

Air Quality at Heathrow Airport – Annual Report for 2012



Customer:

Heathrow Airport Ltd

Customer reference:

ED57523

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Ricardo-AEA reference:

Ref: 57523001– Ricardo-AEA/R/3358 Issue 1

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Executive Summary

This report presents a summary of the 2012 results from an ongoing programme of air pollution monitoring, undertaken on behalf of Heathrow Airport Ltd. The aim is to monitor air pollution around the airport, to provide a reliable assessment of the pollutant concentrations to which local residents are exposed, and assess whether these meet applicable air quality standards and guidelines. The monitoring programme also aims to investigate how air pollutant concentrations are varying over time.

Monitoring continued at four sites:

- LHR2 which is located on the northern apron, near the airport boundary and perimeter road. This site has been used since 1993.
- London Harlington (which is part of the UK's national monitoring network, the Automatic Urban and Rural Network). The site was established in 2003.
- Green Gates (near the north western airport perimeter) which has been operational since 2001, and included in the survey since 2007.
- Oaks Road (a residential location to the south west) which has also been operational since 2001, and included in this survey since 2007.

Oxides of nitrogen and particulate matter (PM₁₀ and the finer size fraction PM_{2.5}) were measured at all four sites throughout 2012. Ozone was measured only at Harlington. Indicative monitoring of hydrocarbons including benzene (by diffusion tubes) was also undertaken at LHR2.

All four sites met the Air Quality Strategy (AQS) objective for 1-hour mean NO₂ concentration in 2012. LHR2 exceeded the AQS objective of 40 µg m⁻³ for annual mean NO₂ concentration (which is widely exceeded in urban areas of the UK). The other three sites met this objective. 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.

All four sites met the AQS objectives for daily mean and annual mean PM₁₀ particulate matter, and the target value for PM_{2.5} particulate matter.

The Harlington site (the only one at which ozone was measured) was within the permitted 10 exceedances of the AQS objective for ozone in 2012.

The indicative annual mean concentration of benzene at Heathrow (LHR2) was well below the Air Quality Strategy objective.

Average concentrations of NO, NO₂, PM₁₀, PM_{2.5} and ozone at the Heathrow sites were generally comparable to those measured at urban background air pollution monitoring sites 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. NO₂, which has both primary and secondary components, showed a similar pattern. PM₁₀ and PM_{2.5} showed a much less pronounced seasonal pattern, but also showed a tendency to be higher in winter. This type of seasonal pattern is typical for these pollutants in urban areas. Ozone (measured at Harlington only) showed higher concentrations in the summer. This is a typical seasonal pattern for ozone, which is formed from other pollutants in the presence of sunlight.

Meteorological measurements at LHR2 allowed the effect of wind speed and wind direction to be investigated. Bivariate plots of pollutant concentration indicated that nearby sources, such as the perimeter road, were probably the main source of NO. In the case of NO₂, there also appeared to be a contribution from the south at higher wind speeds. For both PM₁₀ and PM_{2.5}, concentrations were highest under calm conditions but (particularly for PM₁₀) there

also appeared to be a contribution from an approximately easterly direction at a range of wind speeds.

Several periods of elevated PM_{10} concentration occurred during the early months of the year, going into the Defra “Moderate” band. These periods of elevated particulate pollution were also observed at other sites throughout London: they appear to reflect regional variations in particulate pollution, rather than anything connected with the airport.

There are now Defra air quality bandings for $PM_{2.5}$: Harlington had 14 days of “Moderate” $PM_{2.5}$ and three days of “High” $PM_{2.5}$. The latter occurred in March. All the other sites remained in the “Low” band for this parameter.

Similarly, a period of elevated ozone concentration occurred during late May, with concentrations going into the “Moderate” band on six days. These also appear to have affected a large region, being observed at sites elsewhere in London.

In the long term, annual mean concentrations of total oxides of nitrogen, and NO , appear to show a general decrease over the past decade (although there is considerable year-to-year fluctuation). However, there is less evidence of a downward trend in NO_2 . Also, the proportion of NO_x measured as NO_2 has increased. Annual mean concentrations of PM_{10} do not show a clear trend: concentrations at three sites have increased in the past two years, after a number of years in which they appeared to be decreasing. There is no apparent upward or downward trend in ozone (monitored at Harlington only).

Although the airport is likely to be a significant 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 driven by other factors (such as variations in meteorological conditions and other emissions beyond Heathrow’s control (e.g. non-airport road traffic)).

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1 Introduction

1.1 Background

Heathrow Airport is the world's busiest international airport, handling over 65 million passengers a year. The airport is situated approximately 12 miles to the west of London, but within the general urbanised area of Greater London.

Airports contain many significant sources of air pollutants. Aircraft jet engines emit pollutants including oxides of nitrogen (NO_x), carbon monoxide (CO), oxides of sulphur (SO_x), particulate matter, hydrocarbons from partially combusted fuel, and other trace compounds. There will also be 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 (site LHR2), and outside the airfield at Harlington, Green Gates and Oaks Road.

The pollutants monitored were as follows:

- oxides of nitrogen (nitric oxide (NO) and nitrogen dioxide (NO₂));
- particulate matter (PM₁₀ and PM_{2.5} fractions);
- ozone (O₃)
- volatile organic compounds (VOCs) – benzene, toluene, ethylbenzene and xylenes.

The monitoring is undertaken by Ricardo-AEA Ltd., on behalf of Heathrow Airport Ltd. Year 2012 was the twentieth consecutive year of this ongoing monitoring programme, and this report presents and summarises the fully validated and quality controlled dataset for the period 1st January to 31st December 2012.

In addition to this report, Heathrow Airport has daily access to provisional data from the Heathrow monitoring sites via the Heathrow Airwatch website (<http://www.heathrowairwatch.org.uk/>), and data from the UK's national air quality monitoring network, via the Defra UK Air Information Resource (UK-AIR) at <http://uk-air.defra.gov.uk/>.

1.2 Objectives

The objective of the monitoring programme, as in previous years, is to provide information on levels of air pollution in the area, to which the neighbouring community may be exposed. Also, to provide a reliable assessment in relation to applicable air quality standards, and to determine any trends in air pollution concentrations over time. Meteorological data are also 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.

2 Details of the Monitoring Programme

2.1 Pollutants Monitored

The monitoring programme concentrates on the pollutants which may be of concern around airports. These are listed below. The emission statistics presented here all come from the National Atmospheric Emissions Inventory (NAEI)¹.

2.1.1 Oxides of Nitrogen

Combustion processes emit a mixture of oxides of nitrogen, mainly nitric oxide (NO) and nitrogen dioxide (NO₂), collectively termed NO_x. NO is described as a “primary” pollutant, i.e. it is directly emitted from source. Though NO is not known to have any harmful effects on human health at ambient concentrations, it undergoes oxidation in the atmosphere to form the secondary pollutant NO₂. NO₂ is a respiratory irritant and is toxic at high concentrations. It is also involved in the formation of photochemical smog and acid rain and may cause damage to crops and vegetation.

Major outdoor sources of NO_x in urban areas are fuel combustion in motor vehicles (which account for around one third of total UK emissions), power generation, heating plant and industrial processes. Based on 2010 UK data from the NAEI¹, civil aircraft taking off and landing (on domestic and international flights) are estimated to contribute only 0.95% to total UK emissions of NO_x. Although this is a small percentage for the UK overall, aircraft and other airport-related sources are likely to make a much more significant contribution to local NO₂ levels close to airports. There will also be a substantial contribution from airside vehicles, and from road traffic travelling to and from the airport. NO₂ is therefore the main pollutant of concern around airports.

2.1.2 Particulate Matter

Airborne particulate matter varies widely in its physical and chemical composition, source and particle size. Particulate matter is categorised by particle size: it is most commonly monitored as PM₁₀ (i.e. particles whose effective size is <10 µm) and PM_{2.5} (i.e. particles with effective size <2.5 µm). Fine particles are of most concern, as they are small enough to penetrate deep into the lungs, where they can have the greatest impact upon health.

The main sources of airborne particulate matter in the UK are combustion (industrial, commercial and residential fuel use). This is followed by road vehicle emissions. Based on 2010 NAEI data, 0.1% of UK total PM₁₀ emissions are believed to originate from civil aircraft taking off and landing¹.

2.1.3 Ozone

Ozone (O₃) is not emitted directly into the atmosphere in significant quantities, but is a secondary pollutant produced by reaction between nitrogen dioxide (NO₂) and hydrocarbons, in the presence of sunlight. Whereas nitrogen dioxide (NO₂) acts as a source of ozone, 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".

2.1.4 Volatile Organic Compounds

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 fuels¹. 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 most 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 (2010)¹ 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, although 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).

2.2 Air Quality Limit Values and Objectives

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

2.2.1 European Union

Throughout Europe, ambient air quality is regulated by the European Union (EU) Directive on Ambient Air Quality and Cleaner Air for Europe (2008/50/EC)². This Directive (referred to as the Air Quality Directive) consolidated three previously existing Directives, which set limit values for a range of air pollutants with known health impacts including NO₂, PM₁₀ and benzene.

All Member States of the European Union are required to transpose the provisions of the Directive into their national law. The original Directives were transposed into UK law via the Environment Act 1995 and subsequent Statutory Instruments.

2.2.2 The UK Air Quality Strategy

The Environment Act also placed a requirement on the Secretary of State for the Environment to produce a national Air Quality Strategy containing standards, objectives and measures for improving ambient air quality. The original Air Quality Strategy was published in 1997, and contained air quality objectives based on the recommendations of the Expert Panel on Air Quality Standards (EPAQS) regarding the levels of air pollutants at which there would be little risk to human health.

The Air Quality Strategy has since undergone a number of revisions. These have reflected improvements in the understanding of air pollutants and their health effects. They have also incorporated new European limit values, both for pollutants already covered by the Strategy and for newly introduced pollutants such as polycyclic aromatic hydrocarbons and PM_{2.5} particulate matter. The latest version of the strategy was published by Defra in 2007³.

All Air Quality Strategy (AQS) objectives must be at least as stringent as the EC limit values. The current UK air quality objectives for the pollutants monitored at Heathrow Airport are presented in Table 2-1. In some cases Scotland, Wales or Northern Ireland have adopted different objectives; Table 2-1 shows the AQS objectives that apply in England.

The ozone objective is not included in the Air Quality Regulations for the purposes of Local Air Quality Management, as ozone is a transboundary pollutant and difficult to control by local action. It is frequently exceeded in many areas of the UK, particularly rural areas.

