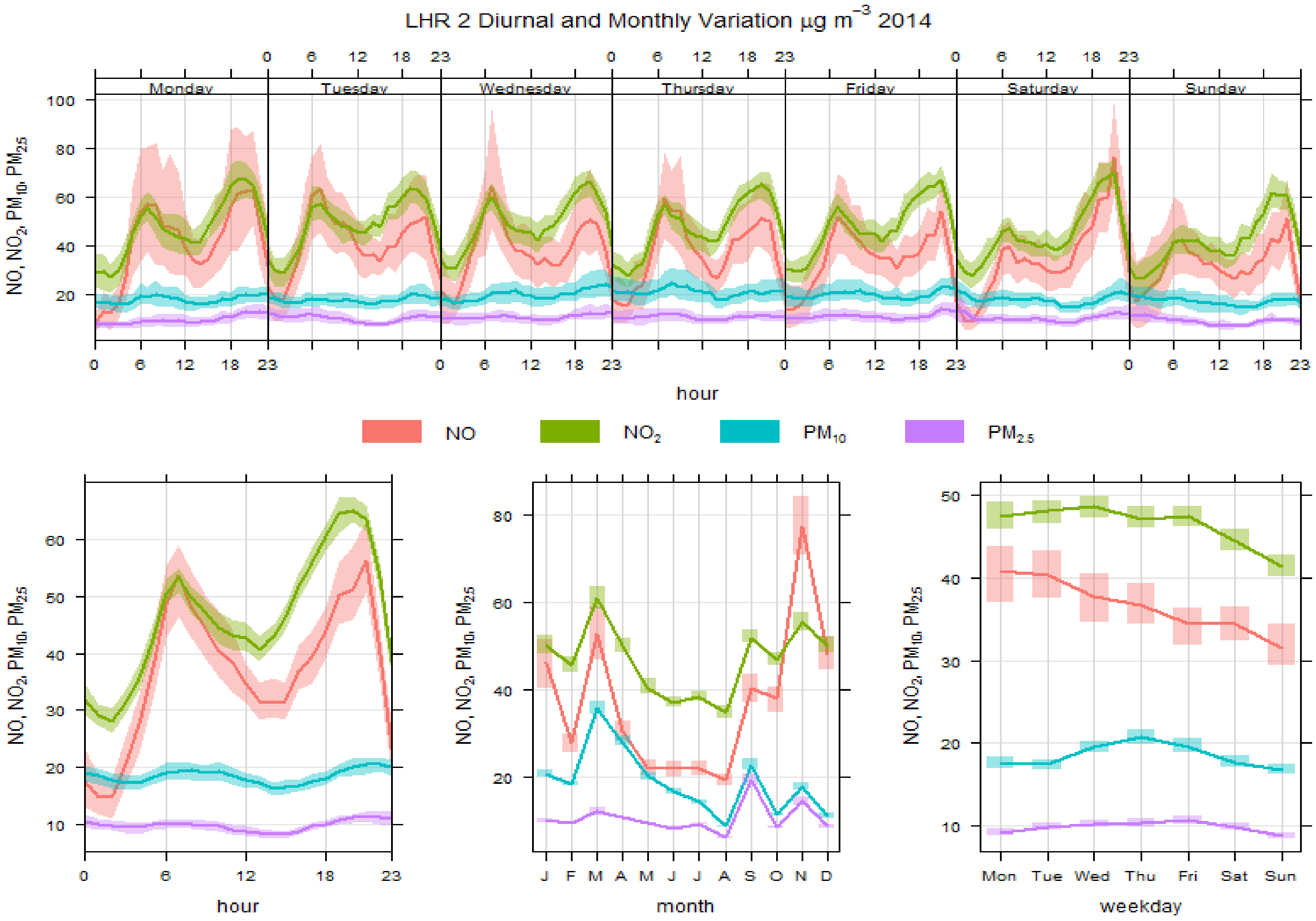


Figure 4.7 – Time series of seasonal and diurnal variations of NO_x, PM and O_3 for the Harlington site, 2014

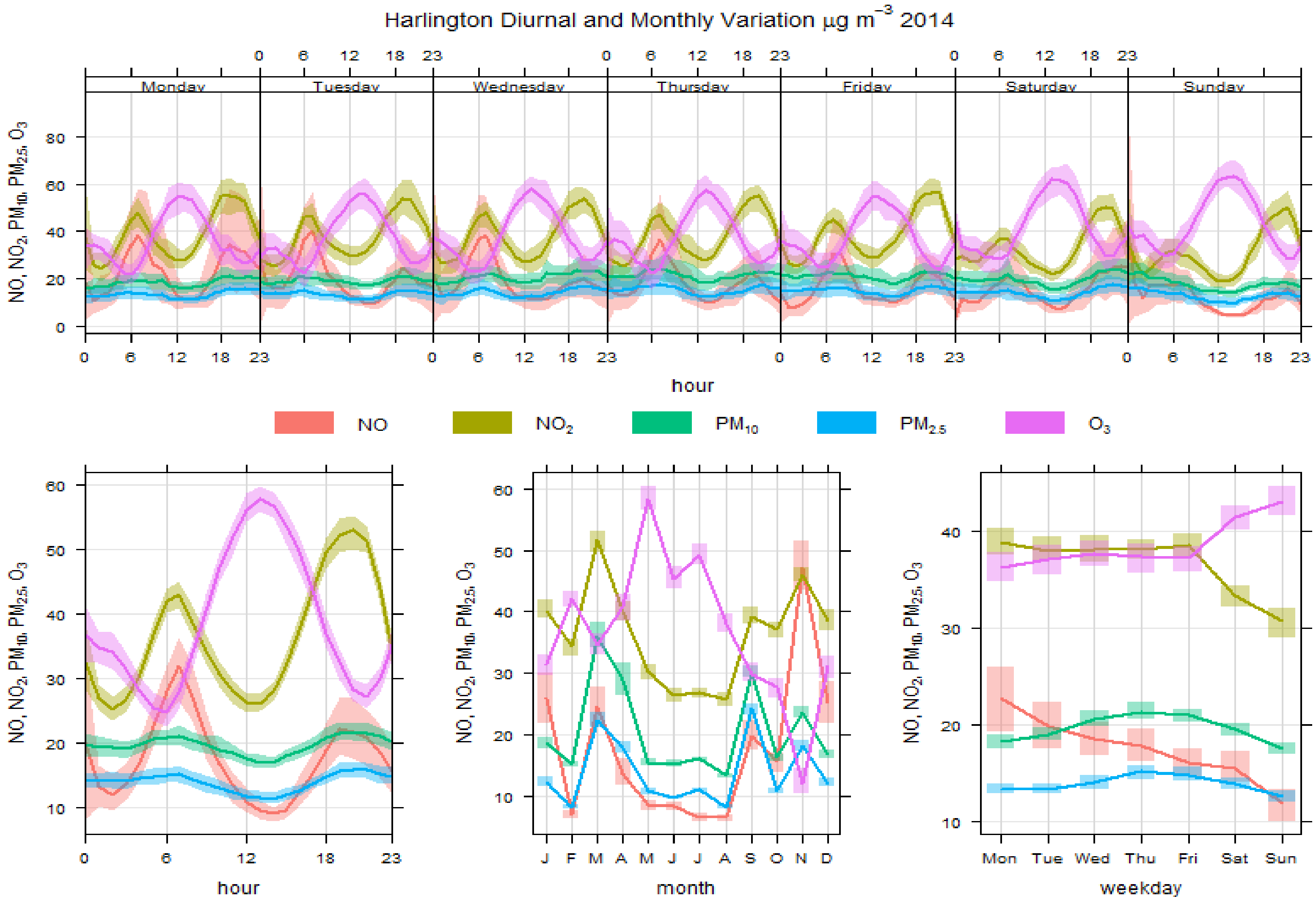


Figure 4.8 – Time series of seasonal and diurnal variations of NO_x and PM for the Green Gates site, 2014

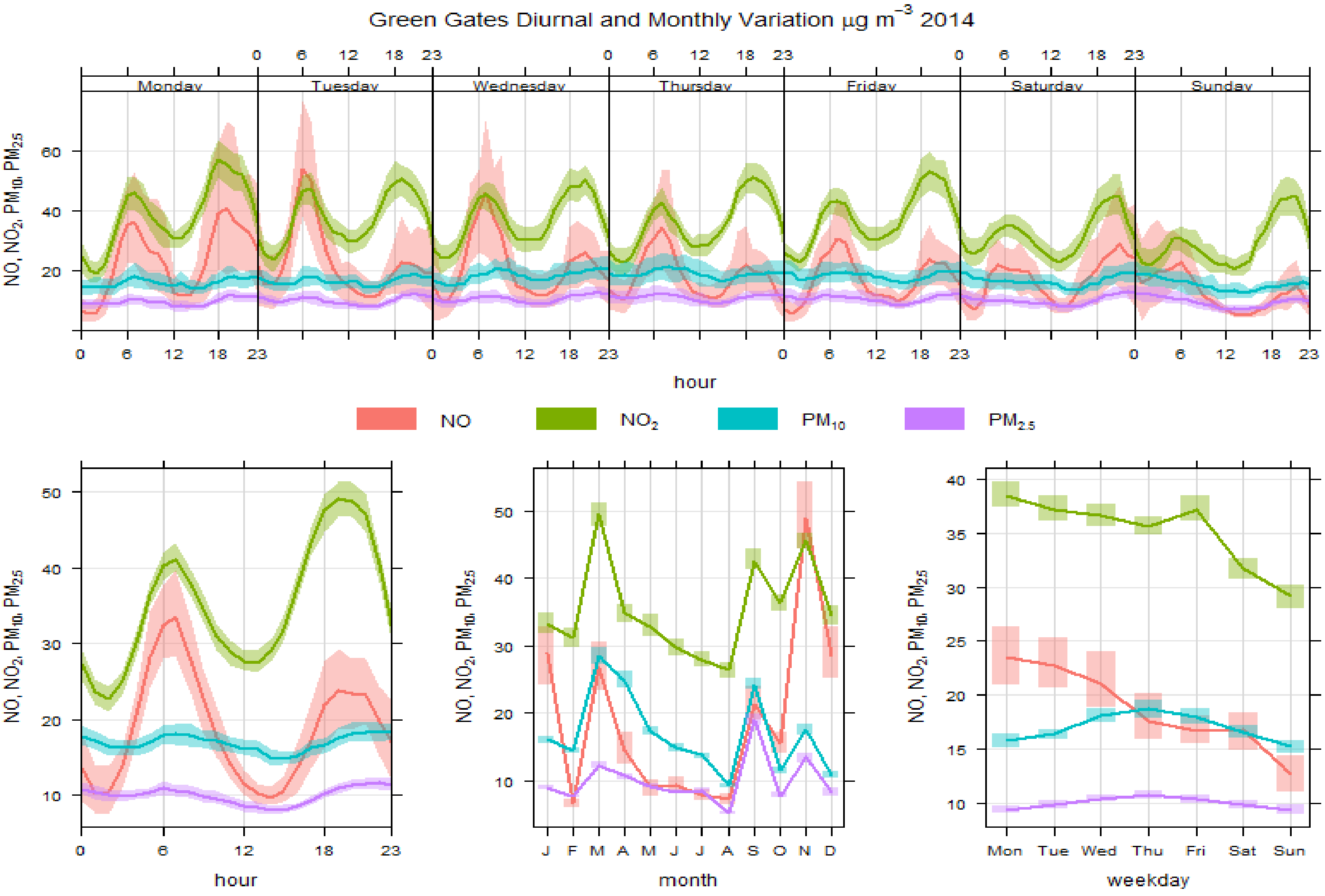


Figure 4.9 – Time series of seasonal and diurnal variations of NOx and PM for the Oaks Road site, 2014