Table 2-1 Air Quality Objectives Relevant to Heathrow Monitoring Programme

Pollutant	Air Quality Objective		To be achieved by
	Concentration	Measured as	
Benzene (England and Wales)	5.00 µg m ⁻³	Annual mean	31 December 2010
Nitrogen dioxide (NO ₂)	200 µg m ⁻³ not to be exceeded more than 18 times a year	1-hour mean	31 December 2005
	40 µg m ⁻³	Annual mean	31 December 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 December 2004
	40 µg m ⁻³	Annual mean	31 December 2004
Particles (PM _{2.5}) (gravimetric)	25 µg m ⁻³	Annual mean (non-mandatory target)	2020
Ozone (O ₃)*	100 µg m ⁻³ not to be exceeded more than 10 times a year	8 hourly running or hourly mean*	31 December 2005

* ozone not included as part of the LAQM regime.

2.3 Location of the Monitoring Sites

The pollutants monitored are shown in Table 2-2. 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.

Table 2-2 Air Quality Monitoring at Heathrow: Locations of Monitoring Sites

Site Name	Description	Parameters monitored	Grid reference
LHR2	Old northern apron	NO _x , PM ₁₀ , PM _{2.5} , benzene (indicative), wind speed, wind direction.	508400 176750
Harlington	Imperial College Sports Ground, 1km north of LHR2	NO _x , PM ₁₀ , PM _{2.5} , Ozone	508299 177809
Heathrow Green Gates	Bath Road, close to north west of airport	NO _x , PM ₁₀ , PM _{2.5}	505630 176930
Heathrow Oaks Road	Residential area to SW of airport.	NO _x , PM ₁₀ , PM _{2.5}	505740 174500

The site locations are shown in Figure 2-1.

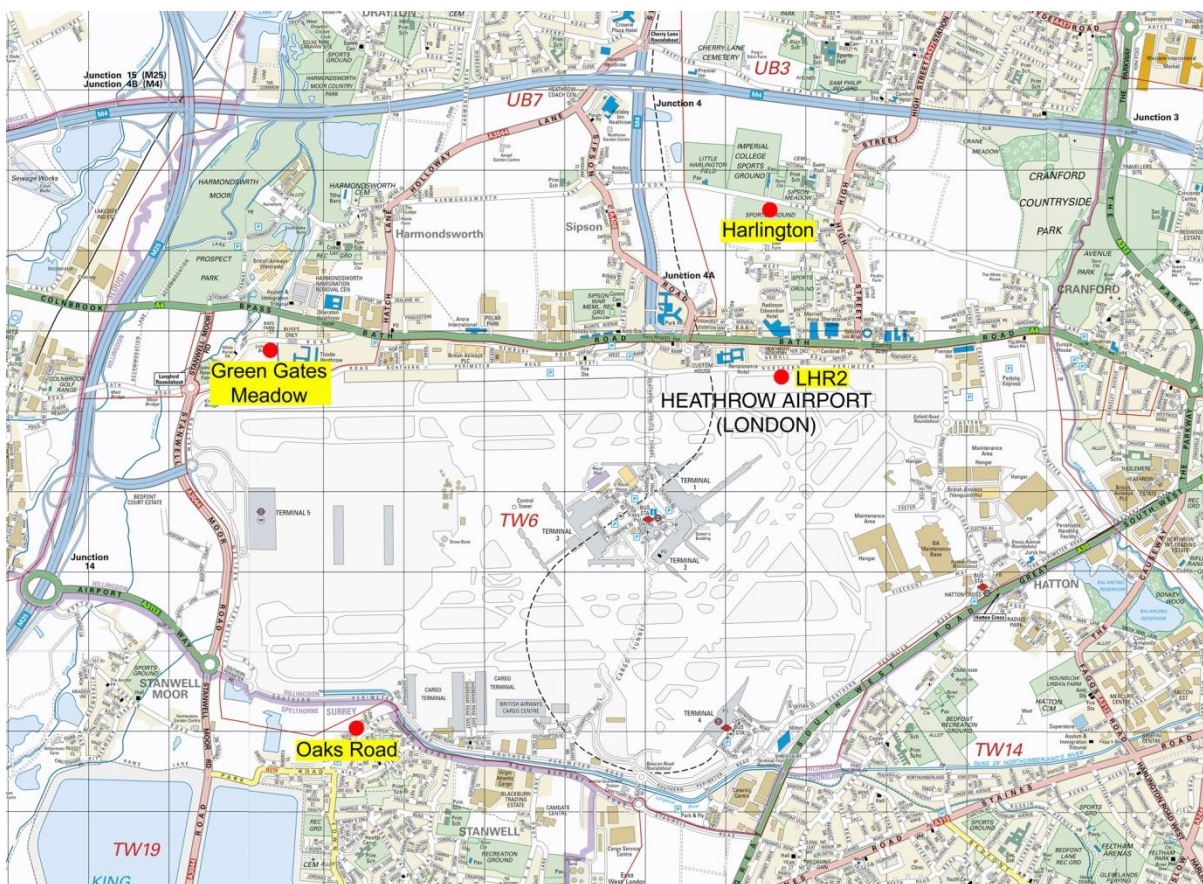


Figure 2-1 Location of Monitoring Sites

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, 14.5m from the kerb and 179m 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 site falls into the category "Other" as defined by the Defra

Technical Guidance on air quality monitoring (LAQM.TG (09)⁴), i.e. " 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. "



Figure 2-2 Heathrow LHR2 Air Quality Monitoring Site

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, strictly these limits do not 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 1km north of LHR2 and 300m from the western edge of Harlington. As of 1st January 2004, the site has been part of the Defra Automatic Urban and Rural Network (AURN). 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. Within the AURN, the site is known by its full name of "London Harlington" but will be referred to as "Harlington" in this report.

Figure 2-4 shows the Green Gates site. This site is close to Bath Road, which runs along the northern perimeter of the airport and is classified as "Other" according to LAQM.TG(09).



Figure 2-3 London Harlington Air Quality Monitoring Site



Figure 2-4 Green Gates Air Quality Monitoring Site

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.



Figure 2-5 Oaks Road Air Quality Monitoring Site

2.4 Monitoring Methods

2.4.1 Automatic Measurements

Continuous automatic analysers are used for monitoring oxides of nitrogen (NO_x), PM₁₀, PM_{2.5} and O₃. These provide real-time data. The analysers use the operating principles listed below: these represent the current state-of-the-art techniques for ambient monitoring of these species.

- NO, NO₂ : chemiluminescence analysers at all four sites.
- PM₁₀: Tapered element oscillating microbalance (TEOM) at LHR2, Green Gates and Oaks Road. FDMS TEOM (a modified form of TEOM which measures both volatile and non-volatile fractions) at Harlington.
- PM_{2.5}: TEOM at LHR2, Green Gates and Oaks Road. FDMS TEOM at Harlington.
- O₃: UV absorption analyser, Harlington only.

Each analyser provides a continuous output, proportional to the pollutant concentration. The results are recorded by an external data logger, which is connected to a modem and interrogated by telephone to download the data to Ricardo-AEA. Data are downloaded hourly and are converted to concentration units at Ricardo-AEA. Details of quality assurance and quality control procedures are given in Appendix 1.

2.4.2 VCM Correction of PM₁₀ Data

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

It is not possible to address this problem by applying a simple correction factor. However, King's College London (KCL) have developed a Volatile Correction Model⁵, which allows TEOM PM₁₀ data to be corrected for the volatile components lost as a result of the TEOM's heated inlet. The model is available at <http://www.volatile-correction-model.info/Default.aspx>. It uses data from nearby TEOM-FDMS particulate analysers, which measure the volatile and non-volatile components of the PM₁₀. The volatile component (which typically does not vary much over a large region), can be added to the TEOM measurement. KCL state that the resulting corrected measurements have been demonstrated as equivalent to the gravimetric reference equivalent. In this report, the VCM has been used to correct PM₁₀ data where applicable. Where this has been done, it is clearly indicated.

There is no requirement to correct PM_{2.5} data measured using the TEOM, and no demonstrated and approved method for doing so.

2.4.3 Diffusive Sampling of Hydrocarbons

Diffusion tubes were used at LHR2 for indicative monitoring of a suite of four hydrocarbons – benzene, toluene, ethylbenzene and xylenes. Diffusion tubes are "passive" samplers, i.e. they 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.

BTEX diffusion tubes were prepared and analysed by Gradko International Ltd., and changed by Ricardo-AEA on a four-weekly basis.

Diffusion tubes are an indicative technique, with greater uncertainty than most automatic methods. The reported margins of uncertainty on the analysis ranged from ± 9.6% to ± 10.3% in 2012. However, uncertainties arising from the exposure phase also contribute to the overall uncertainty: 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 2012 the limit of detection (LoD) varied from 1.83 ng to 5 ng (total mass on tube). This equated to ambient concentrations ranging from 0.02 µg m⁻³ to 0.1 µg m⁻³. **The laboratory advises that results less than 10 x the limit of detection will have a higher level of uncertainty; for the ambient concentrations measured at Heathrow, this was the case for the majority of measurements. The BTEX hydrocarbon measurements are therefore likely to have overall uncertainty > ± 25% and should be treated as indicative only.**

3 Results and Discussion

3.1 Quality Assurance and Quality Control

Following 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 the Heathrow sites are summarised in Table 3-1. These meet the data quality objectives of the Air Quality Directive². “Precision” is defined as the repeatability of a measurement (i.e. how close replicate measurements are to each other), while “accuracy” refers to how close the measurement is to the “true” value.

Table 3-1 Estimated Accuracy and Precision 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*)

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

3.2 Data Capture

Overall data capture statistics for the two monitoring sites are given in Table 3-2. A data capture target of 90% is recommended in the Defra Technical Guidance LAQM.TG(09)⁴.

Table 3-2 Data Capture Statistics 2012

Site	NO	NO ₂	PM ₁₀	PM _{2.5}	O ₃
LHR2	97.3 %	97.3 %	99.0 %	98.7 %	-
Harlington	98.4 %	98.4 %	84.3 %	90.8 %	91.9 %
Green Gates	98.0 %	98.0 %	99.0 %	96.4 %	-
Oaks Road	93.1 %	93.1 %	96.1 %	98.3 %	-

The data capture target was achieved for all measured pollutants at LHR2, Green Gates and Oaks Road.