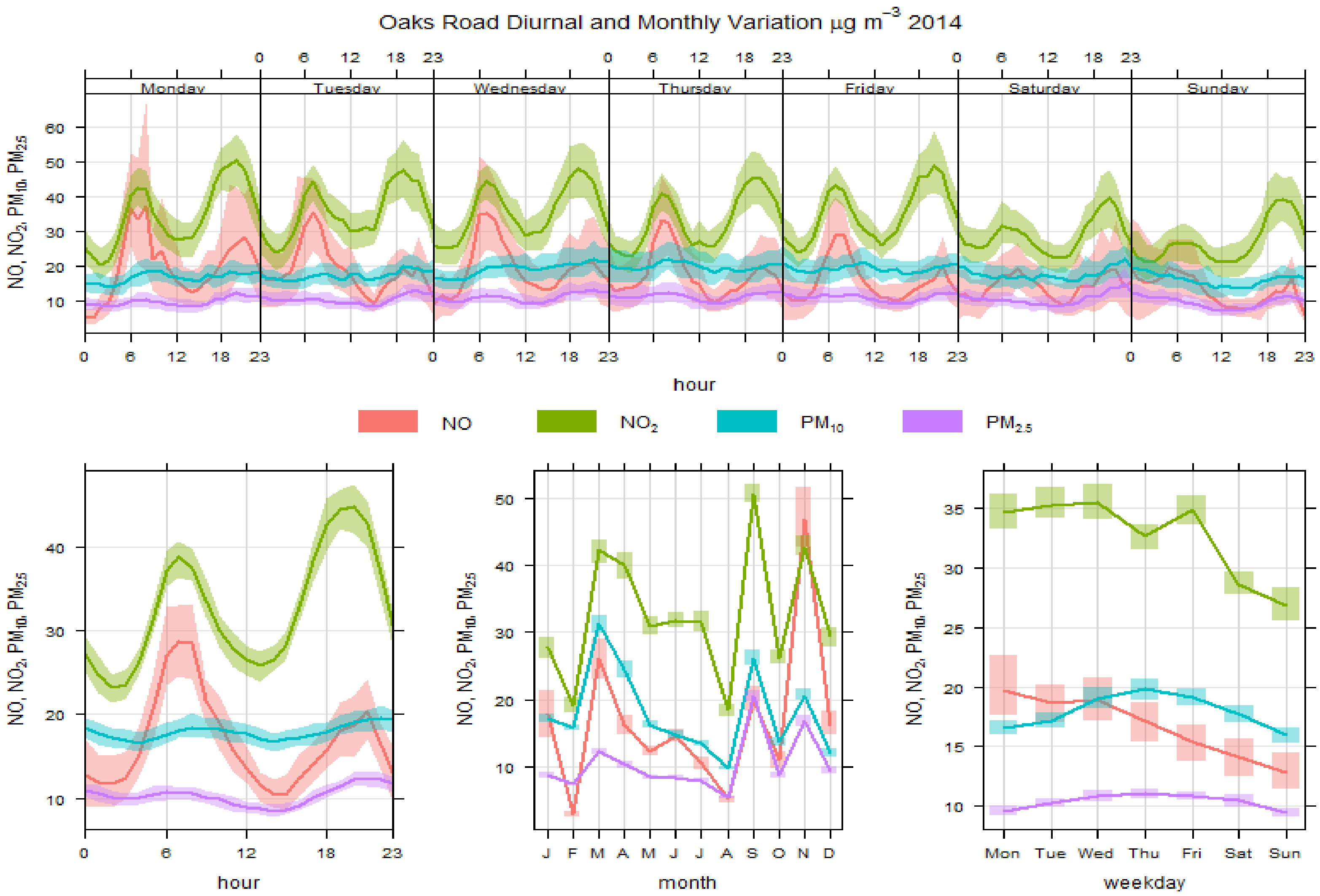


Figure 4.10 – Time series of seasonal variations of BC for the LHR2, 2014

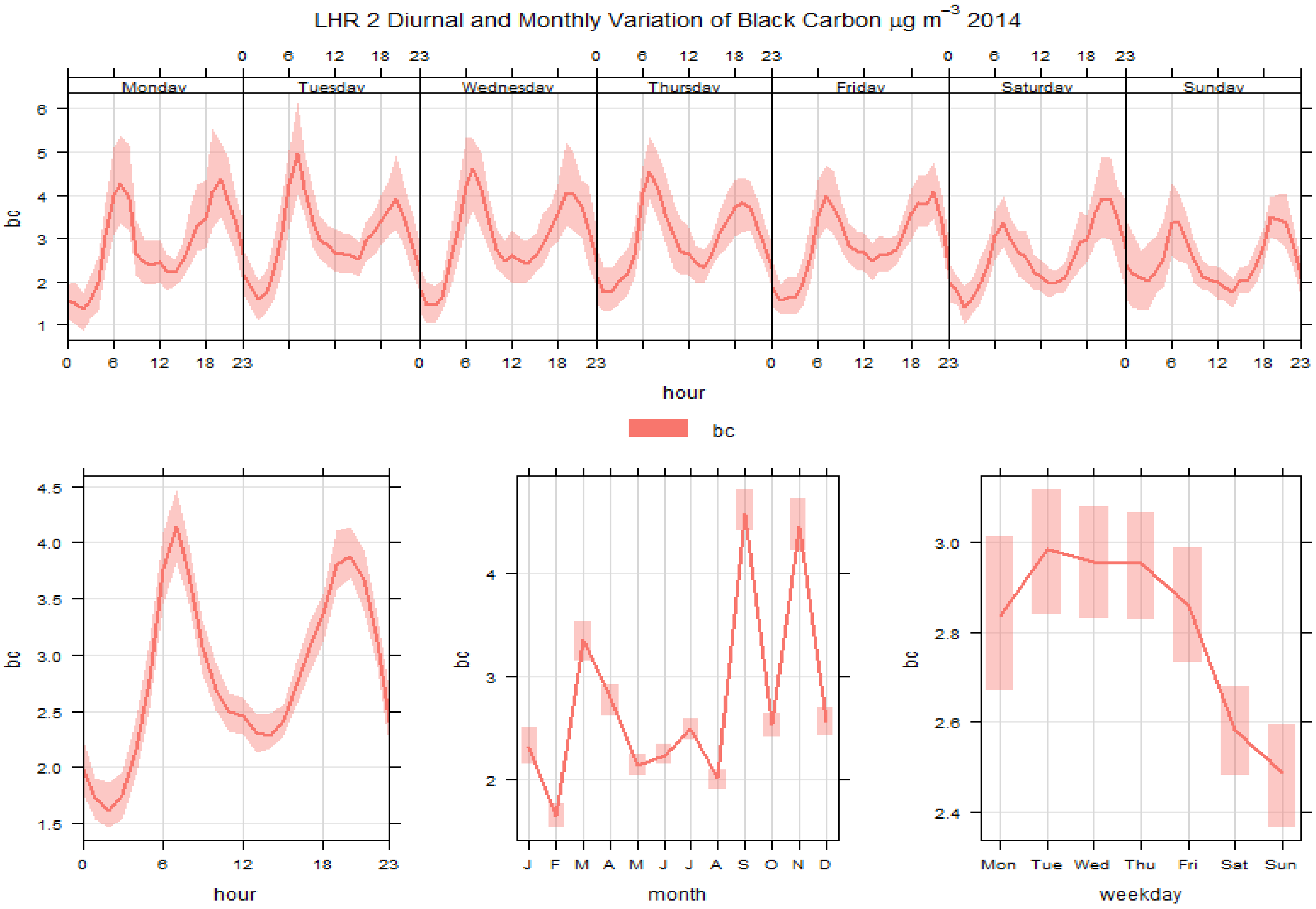
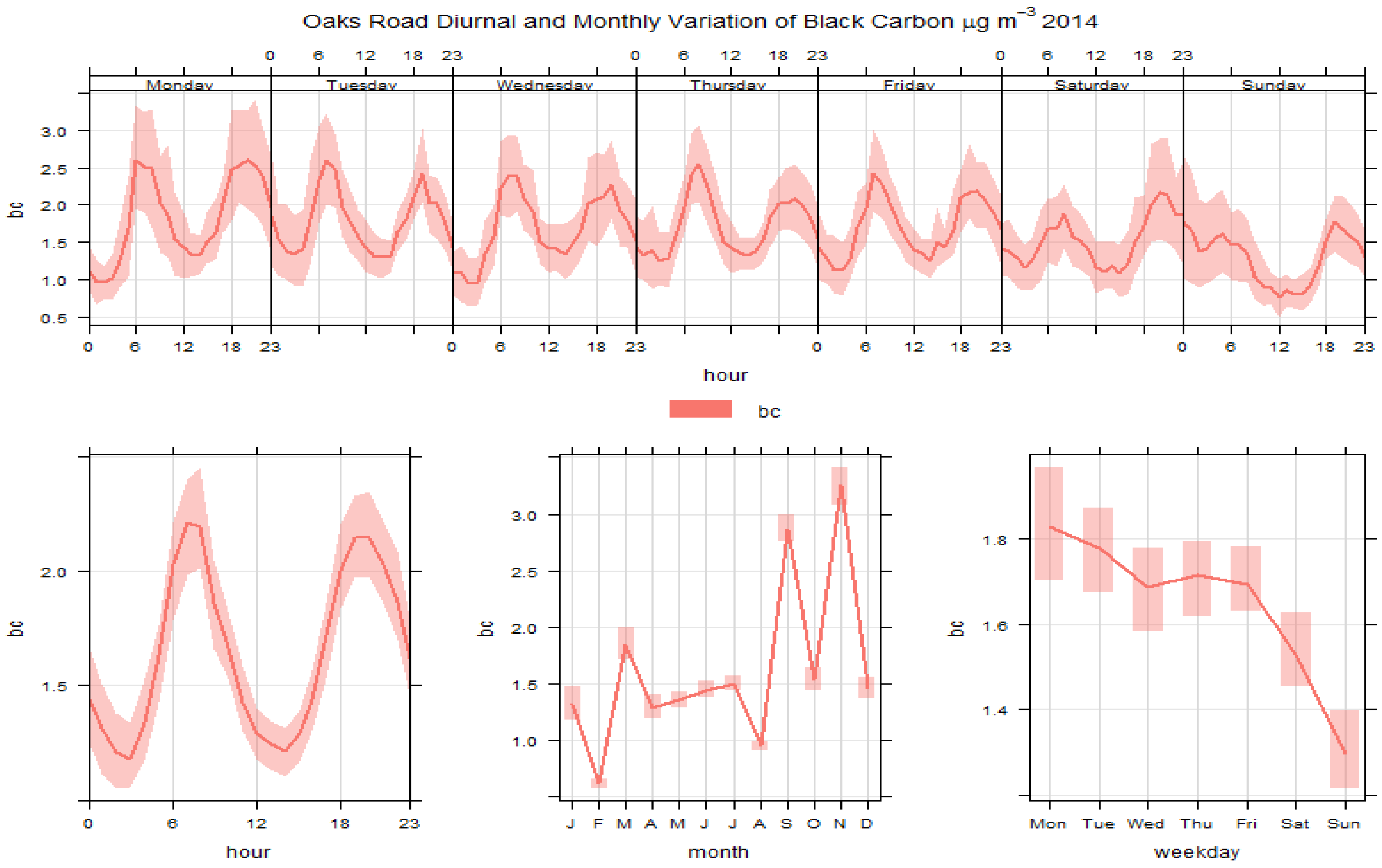


Figure 4.11 - Time series of seasonal variations of BC for the Oaks Road, 2014



4.4.1 Seasonal variation

Seasonal variations seem to follow similar trends for NO_x and PM in all sites during 2014, as it can be observed in the 'month' plots of figures 4.6 to 4.11. Two major concentration peaks were registered in March and September for these pollutants. This peaks are not representative of a typical seasonal variation, and are the result of specific pollution episodes, that are to be explained further on this report (sub chapter 4.7).

As in previous years, PM_{10} and $PM_{2.5}$ concentrations showed much less seasonal variation than oxides of nitrogen. Excluding the March and September peaks, NO and NO_2 concentrations registered in all sites seem to follow a typical seasonal variation for urban areas. The highest concentrations of this pollutants occurred during the winter months. This pattern was also observed in previous years and is typical of urban monitoring sites. The highest levels of primary pollutants tend to occur in the winter months, when emissions may be higher, and periods of cold, still weather reduce pollutant dispersion.

O_3 concentrations registered at Harlington follow a typical seasonal variation for this pollutant, with higher concentrations being registered in May, June and July. At low/mid latitudes, high O_3 concentrations are generally observed during late spring and summer months, where anti cyclonic conditions (characterized by warm and dry weather systems) help increasing the number of photochemical reactions in the atmosphere, responsible for the increasing of ground level ozone production. In addition, the convective fluxes created during hot summer days can also be responsible for an increase of O_3 (stratospheric intrusion). The hot air generated at ground level due to high temperatures is lighter and tends to ascend, being replaced by colder stratospheric air masses coming from above, dragging stratospheric O_3 by subsidence.