At Harlington the data capture target of 90% was achieved for all measured pollutants except PM₁₀. The most significant gap was caused by a period of unstable and noisy data between 1st May and 8th Jun, which required an engineer callout to repair. There was also a short period of unstable volatile data in March, and also some data loss due to a planned zero test in early February. (The zero test procedure involves placing a filter over the inlet to test the instrument’s response to particle-free air over several days – this therefore impacts upon

data capture.) Only Harlington underwent a zero test of this type, due to its being in the AURN.

Data gaps greater than 24 hours are shown in Table 3-3.

Table 3-3 Significant Data Gaps 2012

Site	Pollutant	Period	No. of days	Reason
Harlington	PM ₁₀	2 nd Feb – 7 th Feb	5.2	QA/QC zero test
Harlington	PM ₁₀	31 st Mar – 2 nd Apr	2.6	Engineer replaced drier
Harlington	PM ₁₀	26 th Apr – 8 th Jun	43.6	Noisy data: engineer callout to fix FDMS fault.
Harlington	PM _{2.5}	2 nd Feb – 6 th Feb	4.3	QA/QC zero test
Harlington	PM _{2.5}	1 st Apr – 18 th Apr	17.6	Engineer replaced drier
Harlington	PM _{2.5}	11 th May – 16 th May	5.2	QA/QC zero test
Harlington	PM _{2.5}	6 th Jul – 8 th Jul	1.7	Noisy data following QA/QC audit
Harlington	O ₃	6 th Jul – 27 th Jul	21.3	Sampling fault
Harlington	O ₃	31 st Jul – 6 th Aug	6.1	Analyser fault following power cut
Green Gates	PM _{2.5}	20 th Dec – 31 st Dec	11	Data collection fault
LHR2	NO ₂	10 th Nov – 15 th Nov	5	Analyser fault – PMT Cooling Fan replaced by engineer
LHR2	PM _{2.5}	23 rd Apr – 25 th Apr	2.1	Communications fault – rectified at LSO visit
Oaks Road	NO ₂	1 st Jan – 13 th Jan	13	Analyser fault low response
Oaks Road	NO ₂	6 th Feb – 7 th Feb	1.3	Analyser fault
Oaks Road	NO ₂ / PM _{2.5}	10 th Dec – 11 th Dec	1.8	Power cut
Oaks Road	PM ₁₀	8 th Dec – 17 th Dec	8.5	Analyser software fault following power cut
Oaks Road	PM _{2.5}	27 th Mar – 29 th Mar	2.1	Analyser pump fault

3.3 Presentation of Results

Summaries of the results of the automatic monitoring at the four sites around Heathrow are shown in Table 3-4 to Table 3-7, for Heathrow LHR2, Harlington, Green Gates and Oaks Road respectively.

Time series charts of data for the full year are shown in Figure 3-1 for NO, Figure 3-2 for NO₂, Figure 3-3 for PM₁₀, Figure 3-4 for PM_{2.5} and Figure 3-5 for ozone (at Harlington only). The hourly mean PM₁₀ data shown in Figure 3-3 are “as measured”, i.e. not VCM-corrected in the case of LHR2, Green Gates and Oaks Road.

The “native” units of the analysers used for the gaseous pollutants NO, NO₂ and O₃ are parts per billion by volume (ppb). The measured concentrations of the gaseous pollutants have been converted to microgrammes per cubic metre ($\mu\text{g m}^{-3}$) in this report, for comparison with Air Quality Strategy objectives (which are also expressed in these units). The conversion factors used are given below:

- NO 1 ppb = $1.25 \mu\text{g m}^{-3}$
- NO₂ 1 ppb = $1.91 \mu\text{g m}^{-3}$
- O₃ 1 ppb = $2.00 \mu\text{g m}^{-3}$
- C₆H₆ (benzene) 1 ppb = $3.25 \mu\text{g m}^{-3}$
- C₇H₈ (toluene) 1 ppb = $3.83 \mu\text{g m}^{-3}$
- C₈H₁₀ (ethylbenzene and xylenes) 1 ppb = $4.41 \mu\text{g m}^{-3}$

(at 20°C and 1atm pressure).

The mass concentration of NO_x has been calculated as follows:

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

This conforms to the requirements of the Air Quality Directive² and is also the convention generally adopted in air quality modelling.

PM₁₀ is conventionally reported in units of $\mu\text{g m}^{-3}$, microgrammes per cubic metre. In this report PM₁₀ measured using the TEOM instrument are presented

- (i) “as measured”, and
- (ii) Converted to gravimetric equivalent by use of the KCL Volatile Correction Model (VCM)⁵.

For the purposes of comparison with air quality objectives, VCM-corrected data are used. However, when considering diurnal patterns and relationships between pollutant concentrations and wind direction, the TEOM data are used as measured, i.e. the VCM has not been applied.

At Harlington the PM₁₀ measurements are made using an FDMS analyser, so no VCM correction is necessary.

Table 3-4 Air Pollution Statistics for Heathrow LHR2, 2012

LHR2	NO $\mu\text{g m}^{-3}$	NO ₂ $\mu\text{g m}^{-3}$	NO _x $\mu\text{g m}^{-3}$	PM ₁₀ as measured $\mu\text{g m}^{-3}$	PM ₁₀ (VCM corrected) $\mu\text{g m}^{-3}$	PM _{2.5} $\mu\text{g m}^{-3}$	Ozone $\mu\text{g m}^{-3}$
Maximum 15-minute mean	725	237	1322	209	-	66	-
Maximum hourly mean	619	197	1142	110	114	60	-
Maximum running 8- hour mean	371	128	652	75	94	44	-
Maximum running 24- hour mean	212	108	432	53	85	33	-
Maximum daily mean	184	101	382	48	78	33	-
Average	38	48	106	19	25	11	-
Data Capture	97.3 %	97.3 %	97.3 %	99.0 %	99.0 %	98.7 %	-

Table 3-5 Air Pollution Statistics for Harlington, 2012

LHR2	NO $\mu\text{g m}^{-3}$	NO ₂ $\mu\text{g m}^{-3}$	NO _x $\mu\text{g m}^{-3}$	PM ₁₀ by FDMS $\mu\text{g m}^{-3}$	PM ₁₀ (VCM corrected) $\mu\text{g m}^{-3}$	PM _{2.5} $\mu\text{g m}^{-3}$	Ozone $\mu\text{g m}^{-3}$
Maximum 15-minute mean	666	193	1203	126	-	89	156
Maximum hourly mean	614	180	1117	126	-	89	154
Maximum running 8- hour mean	343	122	643	99	-	80	141
Maximum running 24- hour mean	215	98	426	88	-	71	94
Maximum daily mean	182	90	367	78	-	63	94
Average	18	35	61	18	-	13	34
Data Capture	98.4 %	98.4 %	98.4 %	84.3 %	-	90.8 %	91.9 %

Table 3-6 Air Pollution Statistics for Green Gates, 2012

LHR2	NO µg m ⁻³	NO ₂ µg m ⁻³	NO _x µg m ⁻³	PM ₁₀ as measured µg m ⁻³	PM ₁₀ (VCM corrected) µg m ⁻³	PM _{2.5} µg m ⁻³	Ozone µg m ⁻³
Maximum 15-minute mean	661	201	1211	73	-	69	-
Maximum hourly mean	614	191	1129	71	97	68	-
Maximum running 8- hour mean	379	136	706	54	81	48	-
Maximum running 24- hour mean	230	104	455	40	75	30	-
Maximum daily mean	209	95	415	40	69	30	-
Average	20	33	63	15	21	10	-
Data Capture	98.0 %	98.0 %	98.0 %	99.0 %	99.0 %	96.4 %	-

Table 3-7 Air Pollution Statistics for Oaks Road, 2012

LHR2	NO µg m ⁻³	NO ₂ µg m ⁻³	NO _x µg m ⁻³	PM ₁₀ as measured µg m ⁻³	PM ₁₀ (VCM corrected) µg m ⁻³	PM _{2.5} µg m ⁻³	Ozone µg m ⁻³
Maximum 15-minute mean	508	149	932	166	-	135	-
Maximum hourly mean	478	136	865	143	156	106	-
Maximum running 8- hour mean	289	118	519	66	82	52	-
Maximum running 24- hour mean	182	93	361	44	76	35	-
Maximum daily mean	162	93	324	44	70	34	-
Average	14	30	52	15	22	10	-
Data Capture	93.1 %	93.1 %	93.1 %	96.1	96.1	98.3	-

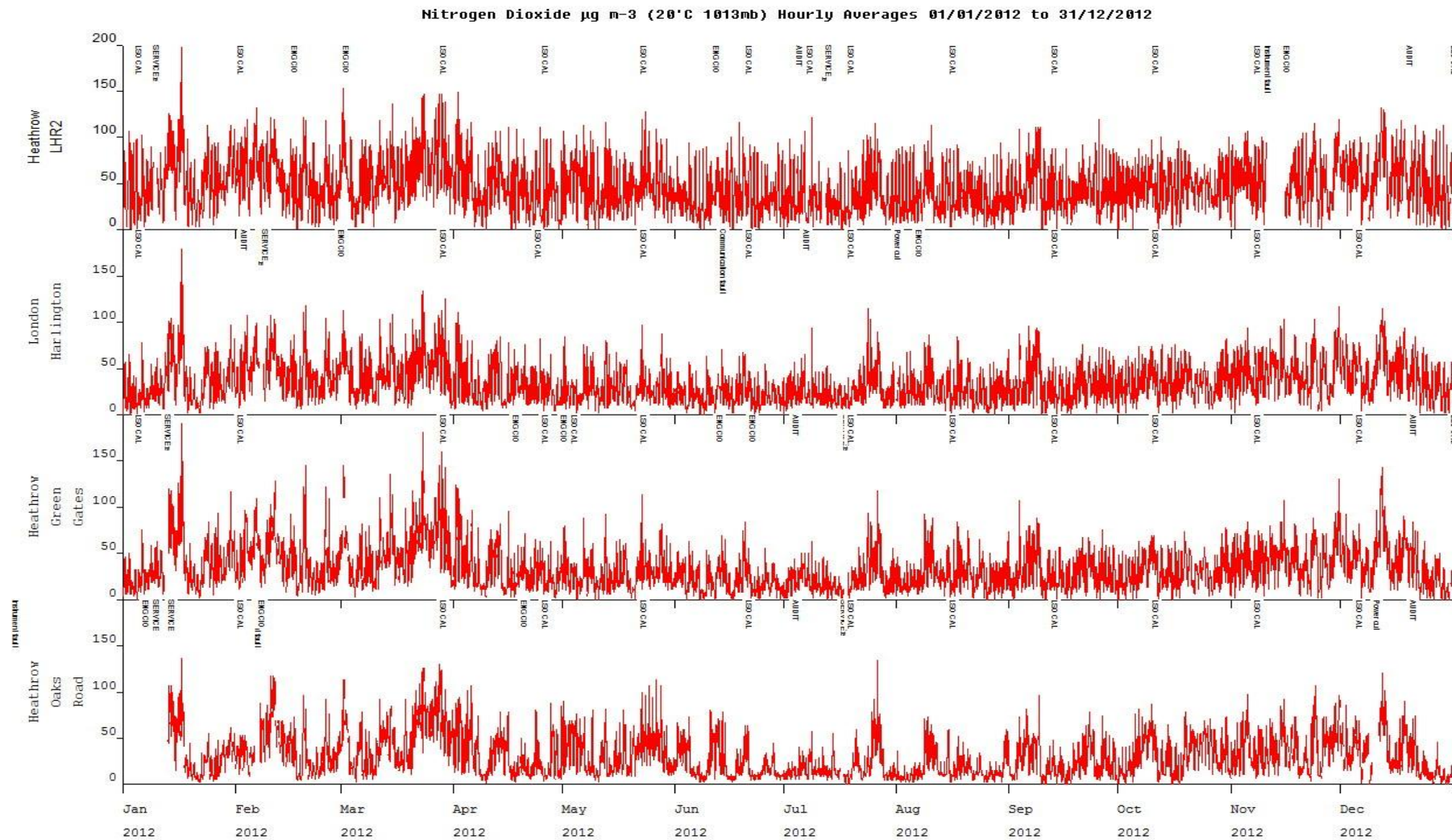


Figure 3-2 Hourly Mean Concentrations of Nitrogen Dioxide at Heathrow Monitoring Sites, 2012

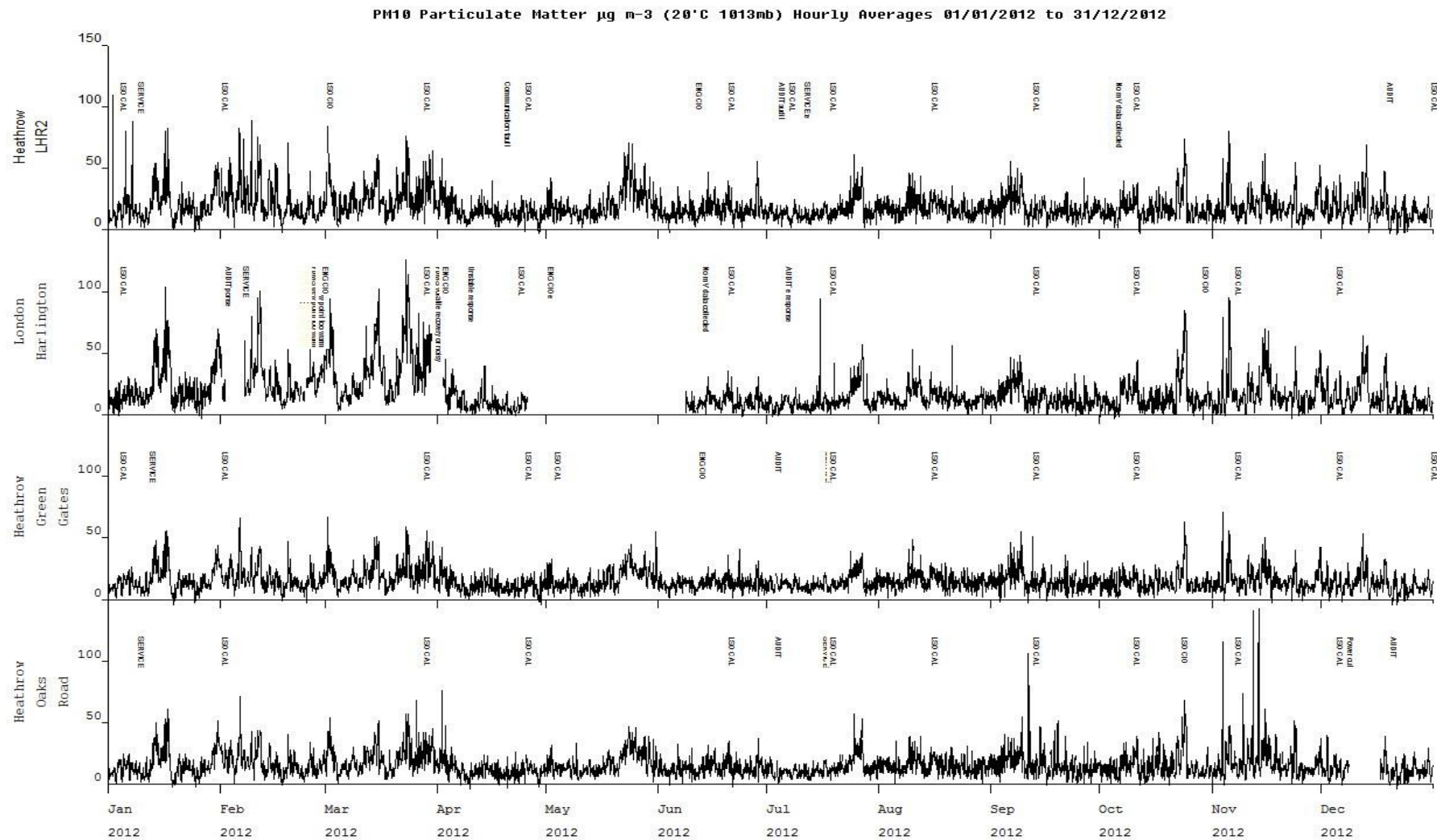


Figure 3-3 Hourly Mean Concentrations of PM₁₀ (as measured) at Heathrow Monitoring Sites, 2012

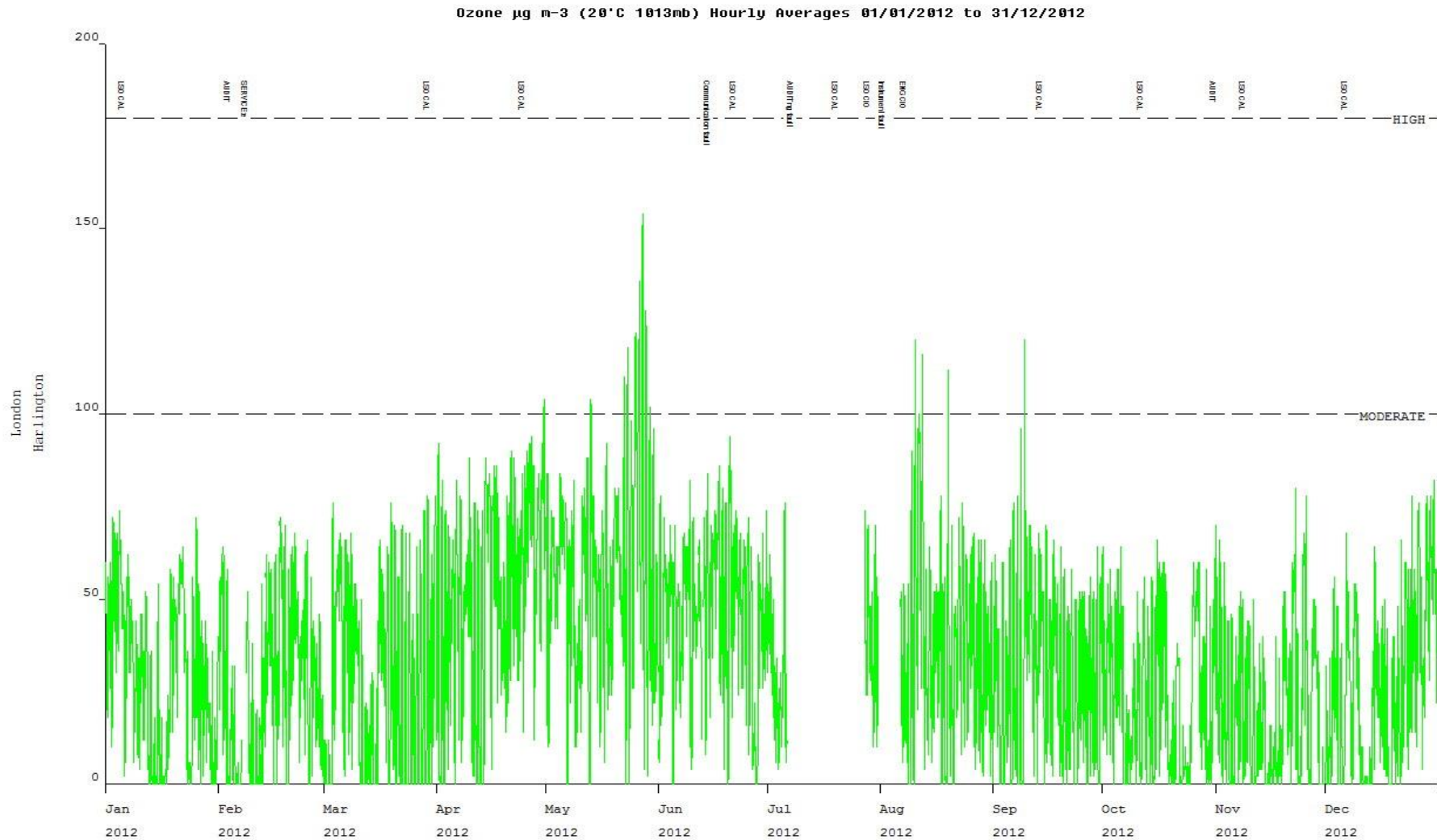


Figure 3-5 Hourly Mean Concentrations of Ozone at Harlington, 2012

Mean concentrations of hydrocarbons, as measured indicatively using diffusion tubes, are shown in Table 3-8. Results were generally low, and frequently close to, or below, the limit of detection (LoD). Therefore, these data should be treated as indicative only. Values less than the limit of detection (<LoD) are shown in red. In line with current guidance, when calculating the annual mean, values < LoD have been treated as ½ LoD. For example, a value of <0.10 $\mu\text{g m}^{-3}$ has been treated as 0.05 $\mu\text{g m}^{-3}$ when calculating the annual means.