BC data was recorded for the first time at LHR2 and Oaks Road sites. The seasonal variation of this pollutant shows in general elevated levels of BC during the winter months. BC is directly related with the incomplete combustion of fossil fuels, it's likely that during winter and colder periods fuel emissions associated to heating and reduced pollutant dispersion might be the main causes of elevated concentrations of this pollutant. Similar peaks as the ones registered for PM can be seen in March and September for this pollutant as explained to be regional episodes registered at UK stations.

4.4.2 Diurnal variation

The diurnal variation analyses viewed in the 'hour' plots in figures between 4.6 and 4.9 showed typical urban area daily patterns for NO and NO_2 in all sites. Pronounced peaks can be seen for these pollutants during the mornings, corresponding to rush hour traffic at around 07:00. Concentrations tend to decrease during the middle of the day, with a much broader evening road traffic rush-hour peak in building up from early afternoon. NO also showed a much smaller peak than NO_2 in the afternoons in all sites. This is likely to be because concentrations of oxidising agents in the atmosphere (particularly ozone) tend to increase in the afternoon, leading to enhanced oxidation of NO to NO_2. A good example of this atmospheric reaction can be seen at the Harlington site. The NO concentration suffers a huge decrease in the early afternoon, while the concentration of O_3 increases on the same proportion. The diurnal concentration of O_3 in Harlington also follows a typical diurnal pattern.

O_3 concentrations always increase during daylight hours due to the photochemical reactions of NO_2 and photo oxidation of VOC's, CO, hydrocarbons, (O_3 precursors). In the afternoon/ night O_3 gets consumed by a fast reaction with NO (NO titration). The absence of sunlight prevents the photolysis of the O_3 precursors.

The diurnal patterns for PM_{10} and $PM_{2.5}$ are determined by two main factors. The first is emissions of primary particulate matter, from sources such as vehicles. The second factor is the reaction that occurs between sulphur dioxide, NO_x and other chemical species, forming secondary sulphate and nitrate particles. Morning and afternoon road traffic rush-hour peaks for PM_{10} and $PM_{2.5}$ could be seen at all four sites, but these were less pronounced than those for oxides of nitrogen.

BC diurnal variation viewed in the 'hour' plots in figures 4.10 and 4.11 appears to follow the same trend pattern of NO_x and PM, with two peaks registered at the same period (07:00 AM and 20:00 PM).

4.4.3 Weekly variation

The analyses of each pollutants weekly variation showed that the same type of diurnal patterns occur for all the days of the week. NO early morning and late afternoon rush hour peaks are in general much more pronounced on the early days of the week (Monday, Tuesday and Wednesday), and much less pronounced during later week days and weekends. The exception is made at the LHR2 site, where an elevated NO peak can be registered on the late afternoon of Saturday. Because NO is a primary pollutant, this can be most probably the cause of vehicle emissions from roads in the vicinity of the site.

BC data decreases during the week in both sites. The highest peaks occur in the beginning of the week (Monday/Tuesday), and the lower values are registered Sunday.

4.5 Source investigation

In order to investigate the possible sources of air pollution being monitored around Heathrow Airport, meteorological data modelled for the Harlington AURN station location were used to add a directional component to the air pollutant concentrations. Meteorological data for 2014 supplied by HAL was not “null padded” and had several large data gaps this made it difficult to cross against other pollutant data in the analysis software. The meteorological data provided from HAL was cross referenced checked against the modelled data for the Harlington, this had a very good agreement verifying this suitable to use for the analysis. The wind rose in Figure 4.12 uses data supplied from HAL and the pollution roses in Figures 4.13 to 4.18 use the modelled data.

Figure 4.12 shows the wind speed and direction data, as supplied by HAL. 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 210 ° to 240 °, showing 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 4.29 m s^{-1}. The maximum measured wind speed was 13.90 m s^{-1}. Some of the highest wind speeds occurred during February 2014.

Figure 4.12 - Wind rose showing the wind speeds and directions at LHR2 in 2014

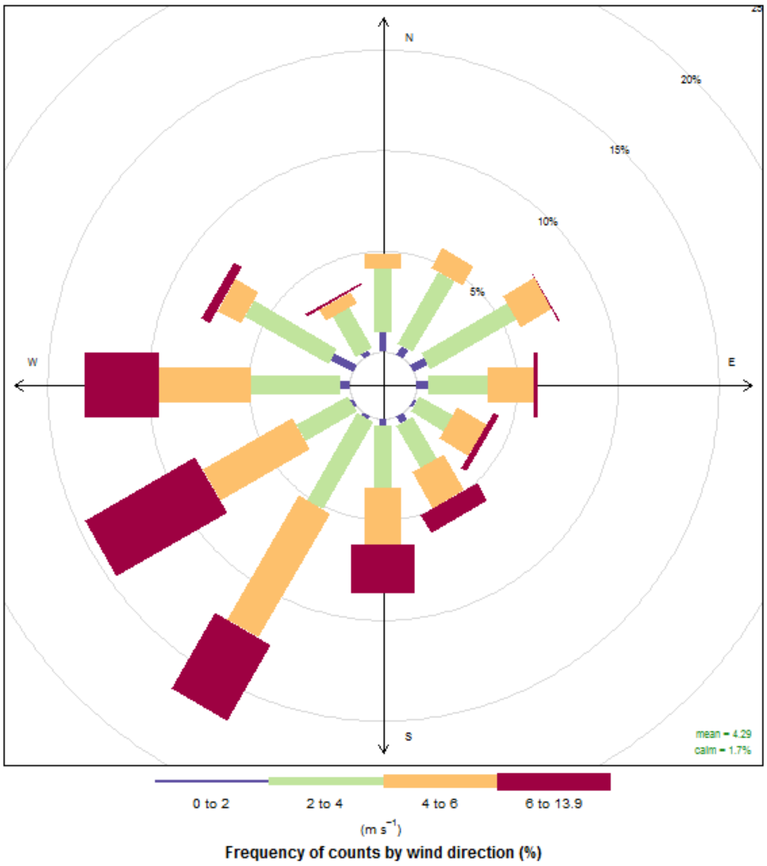


Figure 4.13 to Figure 4.18 show bivariate plots of hourly mean concentrations of NO, NO$_2$, PM$_{10}$, PM$_{2.5}$ and BC at LHR2 against the modelled wind speed and wind direction. Figure 4.19 shows a bivariate plot of ozone concentration at Harlington, plotted using the modelled wind speed and direction data. These plots should be interpreted as follows:

- The wind speed is indicated by the distance from the centre of the plot; the grey circles indicate wind speeds in 2 m s^{-1} intervals.
- The pollutant concentration is indicated by the colour (as indicated by the scale).

These plots therefore show how pollutant concentrations varied with wind direction and wind speed. No VCM correction has been applied to the PM_{10} data used in these analyses, as the intention was to show patterns rather than absolute values.

The plots do not show distance of pollutant emission sources from the monitoring site. However, in the case of primary pollutants such as NO, the concentrations at very low wind speeds are dominated by emission sources close by, while at higher wind speeds, effects are seen from sources further away.

Figure 4.13 – Pollution rose for NO at LHR2

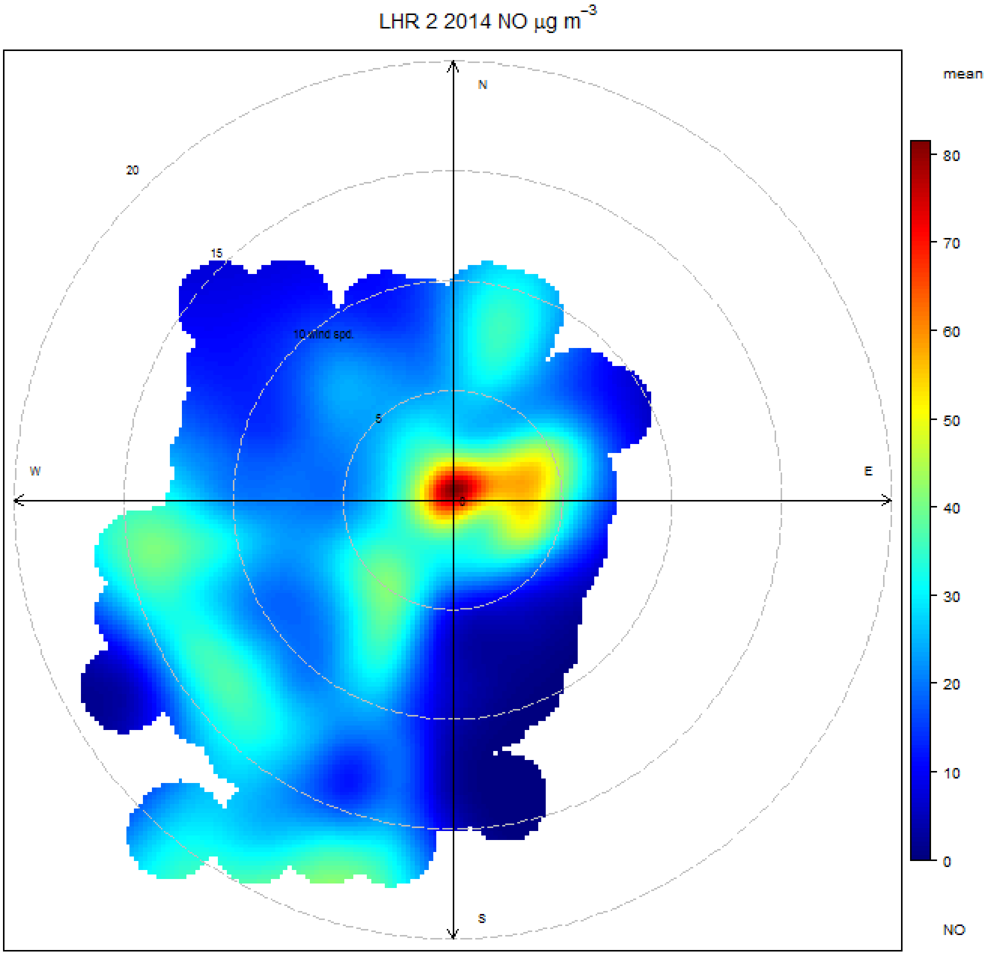


Figure 4.13 shows, as in previous years, that the highest concentrations of NO occurred under calm conditions. Such conditions will have allowed NO emitted from nearby sources (vehicles on the northern perimeter road, Bath Road, and within the hotel car parks beside it) to build up, reaching high concentrations. There were also moderate NO concentrations at greater wind speeds from the south west.

Figure 4.14 – Pollution rose for NO_2 at LHR2

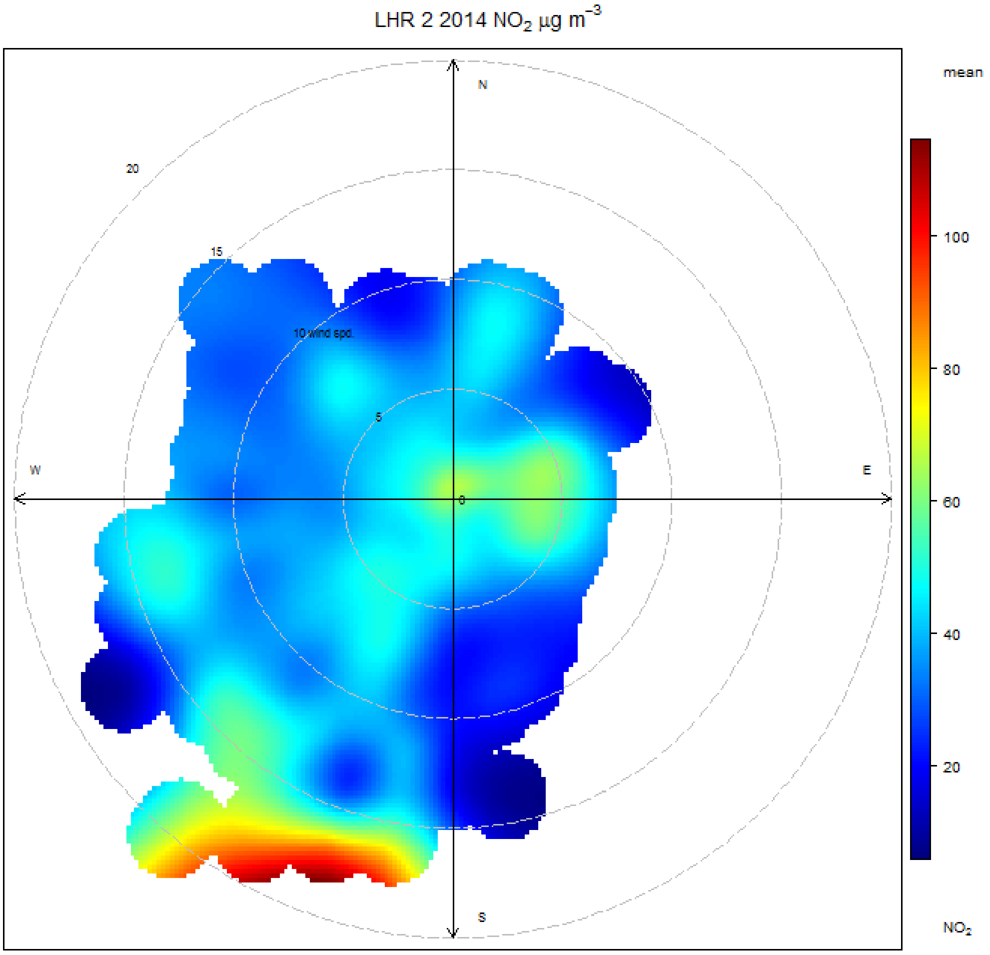


Figure 4.14 shows higher concentrations of NO_2 were associated with two sets of conditions. Calm conditions and light winds from the east brought pollutants from the nearest roads and the built-up area of Harlington. Part of this NO_2 was also created by the fast reaction of local emission NO with ozone. The highest NO_2 concentrations are associated with a wind direction of around 200-220º for high wind speeds, (15-20 ms^{-1}), possibly indicating a major source further away. In this direction are the Terminal 5, the Central Terminal Area (CTA) and the M25.