Table 3-8 Concentrations of Hydrocarbon Species at LHR2, 2012

Start of Exposure Period	Benzene $\mu\text{g m}^{-3}$	Toluene $\mu\text{g m}^{-3}$	Ethylbenzene $\mu\text{g m}^{-3}$	m+p Xylene $\mu\text{g m}^{-3}$	o Xylene $\mu\text{g m}^{-3}$
04/01/2012	0.35	0.53	0.12	0.32	<0.02
01/02/2012	0.37	0.50	0.14	0.26	0.13
01/03/2012	1.04	3.91	0.75	1.83	0.69
28/03/2012	0.57	2.03	0.43	0.92	0.27
25/04/2012	0.72	1.29	0.45	1.00	0.45
22/05/2012	0.31	1.08	0.43	0.87	0.37
20/06/2012	<0.06	0.34	<0.04	<0.04	<0.04
18/07/2012	0.54	1.63	0.56	1.36	0.58
15/08/2012	0.66	1.52	0.52	1.03	0.40
12/09/2012	0.59	1.40	0.31	0.51	<0.06
10/10/2012	<0.10	0.92	<0.06	0.58	<0.06
07/11/2012	<0.10	0.32	<0.06	<0.06	<0.06
05/12/2012	<0.10	<0.07	<0.07	<0.07	<0.07
Annual mean	0.42	1.25	0.31	0.70	0.25

3.4 Comparison with Air Quality Strategy Objectives

This section compares the results from the Heathrow monitoring study in 2012 with relevant AQS objectives. Full details of the applicable Air Quality Strategy (AQS) objectives are summarised in Table 2-1, with Defra air pollution bands in Appendix 2.

3.4.1 Nitrogen Dioxide

The AQS Objectives for nitrogen dioxide are as follows, to have been achieved by December 31st 2005:

- 200 $\mu\text{g m}^{-3}$ as an hourly mean, not to be exceeded more than 18 times per year.
- 40 $\mu\text{g m}^{-3}$ as an annual mean.
- There is also a limit for annual mean total oxides of nitrogen (NO_x), of 30 $\mu\text{g m}^{-3}$, for protection of vegetation. However, this is relevant only in rural areas, so is not considered here.

Oxides of nitrogen were monitored at all four Heathrow sites. No sites recorded any hourly mean NO₂ concentration greater than 200 $\mu\text{g m}^{-3}$. Therefore, all sites met the AQS objective for hourly mean NO₂.

The annual mean NO₂ concentrations at the four sites were 48 $\mu\text{g m}^{-3}$ at LHR2, 35 $\mu\text{g m}^{-3}$ at Harlington, 33 $\mu\text{g m}^{-3}$ at Green Gates and 30 $\mu\text{g m}^{-3}$ at Oaks Road. Only LHR2 therefore

exceeded the annual mean Objective for NO₂ in 2012. As noted in section 2.3, the AQS objectives do not strictly apply at LHR2 as there is no public exposure. The other three sites met this objective. As highlighted in the previous report, occasional exceedances have occurred at other sites, as concentrations of this pollutant vary to some extent from year to year due to meteorological factors. Measured concentrations of NO₂ at all four sites remained within Defra's "Low" band in 2012.

3.4.2 PM₁₀

The AQS Objectives for PM₁₀ are as follows, to have been achieved by December 31st 2005:

- 50 µg m⁻³ gravimetric 24-hour (daily) mean not to be exceeded more than 35 times per year.
- 40 µg m⁻³ gravimetric annual mean.

PM₁₀ was monitored at all four sites. Data obtained using the TEOM instruments (at LHR2, Green Gates and Oaks Road) have been corrected using the King's College London Volatile Correction Model.

The number of daily means above 50 µg m⁻³ in 2012, after VCM correction (where applicable) and where data capture was 90% or more, were as follows - LHR2: 19 days, Green Gates: 9 days, Oaks Road: 12 days. Harlington did not achieve the data capture target of 90%, so compliance with the daily mean objective had to be assessed on the basis of the 90th percentile of daily means rather than the actual number of exceedances. The 90th percentile of daily means was 35 µg m⁻³ at Harlington. This is less than 50 µg m⁻³. Therefore, all four sites met the daily mean PM₁₀ objective.

The annual mean PM₁₀ concentrations, again based on the VCM-corrected TEOM data (and FDMS in the case of Harlington), were as follows: LHR2: 25 µg m⁻³; Harlington 18 µg m⁻³; Green Gates 21 µg m⁻³; and Oaks Road 22 µg m⁻³. All sites were therefore well within the AQS Objective of 40 µg m⁻³ for annual mean PM₁₀ during 2012.

The Defra air quality bandings changed at the beginning of 2012 and the PM₁₀ bands are now based on the fixed daily mean, rather than the running 24-hour mean as was the case in previous years. After VCM correction where applicable, PM₁₀ data were in the Defra "Low" air quality band (i.e. fixed daily mean less than 50 µg m⁻³) the majority of the time at all four sites. However, the daily mean went into the "Moderate" band or higher (daily mean > 49 µg m⁻³) on 20 days at LHR2, 13 days at Harlington, 11 days at Green Gates and 13 days at Oaks Road. Periods of high particulate pollution are discussed in more detail in section 3.6.1.

3.4.3 PM_{2.5}

The 2007 revision of the Air Quality Strategy introduced the following for PM_{2.5}:

- An annual mean objective of 25 µg m⁻³, as a non-mandatory target for 2020.
- An exposure reduction target, for urban background exposure (i.e. urban areas away from major roads – such as parks, residential areas) of 15% reduction in annual mean PM_{2.5} concentration between 2010 and 2020.

The 2012 annual means at the four sites were 11 µg m⁻³ at LHR2, 13 µg m⁻³ at Harlington, 10 µg m⁻³ at Green Gates and 10 µg m⁻³ at Oaks Road. All four sites therefore meet the objective already. Future years monitoring will investigate whether the exposure reduction target of 15% is achieved between the years 2010 and 2020.

There are now Defra air quality bandings for daily mean PM_{2.5}. Harlington had 14 days with "Moderate" PM_{2.5} and 3 days (all in March) with "High" PM_{2.5}. None of the other sites had any.

3.4.4 Ozone

The Air Quality Strategy objective for ozone is:

- $100 \mu\text{g m}^{-3}$ as a daily maximum 8-hour running mean (not to be exceeded more than 10 times per year).

Ozone was measured at Harlington only. Harlington exceeded the AQS Objective for ozone on five days during 2012: this is within the permitted maximum of 10 days during the year. The site has exceeded the objective several times in recent years; most recently in 2011. Ozone exceedances can vary considerably from year to year, depending on meteorological factors, so further exceedances in future years are possible.

Hourly mean ozone concentrations at Harlington went into the Defra “Moderate” band (based since 1st Jan 2012 on the maximum daily 8-hour running mean) on 6 days during the year. However, ozone concentrations did not go into the “High” band.

3.4.5 Benzene

The Air Quality Strategy sets the following objectives for benzene:

- $3.25 \mu\text{g m}^{-3}$ (for the calendar year mean in Scotland and Northern Ireland), to have been achieved by 31st December 2010.
- $5 \mu\text{g m}^{-3}$ (for the calendar year mean in England and Wales), to have been achieved by 31st December 2010.

Only the 2010 England and Wales objective will be considered here.

Benzene was monitored indicatively at LHR2 using BTEX diffusion tubes, with exposure periods of nominally four weeks. Individual measurements ranged from $<0.06 \mu\text{g m}^{-3}$ to $1.04 \mu\text{g m}^{-3}$. The annual mean benzene concentration recorded for 2012 was $0.42 \mu\text{g m}^{-3}$. This is well below the 2010 Objective of $5 \mu\text{g m}^{-3}$.

3.5 Temporal Variation in Pollutant Concentrations

3.5.1 Seasonal Variation

Figure 3-6, Figure 3-7, Figure 3-8 and Figure 3-9 show the variation of monthly averaged pollutant concentrations during 2012 at the four sites LHR2, Harlington, Green Gates and Oaks Road respectively. **Monthly means are shown only where data capture is at least 75%.** The PM_{10} data shown here, where measured using the TEOM, are “as measured”, i.e. they have not been corrected using the Volatile Correction Model (as the intention is to show seasonal patterns rather than absolute values).

Both NO and NO_2 were generally higher in the winter months than in the summer. This is a typical pattern for urban areas. In 2012, the highest concentrations of these pollutants occurred in March and/or November.

As in previous years, PM_{10} and $\text{PM}_{2.5}$ concentrations showed much less seasonal variation than oxides of nitrogen. However, concentrations of particulate matter also tended to be slightly higher in winter.

The secondary pollutant ozone (which is not usually emitted directly from any source, but is formed in the atmosphere from reactions involving other pollutants) showed highest concentrations in summer at the one site where it was measured, Harlington. This is the typical seasonal pattern for this pollutant; ozone levels are usually highest in hot, still, sunny weather conditions which can give rise to “summer smog”.

This general pattern is similar to that found at most urban monitoring sites. Highest levels of primary pollutants tend to occur during the winter months, when lower temperature and wind speed often lead to periods of reduced pollutant dispersion. For secondary pollutants, in particular ozone, high concentrations can also often occur during summer months when chemical reactions in the atmosphere are promoted by high temperatures and strong sunlight.