Figure 4.15 – Pollution rose for PM_{10} at LHR2

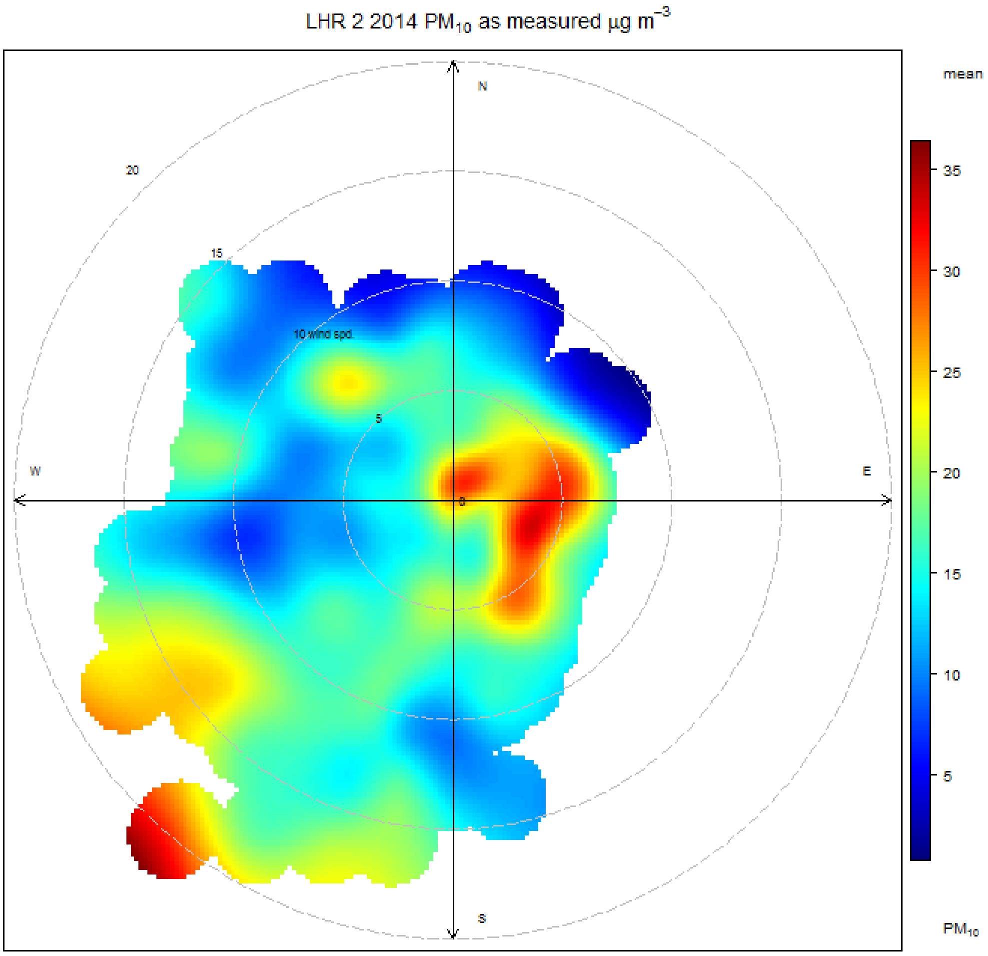


Figure 4.15 (for PM_{10}) shows high concentrations occurred under calm conditions very close to the monitoring station (east and south east). There was also a moderate source shown from approximately 310 ° for wind speeds between 5 and 10 ms^{-1}. At higher wind speeds, elevated concentrations appeared from the south west, as shown in the NO_2 pollution rose in Figure 4.14 there are numerous sources in this direction such as Terminal 5, the Central Terminal Area (CTA) and the M25.

Figure 4.16 – Pollution rose for $PM_{2.5}$ at LHR2

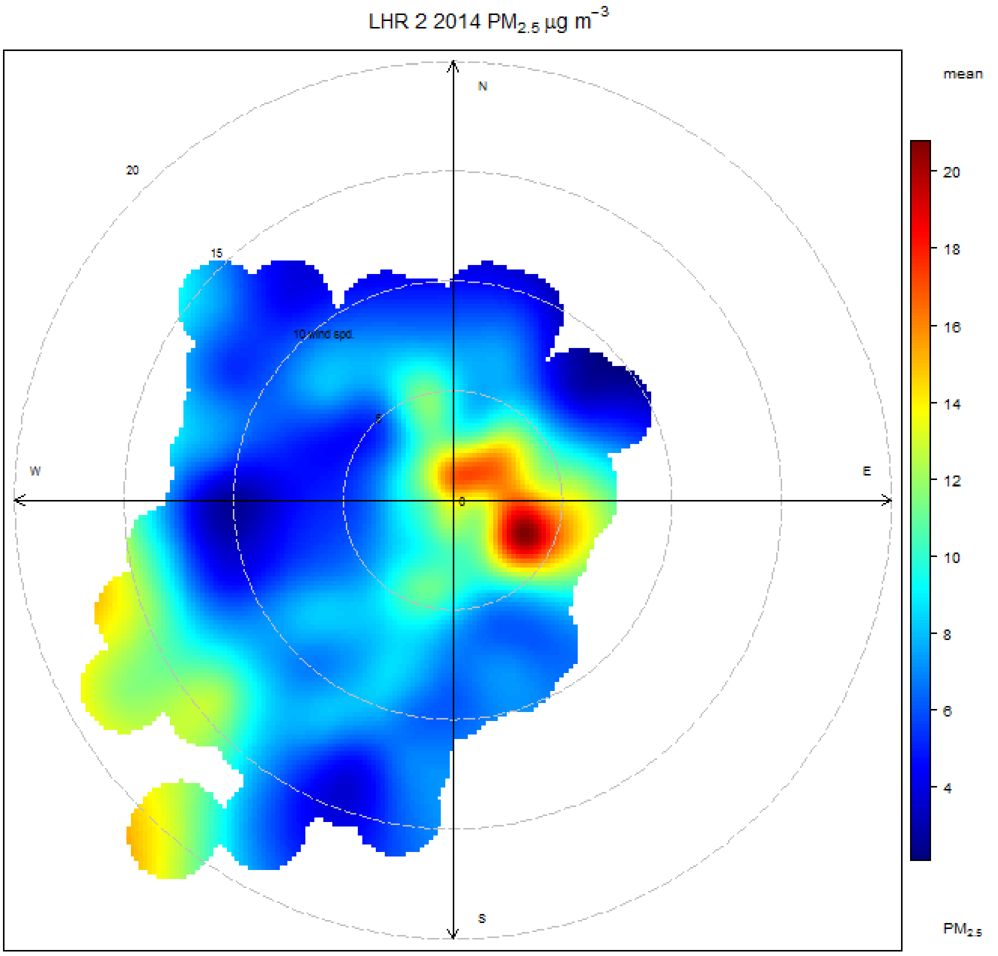


Figure 4.16 shows a similar directional pattern for $PM_{2.5}$ to the one seen for PM_{10}. At low wind speeds, there appeared to be a build-up close to the monitoring location, suggesting the same sources were involved for both particulate size fractions. The signatures at higher wind speeds were also similar, although $PM_{2.5}$ showed a lower contribution than the ones seen for PM_{10} (note that the scales vary between Figures 4.15 and 4.16).

Figure 4.17 – Pollution rose for BC at LHR2

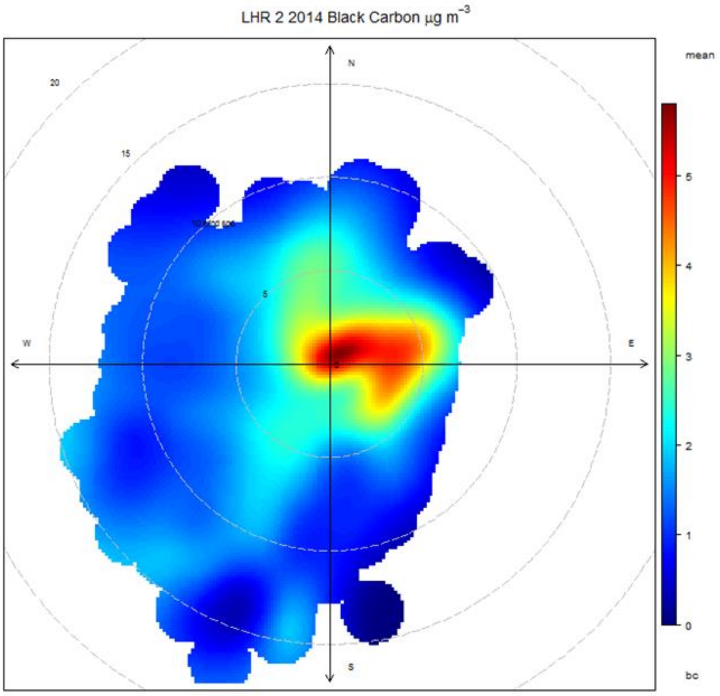
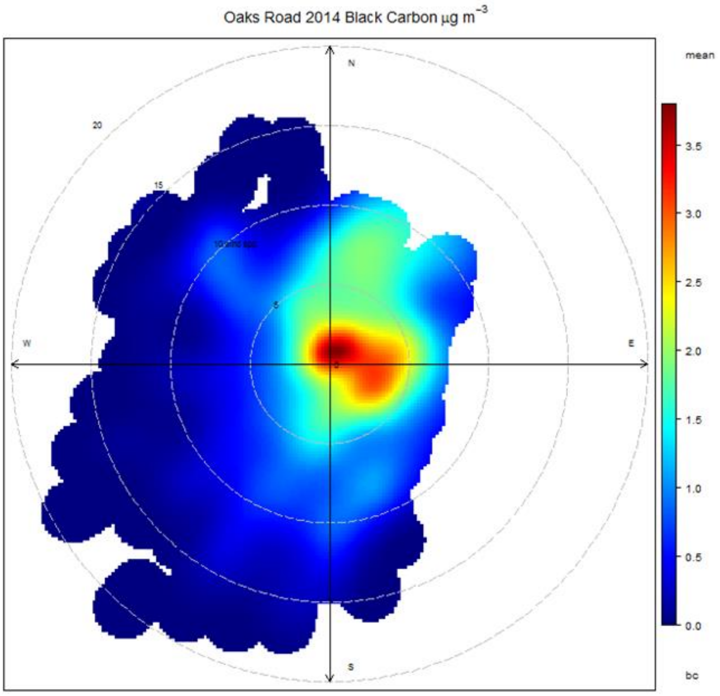
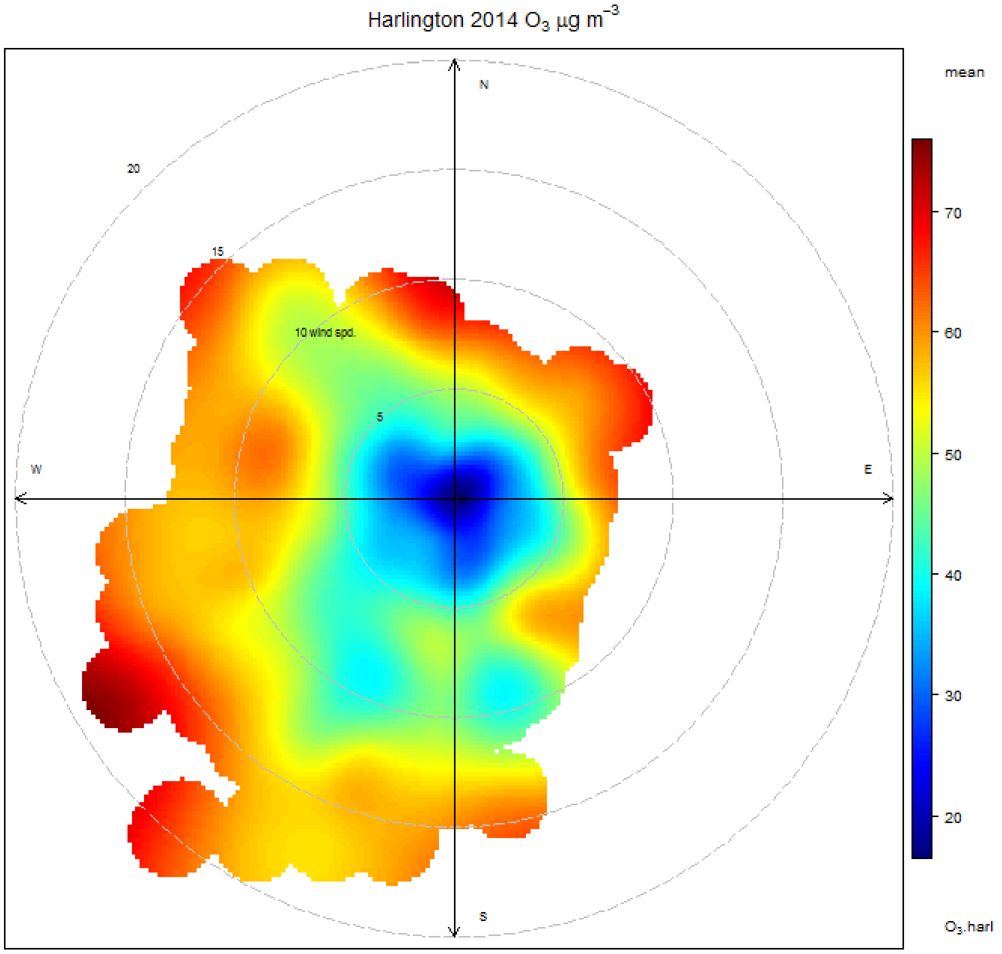


Figure 4.18 – Pollution rose for BC at Oaks Road



Figures 4.17 and 4.18 show the BC pollution roses for LHR2 and Oaks Road. These plots show that both sites have registered the highest BC concentrations when wind speed was low, which suggests that the major sources of BC are local. At LHR2, some moderate levels of BC seem to come from the south west, in consistency with the pollution roses of NO, NO_2 and PM.

Figure 4.19 – Pollution rose for O_3 at Harlington



The pollution rose for ozone (Figure 4.19) is based on ozone concentration data from Harlington, combined with modelled wind speed and direction data. The pattern for ozone was similar to the one of 2013. Lower ozone levels seem to appear at low wind speeds, which shows that ozone was being consumed by NO from local emissions. High levels of NO caused by the combustion of fossil fuels tend to react fast with O_3 to produce NO_2 (destruction of ozone by titration with NO). O_3 levels tend to be higher at high wind speeds, where the effect of local NO emissions is not so well pronounced, this prevents ozone being consumed.

4.6 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.

The historic Air Quality Index data presented at the Department of Environment, Food & Rural Affairs (DEFRA) UK-air website[11] shows 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[12].

According to a study from the Public Health England (PHE) [13], 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 4.20 - Air quality Index and air mass back trajectories calculated for the 29th March 2014

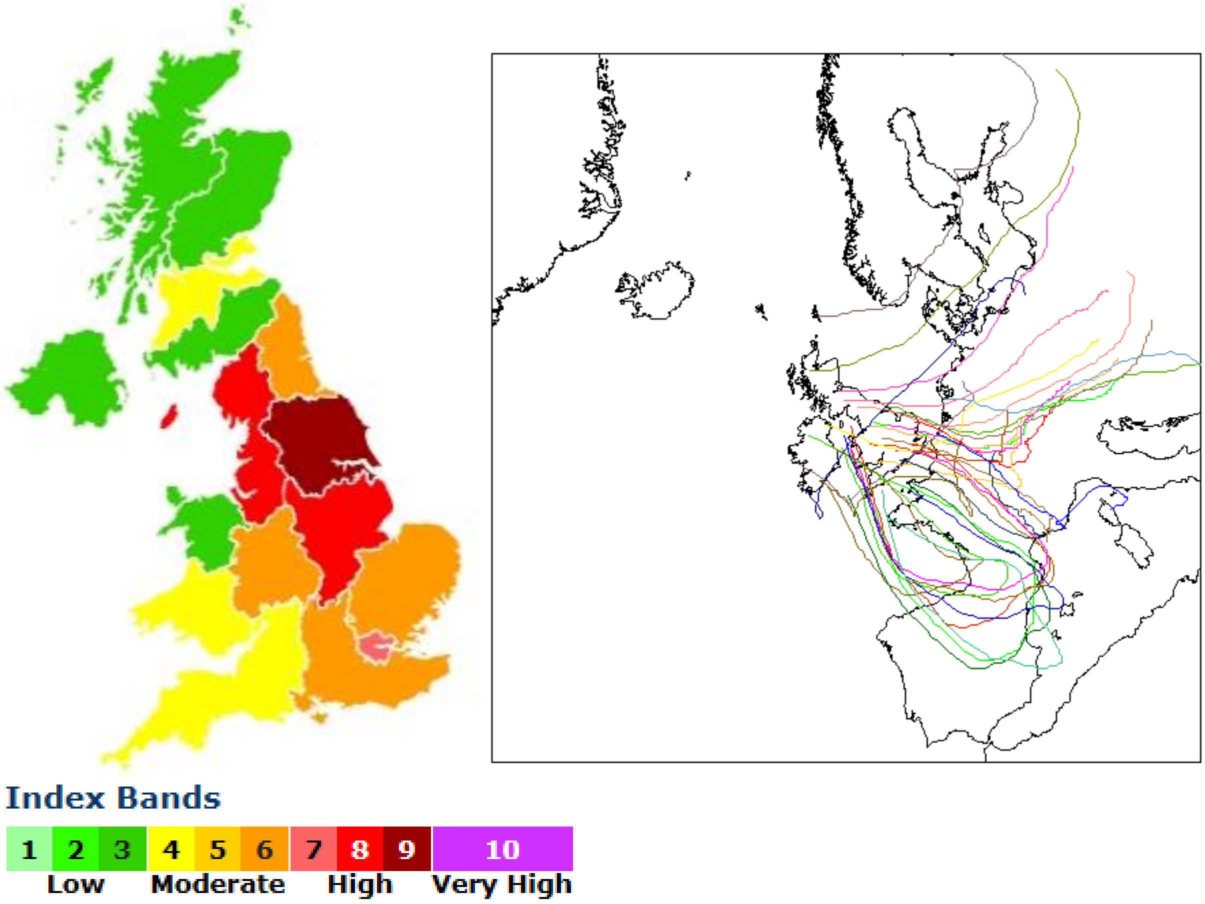


Figure 4.20 shows an example of one extremely high air pollution episode. The region of Greater London has an index band of 10 (Very High). The air mass trajectories calculated using the Hybrid Single Particle Lagrangian Integrated Trajectory Model (HYSPLIT)[14] for the same day, clearly show the displacement of air masses from southern Europe towards the U.K.

4.6.1 Particulate Matter (PM)

The AQS objective establishes a daily mean limit value of 50 µg m^{-3} for PM_{10}, not to be exceeded more than 35 times a year, this limit was achieved at all sites for 2014.

At LHR2 and Oaks Road 7 exceedances were recorded. This sites have measured high concentrations of PM_{10} on 12th, 13th, 14th, 28th and 29th March and on 2nd and 3rd April.

Green Gates and Harlington have registered 5 exceedances each: 13th, 14th March and 2nd and 3rd April (both). Green Gates has one exceedance on 29th of March and Harlington on the 28th.

This exceedances match with the exact days where the previously mentioned high pollution episodes were registered.

The origin of the high concentration peaks registered in March/April in all sites are the result of UK-wide pollution/trans-boundary episodes that have struck the UK during that particular period in time.

Some high values of PM_{10} were also registered during September. This episodes were not high enough to cause an exceedance, since they were all the values were below 50 µg m^{-3}. However, they have influenced the seasonal variation of this pollutant and their contribution should be acknowledged.

At the moment, no AQS objective exists for $PM_{2.5.}$ An annual mean objective of 25 µg m^{-3}, as a non-mandatory target exists for 2020. The highest annual mean for this pollutant was registered at

Harlington at 14 µg m^{-3}. All the other sites have registered average values of 10 µg m^{-3}, almost half of the average concentration target limit for 2020.

4.6.2 Nitrogen oxides (NO_x),

No particular periods of elevated concentration were registered for this pollutant in 2014. Some high concentrations were recorded during the same high trans-boundary pollutant episodes mentioned for PM, however, no limit value was exceeded.

4.6.3 Ozone

O_3 was measured at Harlington only. The AQS objective for daily maximum on a 8 hour running mean is of 100 µg m^{-3} (not to be exceeded more than 10 days a year). Harlington exceeded the AQS objective for ozone on 8 days during 2014 – 3 days in May and 5 days in July. Typical end of spring/summer days where good weather conditions contribute to the increase of O_3 ground levels. This result is below the permitted maximum. Defra “Moderate” air quality O_3 levels were registered in 32 occasions along this period of days in May and July.

4.7 Comparison with other UK sites

Annual mean pollutant concentrations at the four HAL sites are compared in Table with those measured at other air quality monitoring sites in and around London and the south of England. The sites selected are all part of the UK’s national Automatic Urban and Rural Network (AURN) and are as follows:

- London Bexley: a suburban site in a residential area to the south east of London.
- London North Kensington: an urban background site at a school in Kensington, to the west of central London.
- London Bloomsbury: an urban background site in Russell Square, central London
- London Marylebone Road: a kerbside city centre site close to a busy major road: this site measures some of the highest pollutant concentrations in London
- Harwell: a rural site in Oxfordshire, included for comparative purposes.

Table 4.4 - Annual mean (NO_x, PM, O_3, BC) and Hourly Max (BC) pollutant concentrations at Heathrow compared with other sites, 2014

Site	Type	NO_2 (µg m^{-3})	PM_{10} (µg m^{-3})	$PM_{2.5}$ (µg m^{-3})	O_3 (µg m^{-3})	BC (µg m^{-3})	BC (Hourly max) (µg m^{-3})
LHR2		46	19	10	-	3	20
Harlington		36	20	n/a	39	-	-
Green Gates		35	17	10	-	-	-
Oaks Road		33	18	10	-	2	16
London Bexley	Suburban	27	-	16	-	-	-
London North Kensington	Urban	51	19	15	28	1	18
London Bloomsbury	Urban	34	-	16	41	-	-
London Marylebone road	Urban	94	26	18	14	6	23
Harwell	Rural	8	n/a	9	56	0.4	5

** n/a refers to a data capture below 75%’;–‘means that the pollutant was not measured at that location.*

The annual mean NO_2 concentrations at LHR2 and Harlington were comparable to those at the urban background sites, London North Kensington and London Bloomsbury respectively. None of the Heathrow Airport sites had NO_2 concentrations as high as those at London Marylebone, a city centre site beside a congested major road. Annual mean NO_2 concentrations at Green Gates and Oaks Road were higher than those at the suburban London Bexley site. They were comparable with the annual mean at London Bloomsbury.

The annual mean PM_{10} concentrations at all four Heathrow sites were lower than the mean for London Marylebone Road and comparable with London North Kensington.

$PM_{2.5}$ concentrations were lower than those for any of the comparison sites. However, this may be due to under-estimation by the TEOM analyser (which for $PM_{2.5}$ cannot be corrected for using the VCM). They could only be comparable with Harwell, rural site.

Concentrations of ozone tend to be higher in rural areas because of the chemistry of its formation. This is demonstrated by the annual mean recorded at Harwell, which was higher than those at the other sites. The annual mean concentration at Harlington is comparable with that measured at London Bloomsbury. As expected, the ozone's annual mean at London Marylebone Road, an urban traffic site (highly influenced by intense local emission sources, is the lowest of them all.