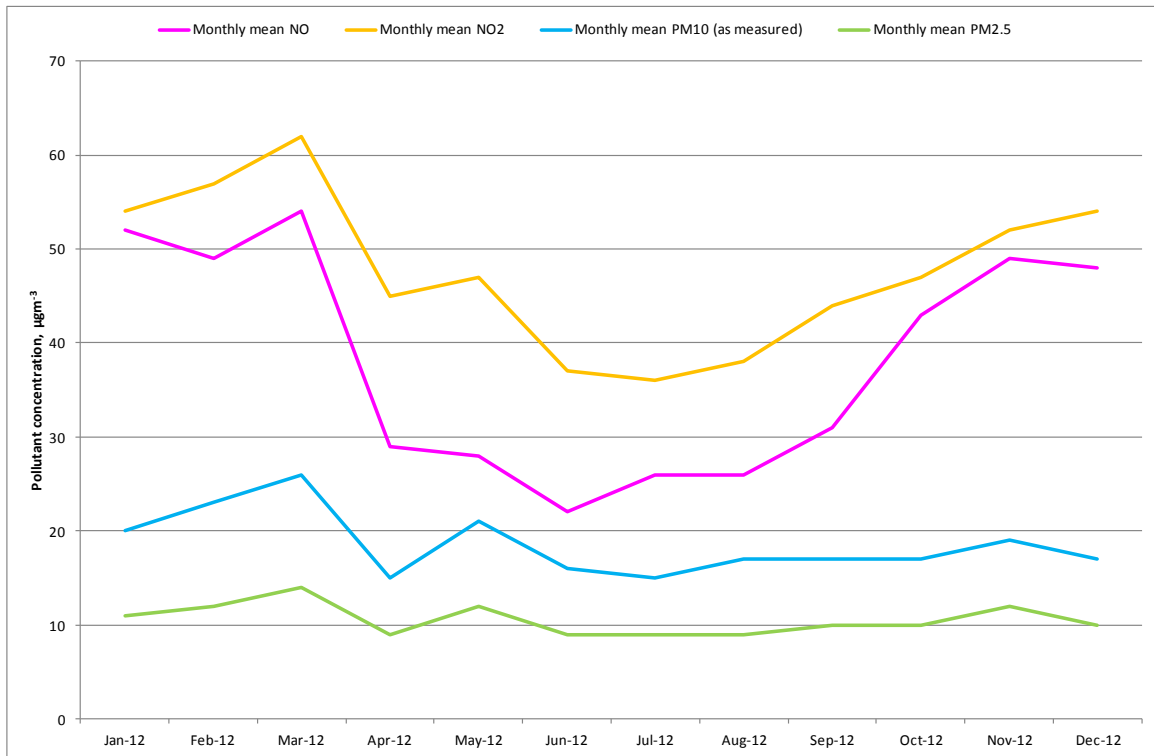


Figure 3-6 Seasonal Variation in Pollutant Concentrations at LHR2, 2012

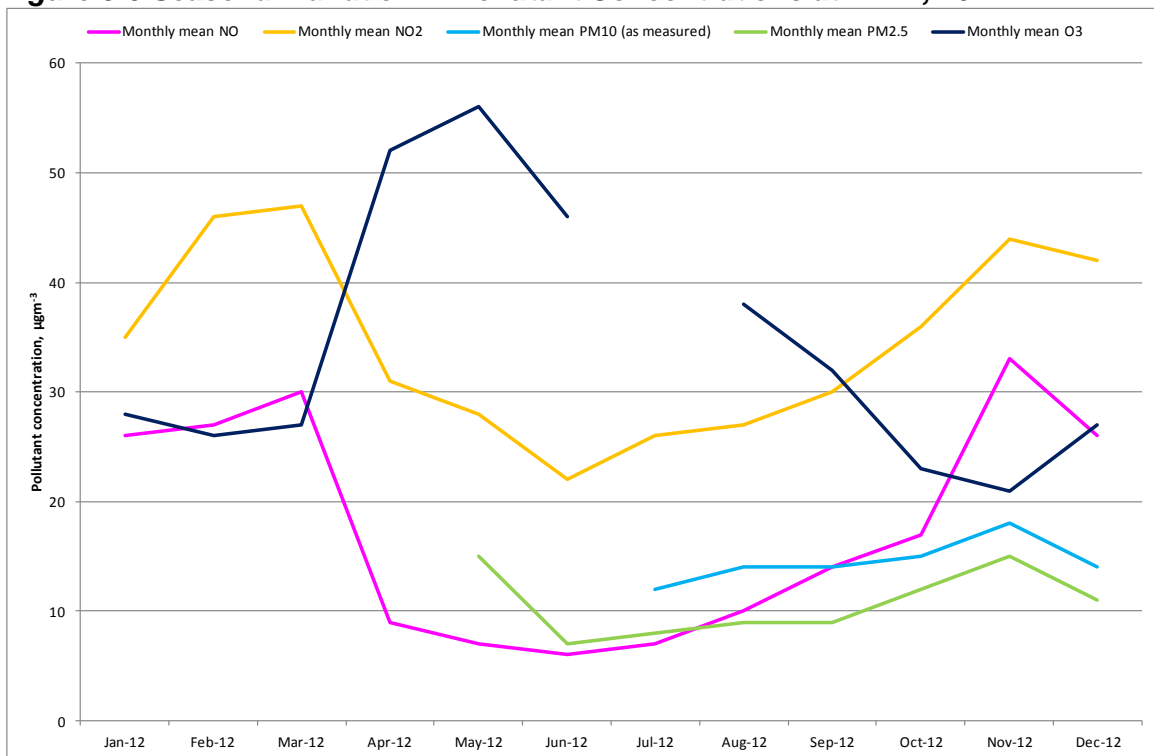


Figure 3-7 Seasonal Variation in Pollutant Concentrations at Harlington, 2012

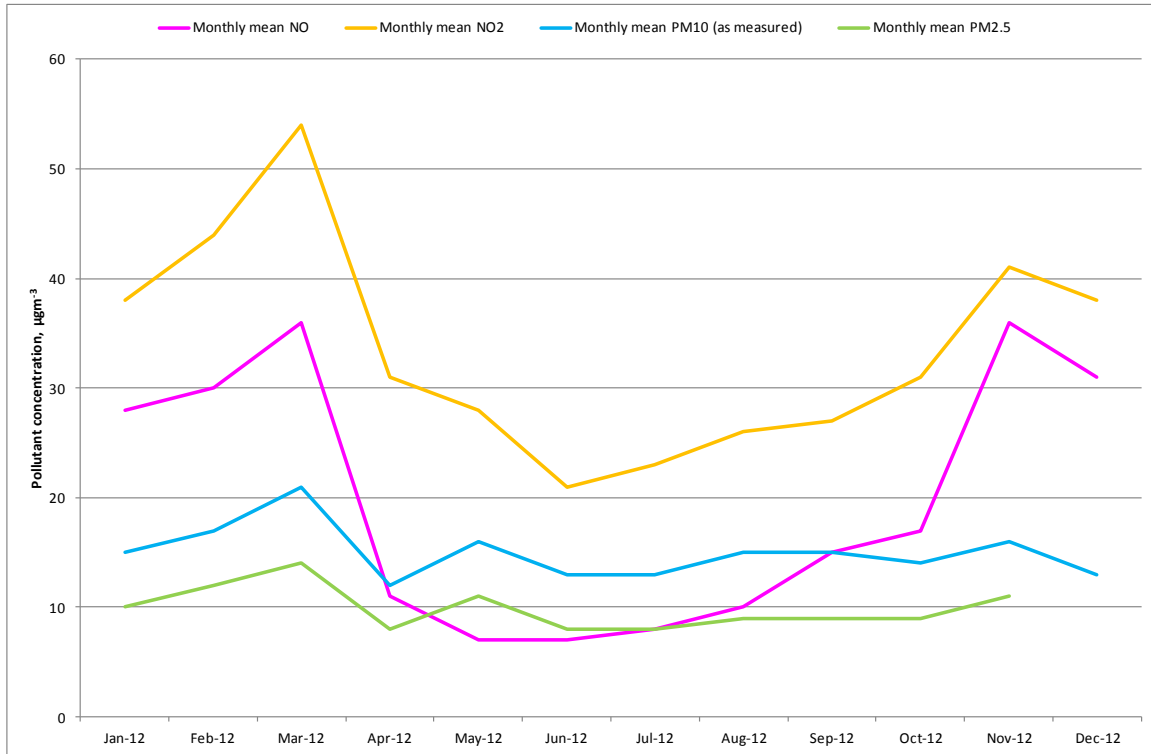


Figure 3-8 Seasonal Variation in Pollutant Concentrations at Green Gates, 2012

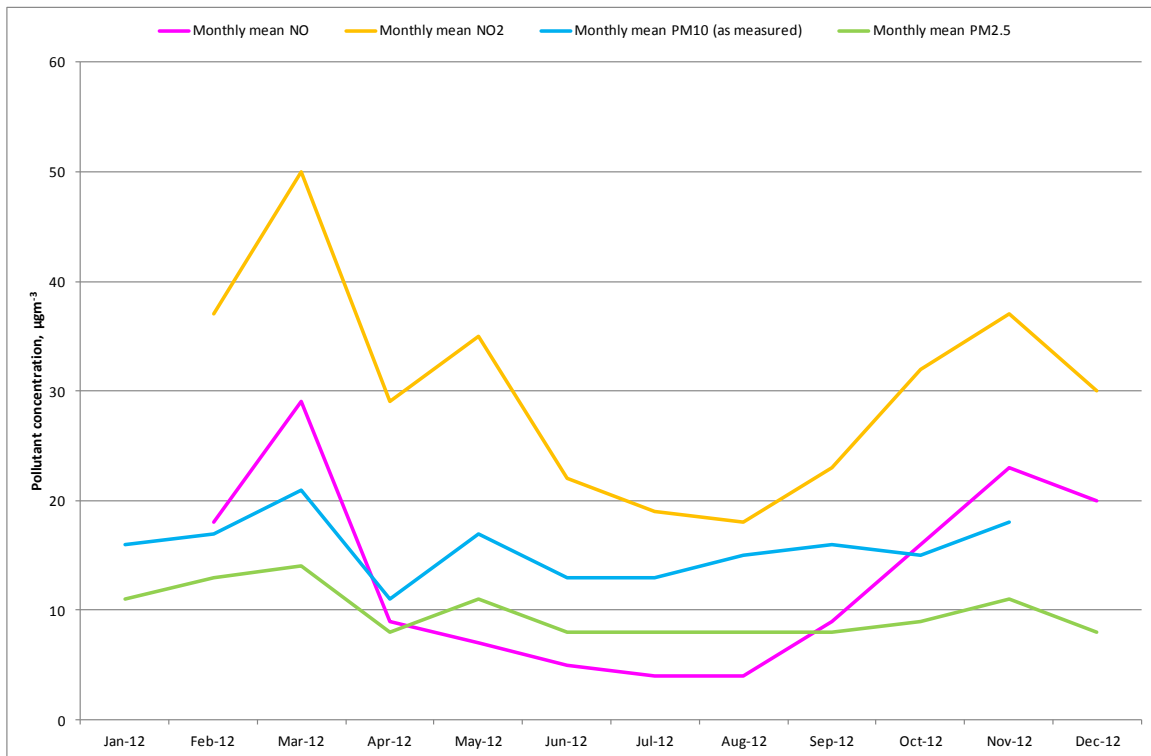


Figure 3-9 Seasonal Variation in Pollutant Concentrations at Oaks Road, 2012

3.5.2 Diurnal Variation

The average variation of hourly concentrations throughout the day, at the four Heathrow sites, is shown in Figures 3-10 to 3-13.

The PM₁₀ data shown here are TEOM (or FDMS) data as measured – TEOM data have not been corrected to gravimetric equivalent using the VCM.

The curves for NO at all sites show the typical daily cycle for these pollutants in urban areas. The distinct morning peaks at around 0700 probably arise from general rush-hour road traffic emissions. Concentrations decrease during the middle of the day, with a lower and broader evening rush-hour peak commencing after 1500.