BC data at LHR2 and Oaks Road is comparable with BC data from North Kensington. The highest BC values were found at Marylebone, which was expectable, due to the nature and location of the site (close to a major busy road), in London. The lowest concentrations of BC were registered at Harwell, a rural site, far away from the influence of major pollutant sources.

4.8 Long-term changes in pollutant concentrations

LHR2 has been in operation for 20 years (following installation in 1993). The other three sites have all been in operation since 2003 or earlier. There is now a considerable amount of data which can be used to assess how pollutant concentrations have changed over this period. Annual mean concentrations of NO_x, NO, NO_2, PM_{10}, $PM_{2.5}$ and O_3 are illustrated below in Figures 4.21 to 4.26. Annual means are only shown for years in which data capture was at least 75%.

BC data was not included in this section as this is the first year this has been measured.

Figure 4.21- Time series for annual mean NO

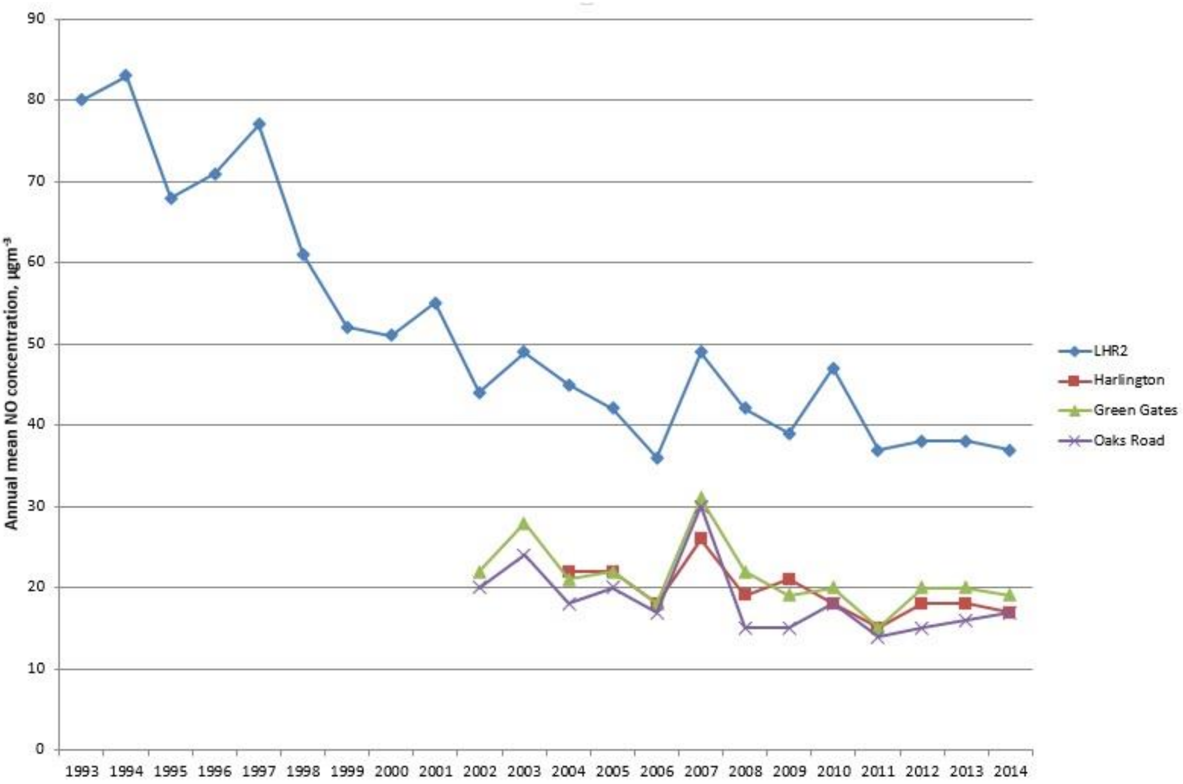
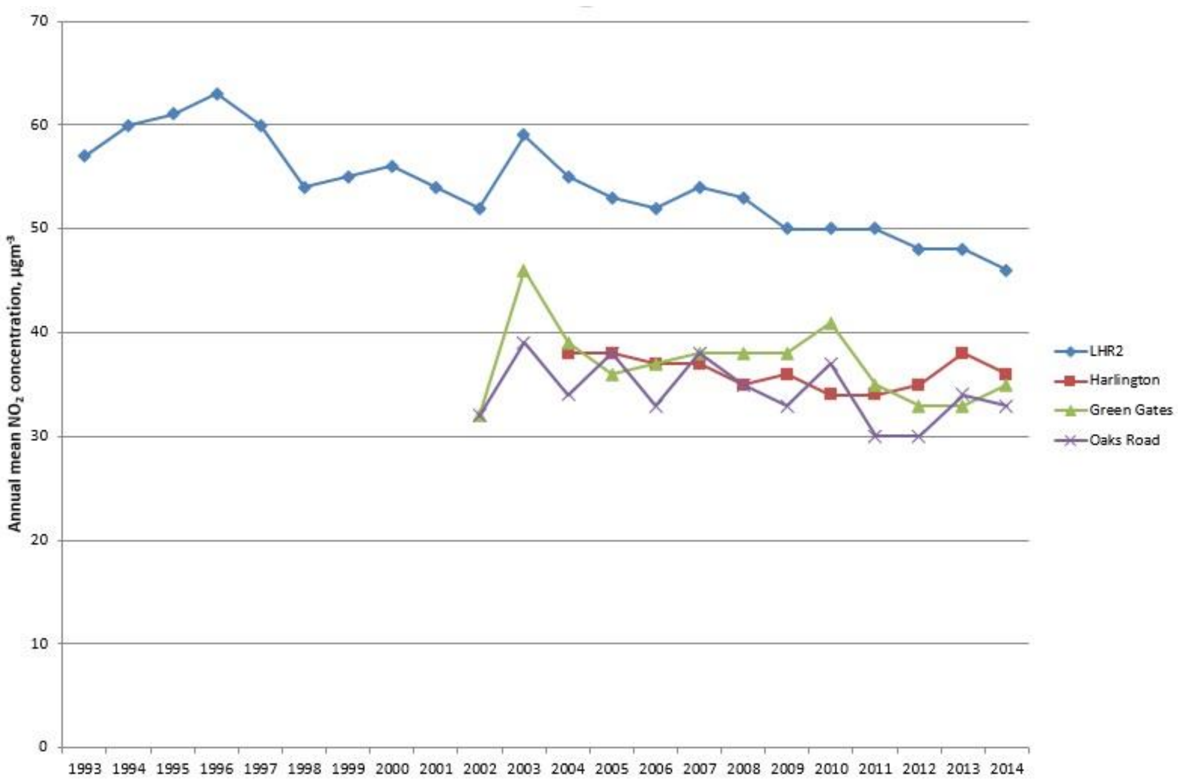


Figure 4.21 shows how annual mean concentrations of total NO have changed at the four sites, since the first site (LHR2) came into operation. There was a clear decrease throughout the 1990s at this site. Since about 2002, concentrations have fluctuated between approximately 38 µg $m^{-3}$and 50 µg m^{-3}. At the other three sites, a slight decrease in annual mean NO_x has occurred during the period 2007-2011, although considerable variations have occurred from one year to the next. NO concentrations seem to have slightly stabilised since 2012 in all sites.

Figure 4.22- Time series for annual mean NO_2.



In the case of NO_2 (illustrated in Figure 4.22), there is a downward trend at LHR2, although this is less marked than those seen for NO in the previous figures. The annual mean concentrations at Harlington, Green Gates and Oaks Road have fluctuated between 30 µg m^{-3} and 40 µg m^{-3} apart from two peaks at Green Gates in 2003 and 2010.

Figure 4.23 shows the annual mean concentration of NO_2 as a percentage of the total NO_x. From the early 1990s to about 2006 NO_2 accounted for an increasing percentage of total NO_x at LHR2. Since then, it has fluctuated between 45 % and 50%. The proportion of NO_x measured as NO_2 at the other three sites has been consistently higher, but has followed broadly similar yearly variations to those seen at LHR2. This percentage seems to have stabilized in all sites since 2012.

An increasing trend in the proportion of NO relative to NO_x has been observed in the UK as a whole. The Air Quality Expert Group[5] considered this may be due to an increase in the proportion of total NO_x emitted as NO_2 resulting from an increased proportion of diesel cars and more prevalent use of catalytically regenerative particulate traps on buses.

Figure 4.23 - Time series for NO_2 as a percentage of total NO_x

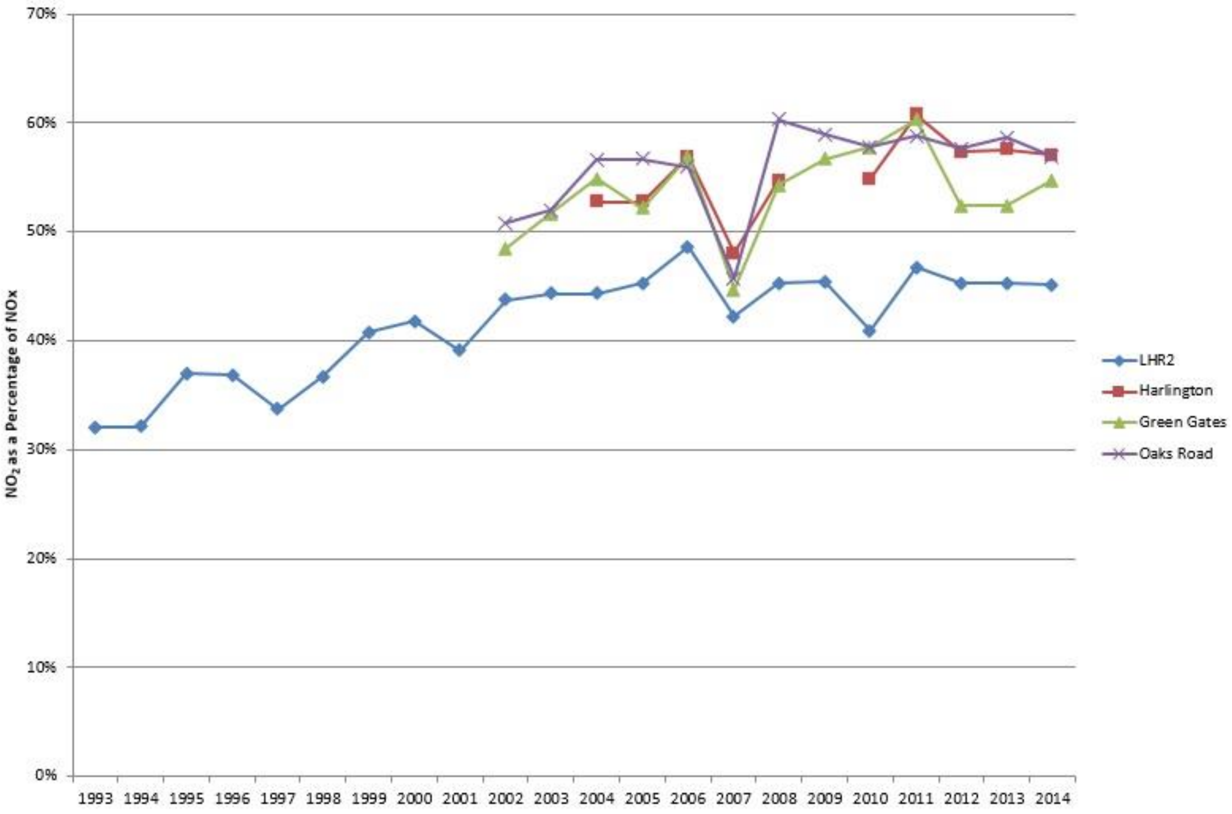


Figure 4.24- Time series for annual mean PM_{10}

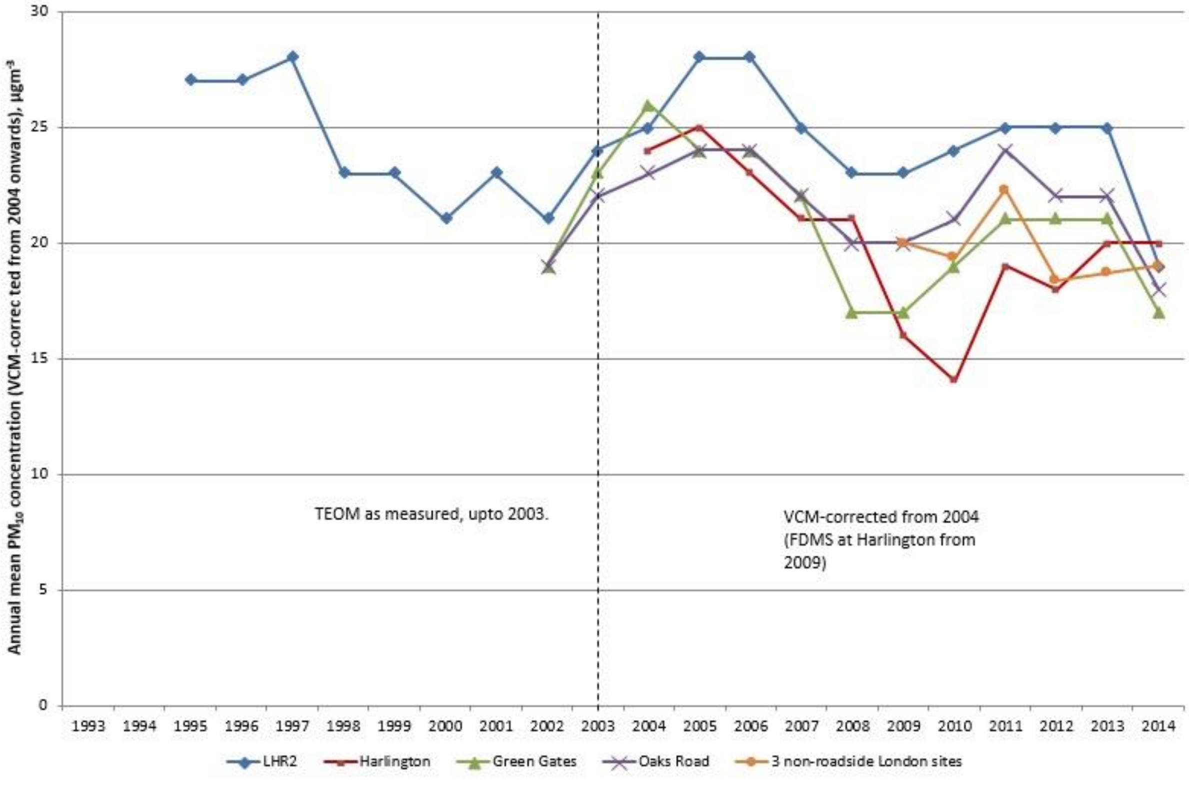


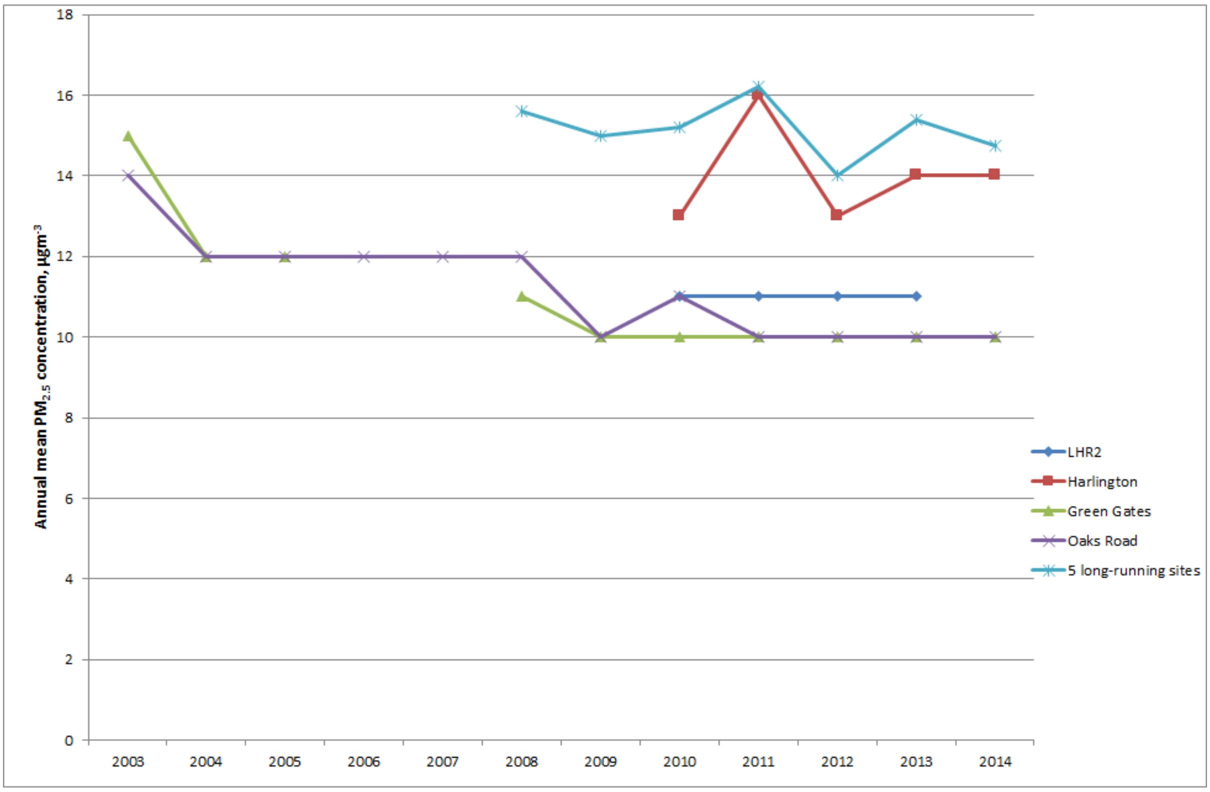
Figure 4.24 shows the annual averages of PM_{10} collected for LHR2 since 1995 and for all sites since 2002. Data for 2014 recorded by a standard TEOM was VCM corrected for LHR2, Green Gates and

Oaks Road until the 23rd of June. After that period, a FIDAS instrument was installed. The FIDAS instrument as of current procedures requires no correction factor.

The annual mean of PM_{10} is lower in 2014 for the Green Gates, Oaks Road and LHR2 stations when compared with results from 2013. Decreases in long terms trends can be seen when installing new instrument techniques due to general improvements in measurement performance. The signal noise given by the FIDAS instrument is much lower than the one given by the TEOM's, the processing of the baseline data from this instrument is much improved.

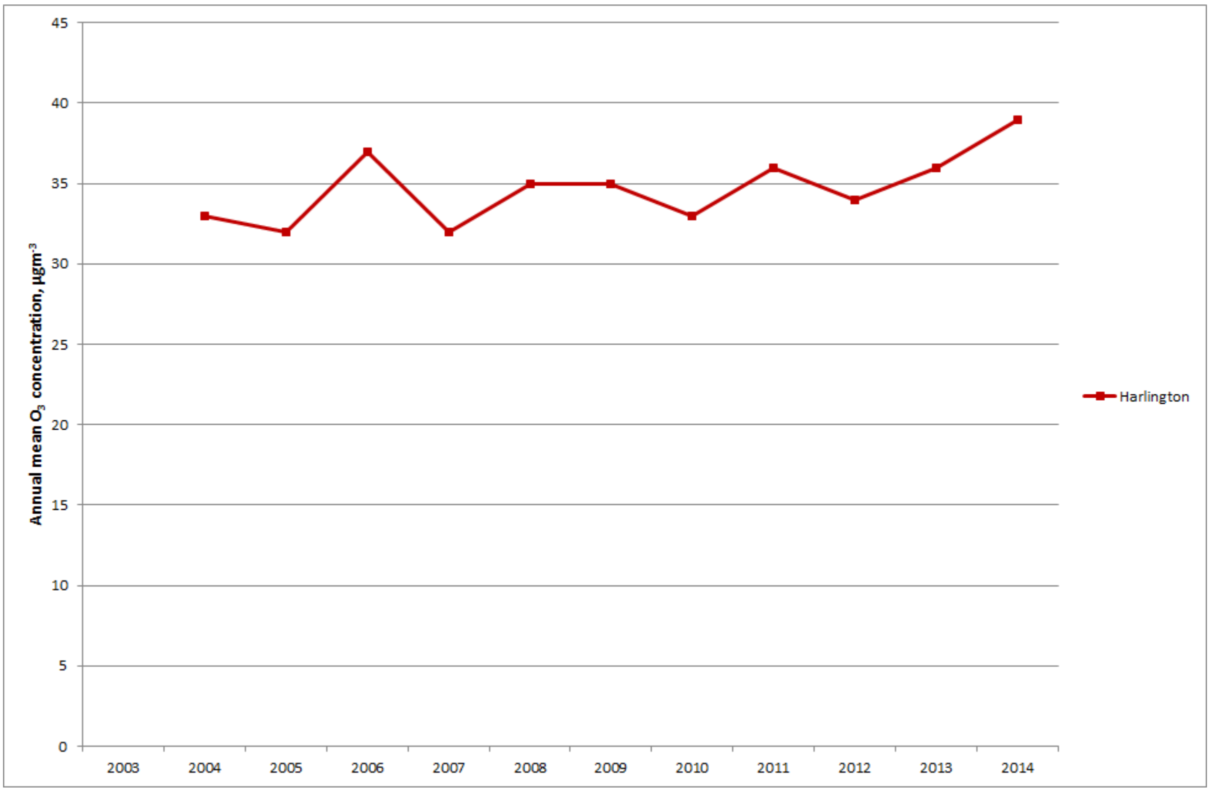
Figure 4.25 shows how annual mean concentrations of $PM_{2.5}$ have changed over time. For Green Gates and Oaks Road, where trends can be observed over several years, concentrations have decreased and remained stable since 2010. Also shown is the mean result from five urban non-roadside monitoring sites in London that have all measured $PM_{2.5}$ since 2008. These are: London Bexley, London Bloomsbury, London Eltham, London North Kensington, London Teddington and London Westminster. The mean from these five sites shows a similar pattern to London Harlington. The annual average of PM2.5 at LHR2 is not displayed on the graph as this didn't meet the >70% data capture required to calculate an annual average.

Figure 4.25 - Trends in annual mean $PM_{2.5}$



Ozone was only measured at Harlington, as illustrated in Figure 4.26. A slight upward trend can be detected. The measured O_3 levels have been increasing since 2012. Annual means of NO and NO_2 have remained stable, which can clearly indicate that the increase of ozone is not made due to the “consumption” of NO. This probably means that the registered increase of ozone levels is due to an increase of sun hours during the year, favouring photochemistry reactions with ozone precursors (CO, VOc, etc) leading to the creation of ozone. Some stratospheric intrusion typical of really hot sunny days might also occur, at a lesser scale, and contribute to the increase of ozone levels. The balance of production and loss reactions combined with atmospheric air motions determines the global distribution of ozone on timescales of days to many months.

Figure 4.26 - Trends in annual mean ozone at Harlington



4.9 Relationship with airport activity

In this section, the potential for correlation between airport activity and pollutant concentrations is investigated by comparing pollutant concentrations with Aircraft Transport Movements (ATM) at Heathrow.