For NO₂, which has secondary components, the morning rush-hour peak is again visible, and is in most cases higher than the morning NO peak (the exception is LHR2, as was also the case in 2011). The afternoon NO₂ peak is typically higher than the morning peak. This is likely to be because in the afternoon, concentrations of oxidising agents in the atmosphere (particularly ozone) tend to increase, leading to enhanced oxidation of NO to NO₂. The afternoon NO₂ peak is higher than the morning NO₂ peak at all four Heathrow sites.

The diurnal pattern for PM₁₀ and PM_{2.5} is determined by two factors:

- (i) emissions of primary particulate matter, from sources such as vehicles, and
- (ii) reactions between sulphur dioxide, NO_x and other chemical species, forming secondary sulphate and nitrate particles.

The morning and afternoon “rush-hour” peaks for PM₁₀ and PM_{2.5} at all four sites are less pronounced than those for oxides of nitrogen.

Ozone (measured at Harlington only) exhibited a typical diurnal pattern for ozone, with highest concentrations in the afternoon.

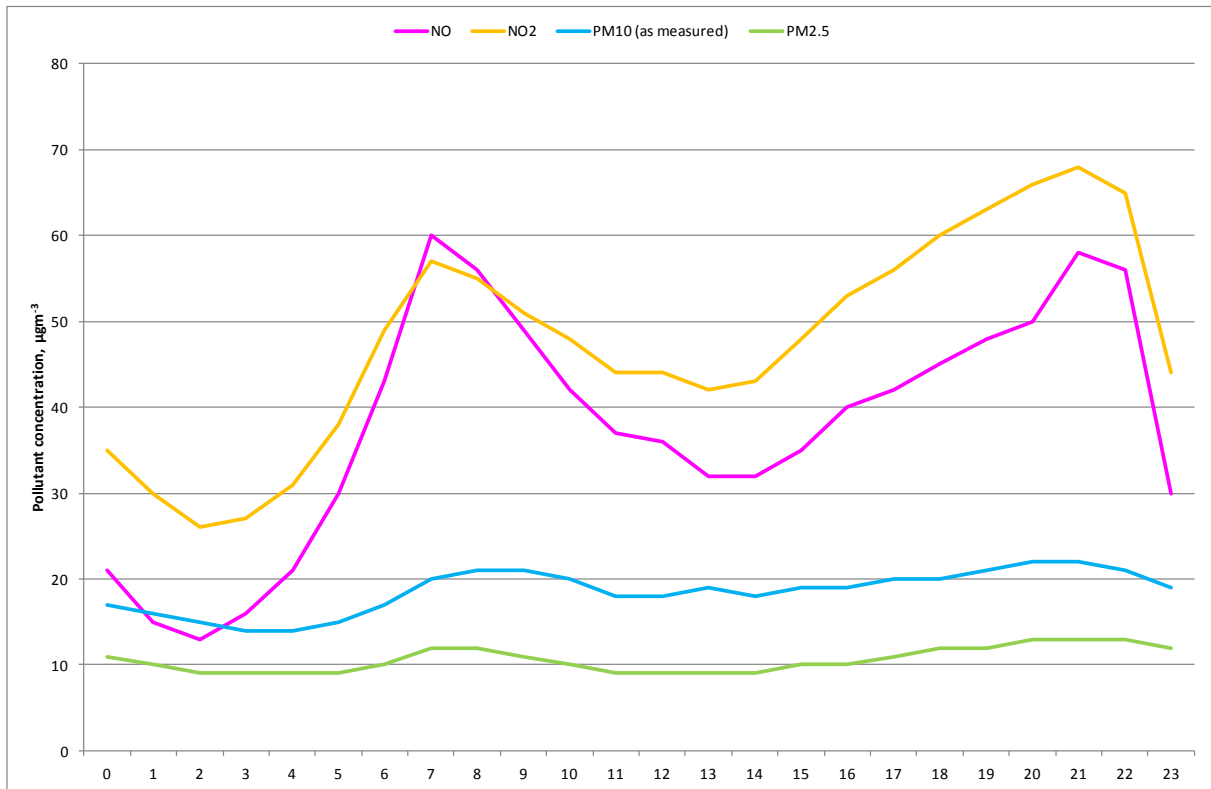


Figure 3-10 Diurnal Variation in Pollutant Concentrations at LHR2, 2012

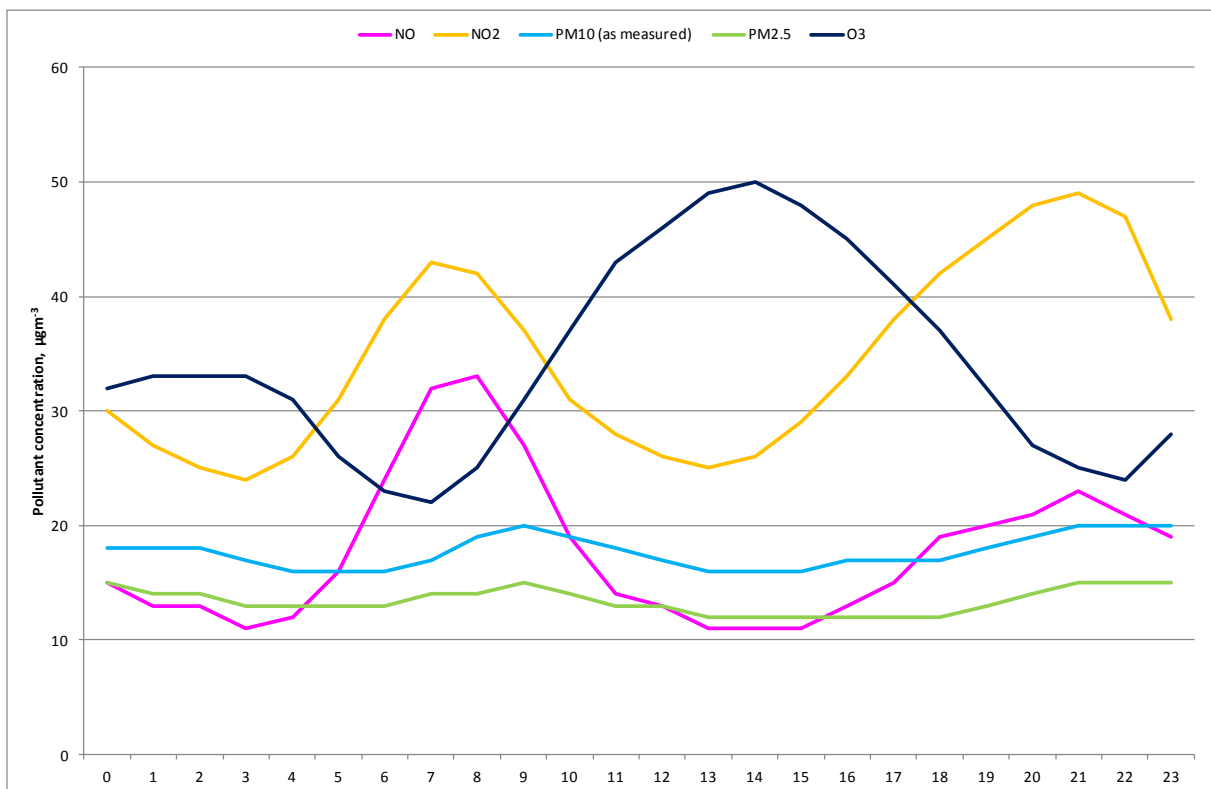


Figure 3-11 Diurnal Variation in Pollutant Concentrations at Harlington, 2012

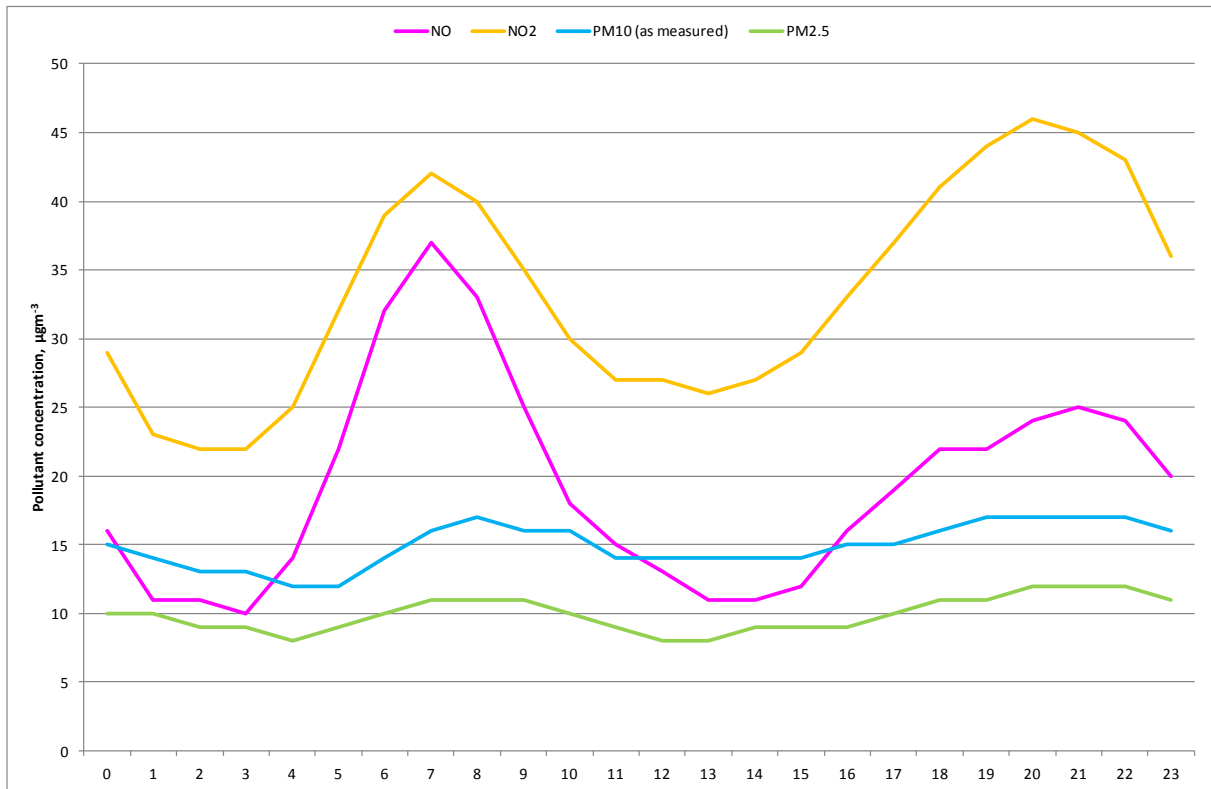


Figure 3-12 Diurnal Variation in Pollutant Concentrations at Green Gates, 2012

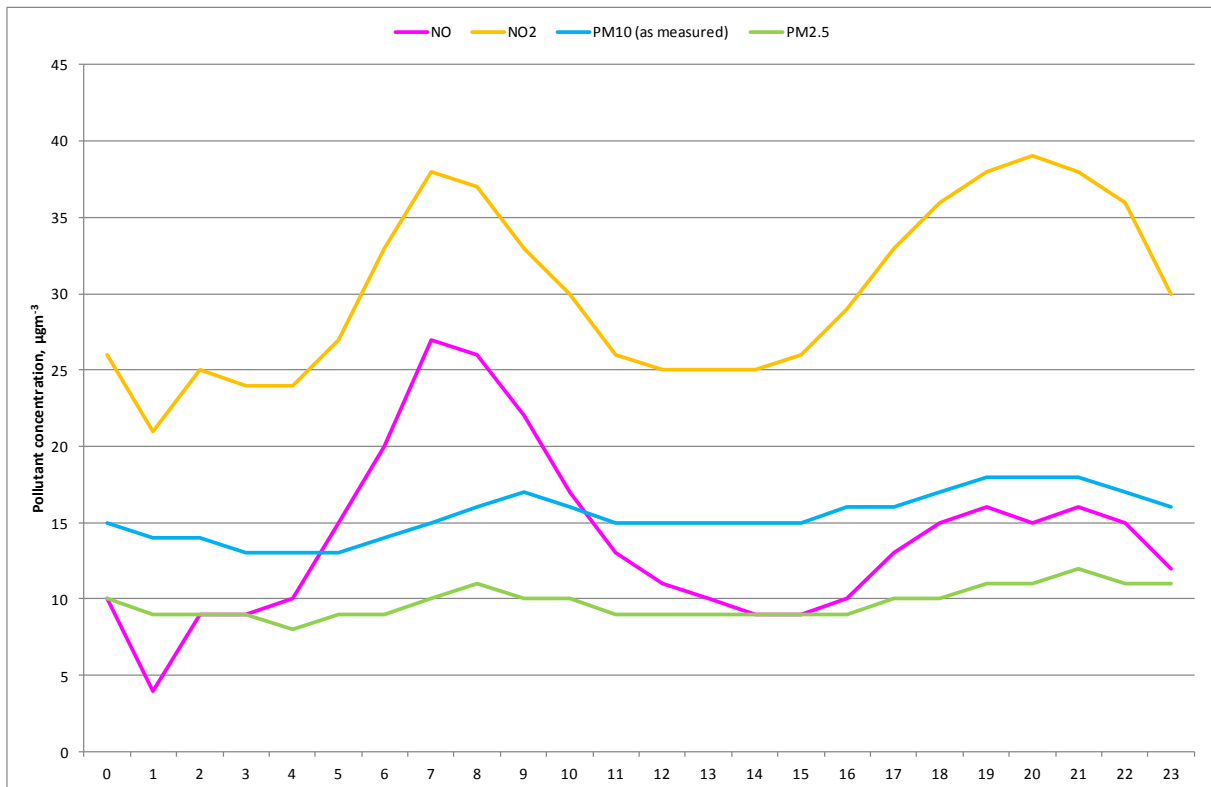


Figure 3-13 Diurnal Variation in Pollutant Concentration at Oaks Road, 2012

3.6 Periods of Elevated Pollution

This section briefly reviews the periods of higher pollution that occurred during the year. These are identified on the basis of the Defra Daily Air Quality Index, used to communicate information about current and forecast air quality to the public. The Index is based on a scale of 1-10, divided into four bands (Low, Moderate, High and Very High): this provides a simple indication of pollution levels, similar to the pollen index. Low air pollution is between 1 and 3, Moderate is between 4 and 6, High is between 7 and 9, and Very High is 10 on the scale. This is intended to allow sensitive people to take any necessary action.

The concentration ranges associated with each band within the index are presented in Appendix 2. The air quality index and the thresholds corresponding to each band were changed at the beginning of 2012. The bands used here are those in use during calendar year 2012.

There were no periods of high NO₂ concentration: this pollutant remained in the “Low” band throughout the year at all sites.

3.6.1 PM₁₀

Notable days or periods on which the daily mean PM₁₀ concentration at two or more of the Heathrow sites went into the “Moderate” band (daily mean > 49 µg m⁻³) or exceeded the AQS objective of 50 µg m⁻³ during 2012 were as follows:

- 17th Jan, 31st Jan (LHR, Harlington and Oaks Road only)
- 11th – 12th Feb
- 1st - 2nd Mar
- 15th Mar
- 22nd – 24th Mar
- 30th Mar
- 24th Oct.