Figure 4.27 -Time series for annual ATM and annual mean NO_x concentrations

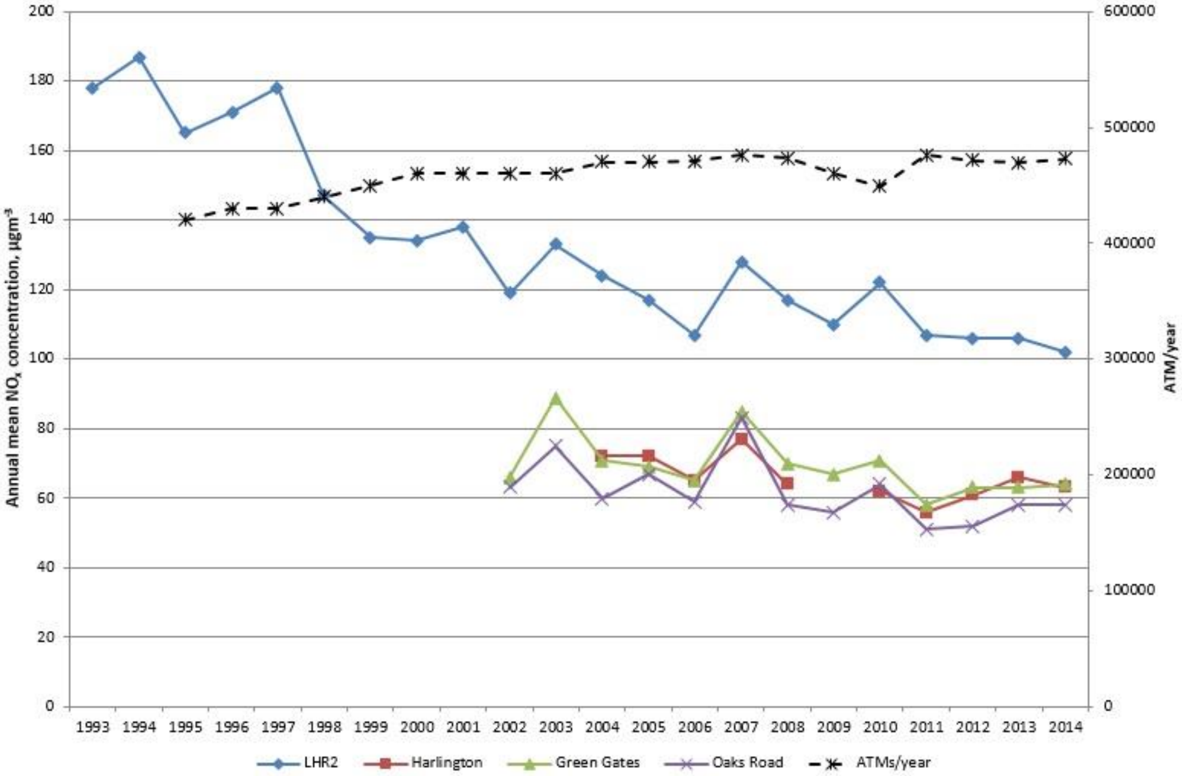


Figure 4.27 shows annual mean NO_x concentrations at the four monitoring sites, together with annual total ATMs. ATMs rose steadily at Heathrow from 1995 to 2007, after which there was a decline until 2011. Since then, ATMs have remained steady at around 470,000. Local ambient concentrations in NO_x have fluctuated over the same period, but there is no obvious relationship between NO_x concentrations and airport activity. (However the airport activities will contribute to NO_x concentrations in the area.)

Figure 4.28 - Time series for annual ATM and annual mean PM_{10} concentrations

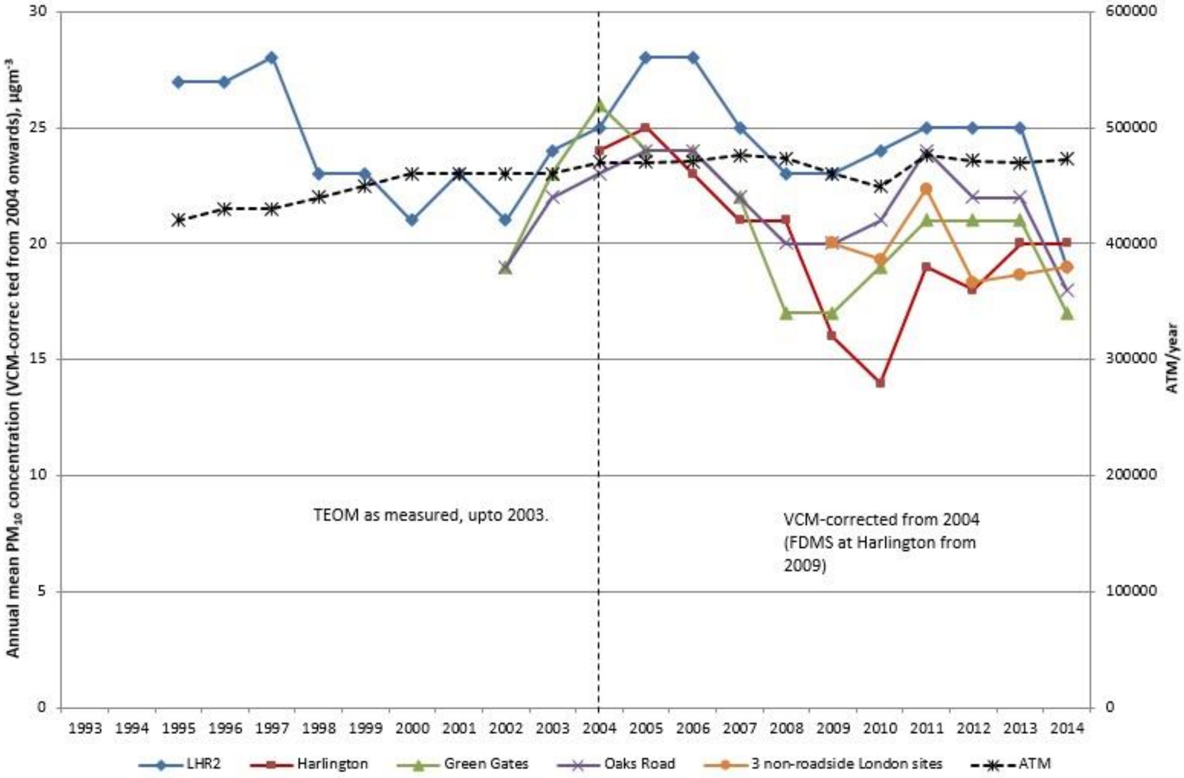


Figure 4.28 shows the same comparison for PM_{10}, with no clear relationship being apparent between annual mean PM_{10} and changes in air transport movements. This does not mean that the airport is not a major contributor to local ambient PM_{10}, but suggests that variations in ambient PM_{10} concentrations are also dependent on other factors. This simple analysis of air traffic movements indicate that annual variation in pollutant concentrations (i.e. the periods of high and low concentration) around Heathrow are influenced to a greater extent by general meteorological factors than by air traffic movement.

5 Conclusions

The following conclusions have been drawn from the results of air quality monitoring around Heathrow Airport during 2014.

Oxides of nitrogen and particulate matter (as PM_{10} and $PM_{2.5}$) were monitored throughout 2014 at four sites around Heathrow Airport (LHR2, London Harlington, Green Gates and Oaks Road). Ozone was measured at Harlington. VOC's were indicatively monitored using diffusion tubes at LHR2 during 4 months. BC was measured for the first time at LHR2 and Oaks Road. The conclusions of the 2014 monitoring programme are summarised below.

1. Data capture of at least 90% was not achieved for some of the pollutants monitored at LHR2 and Harlington. This target was not achieved at Harlington for PM_{10} and O_3, for which the data capture was 88 and 84%, and at LHR2 for $PM_{2.5}$, where the data capture was 62%.
2. Oxides of nitrogen were monitored at all four sites. No sites exceeded the AQS objective of 200 µg m^{-3} for hourly mean NO_2 more than the 18 permitted times per year during 2014.
3. One site, LHR2, exceeded the annual mean AQS objective of 40 µg m^{-3} for NO_2 in 2014, with an annual mean of 46 µg m^{-3}, although the EU limit values and AQS objectives do not apply at the LHR2 site, because it is within the airport boundary where there is no public exposure. The other three sites did not exceed this objective.
4. All four sites met the AQS objective for 24-hour mean PM_{10}. Measurements were made using a TEOM instrument until late June, these data were converted to gravimetric equivalent using the King's College Volatile Correction Model (VCM), from late June to December, PM data started being measured using a FIDAS instrument with no correction required.
5. All four sites met the annual mean AQS objective of 40 µg m^{-3} for PM_{10}, again after correction, where applicable, to gravimetric equivalent using the VCM.
6. Ozone was measured at Harlington only, this site exceeded the AQS objective for ozone on 8 days during 2014, which is less than the permitted maximum of 10 days per calendar year. Harlington has exceeded the objective before, the most recent occurrences being in 2006, 2008, 2009, 2011 and 2013. The AQS objective was met in 2014.
7. Diffusion tube measurements at LHR2 indicate that this site met the AQS objective for benzene although there wasn't enough data to calculate a reliable annual average due to the tube measurements ending in April 2014.
8. Seasonal variations in pollutant concentrations at all sites were similar to those observed in previous years and at other urban background sites. Both NO, NO_2 and BC exhibited higher concentrations during the winter months. PM_{10} and $PM_{2.5}$, which have both primary and secondary components, showed a much less pronounced seasonal pattern. Ozone levels were highest during the spring and summer, as is typical.
9. The diurnal patterns of concentrations of all pollutants were similar to those observed at other urban monitoring sites. Peak concentrations of NO, NO_2, particulate matter and BC coincided with the morning and evening rush hour periods, and levels of ozone peaked in the afternoons.
10. Several periods of elevated PM_{10} concentration (daily mean concentration in the Defra "High" and "Very High" bands) occurred during 2014. As in previous years, other urban background monitoring sites in London and the south east of England showed a similar pattern of elevated PM_{10} concentrations during the above periods. This indicates that the higher concentrations measured at Heathrow reflected regional variations in PM_{10} concentration, rather than any emission sources specific to the airport.
11. Ozone concentration (measured at Harlington only) went into the "Moderate" band for 32 times in 8 days in 2014.
12. Modelled meteorological data was used at LHR2, allowed the effect of wind direction and speed to be investigated. Bivariate plots of NO and BC concentration and wind data showed that concentrations of NO and BC at LHR2 were typically highest in calm conditions, indicating that the main sources of this pollutants were nearby. The pattern was slightly different for NO_2, with a strong signal also appearing from the south west and at higher wind speeds. The patterns for PM_{10} and $PM_{2.5}$ were similar with the pattern for NO_2, showing contributions from sources on a bearing of approximately 70 ° at a range of wind speeds. In the case of PM_{10} there were also contributions from the south west at higher wind speeds.
13. Mean concentrations of pollutants at the four Heathrow sites in 2014 were comparable with those measured at other suburban and urban background monitoring sites in London.

14. Long-term data from this monitoring programme indicate that annual mean concentrations of the primary pollutant NO have decreased, although they have fluctuated around a more constant level in recent years. A decrease is also observed in annual mean concentrations of NO_2 at LHR2, although the pattern is less marked at the other sites. PM_{10} has shown a slight increase. The proportion of total NO_x measured as NO_2 has stabilized over the last 3 years, and O3 level continue to increase.
15. Neither seasonal patterns, nor long-term trends, in pollutant concentration at the Heathrow sites showed once more any obvious relationship to annual aircraft transport movements. Although the airport is likely to be a significant contributor to local air pollution, ambient concentrations are also influenced by meteorological and other factors.

6 Acknowledgements

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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 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 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 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) 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)* 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 over 10 days 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	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	888-1,064	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 Heathrow air quality monitoring stations:

- NO, NO_2: chemiluminescence with ozone.
- PM_{10} and $PM_{2.5}$: Tapered Element Oscillating Microbalance (TEOM) at LHR2, Green Gates and Oaks Road until the 23rd of June 2014 (inclusive). Fine Dust Analysis Systems (FIDAS) from the 24th of June to the 31st of December 2014. Filter Dynamics Measurement Systems (FDMS) TEOM (a modified form of TEOM which measures both volatile and non-volatile fractions) at Harlington.
- O_3: UV absorption analyser, Harlington only.
- Black Carbon (BC): Aethalometer, LHR2 and Oaks Road only.

These methods were selected in order to provide real-time data. The chemiluminescence and the UV absorption analysers are the European reference method for ambient NO_2 and O_3 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 analysers for NO_x and O_3 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.

Aethalometers quantify black carbon on filter samples based on the transmission of light through a sample. The sample is collected on a quartz tape, and the change in absorption coefficient of the sample is measured by a single pass transmission of light through the sample measured relative to a clean piece of filter. The aethalometers operate most commonly at two wavelengths, 880 nm and 370 nm. The 880 nm wavelength is used to measure the black carbon (BC) concentration of the aerosol, while the 370 nm wavelength gives a measure of the “UV component” of the aerosol[15].

The FDMS unit provides particulate matter (PM) measurement that closely correlates with gravimetric PM mass concentration, as measured with the EU Reference Sampler. The FDMS system accounts for volatile PM that may not be detected by earlier TEOM models. The device provides high-resolution PM mass concentration readings for both short-term averages (one hour) as well as 24-hour averages. The system’s basic output consists of a 1-hour average mass concentration (in $\mu g/m^3$) of PM updated every six minutes. FDMS units automatically measures mass concentrations (ug/m^3) that include both non-volatile and volatile PM components.

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 (PM_1, $PM_{2.5}$,PM_4, PM_{10} and Total Suspended Particles (TSP).

The PM 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) [9]. 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.

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[10].

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 NO_x 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 Heathrow are summarised in Table 3.1 on page 10.

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 NO_x has been calculated as follows:

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

This complies with the requirements of the Air Quality Directive[3] and is also the convention generally adopted in air quality modelling.

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