Some other urban background monitoring sites in London (London Bloomsbury and London North Kensington) showed a similar number of “Moderate” days to Harlington, Green Gates and Oaks Road. Similarly, the roadside London Marylebone Road site showed a similar pattern to LHR2, in terms of days when PM₁₀ went into the “Moderate” band (although actual concentrations at London Marylebone Road were higher). This indicates that (as in previous years), the days when higher concentrations were measured at Heathrow were reflecting regional variations in PM₁₀ concentration, rather than any emission sources specific to the airport.

3.6.2 PM_{2.5}

In 2012, new Defra air quality bandings for PM_{2.5} came into use. All sites except Harlington remained within the Defra “Low” band in 2012. Harlington, however, had 14 days of “Moderate” PM_{2.5} on the following days:

- 17th Jan, 31st Jan
- 11th – 12th Feb
- 1st – 2nd Mar, 14th Mar, 22nd Mar and 29th – 30th Mar
- 24th Oct.
- 15th – 16th Nov
- 12th Dec.

There were also three days of “High” PM_{2.5}, on 15th Mar, 23rd-24th Mar. Therefore, most of these days coincided with days of “Moderate” PM₁₀.

3.6.3 Ozone

The maximum daily 8-hour mean ozone concentration (measured at Harlington only) went into the “Moderate” band on 145 occasions on 6 days. These were all between 23rd and 28th May. Many other sites in London, including London North Kensington, London Teddington, London Bloomsbury and London Eltham also measured similarly high ozone concentrations over this period.

3.7 Discussion of Data in Relation to Sources

In order to investigate the possible sources of air pollution that are being monitored at Heathrow Airport, meteorological data recorded at the LHR2 Site were used to add a directional component to the air pollutant concentrations.

Figure 3-14 shows the wind speed and direction data. The lengths of the “spokes” against the concentric circles indicate the percentage of time during the year that the wind was measured from each direction. The prevailing wind directions were in the range 210^o-270^o. Each “spoke” is divided into coloured sections: these are wind speed intervals of 2 ms⁻¹ as shown by the scale bar in the plot. The mean wind speed was 3.8 ms⁻¹: this is a relatively high mean wind speed, and reflects the exposed position of the monitoring site.

Five hourly means were rejected from the wind dataset: these were isolated spikes between 19-45 ms⁻¹ which occurred on 4th Feb, 17th Feb and 9th May 2012. Because of their magnitude (storm force or greater) they were considered unlikely to be genuine.

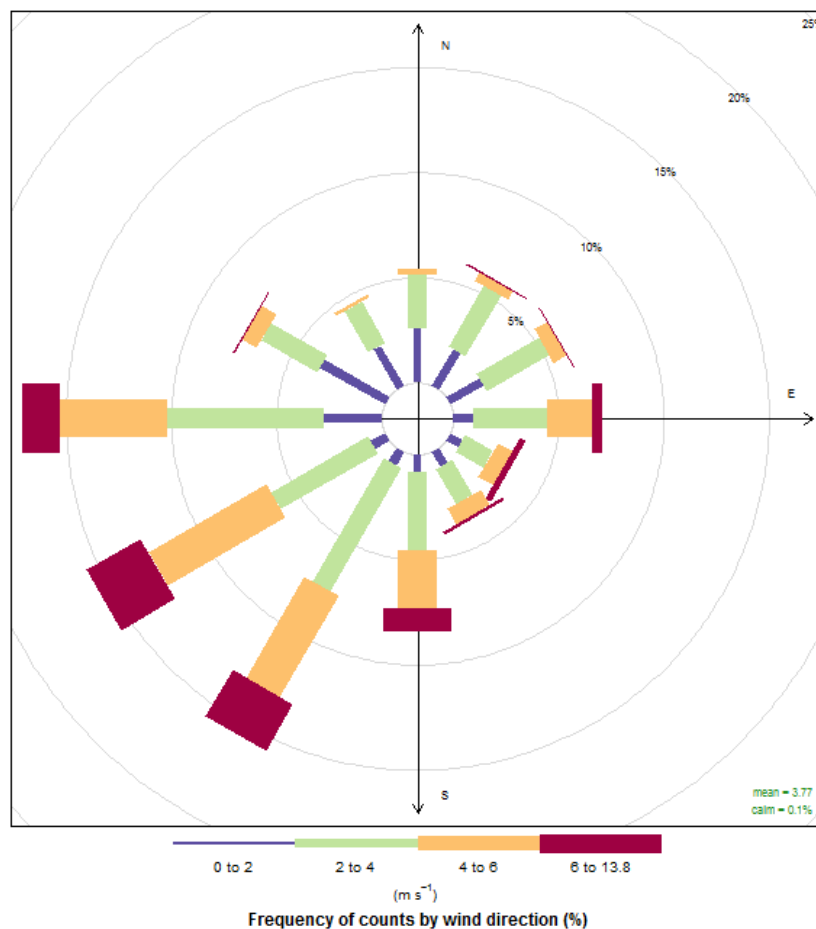


Figure 3-14 Wind Rose for LHR2

Figure 3-15 to Figure 3-198 show bivariate plots of hourly mean NO, NO₂, PM₁₀ and PM_{2.5}, concentrations at LHR2 against the corresponding wind speed and wind direction. Figure 3-19 shows a bivariate plot of ozone concentration at Harlington, plotted using wind speed and direction data from LHR2. 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 ms⁻¹ intervals.
- The pollutant concentration is indicated by the colour (as indicated by the scale).

These plots therefore show how pollutant concentration varies with wind direction and wind speed. No VCM correction has been applied to the PM₁₀ data used in these analyses, as the intention is to show patterns rather than absolute values.

Figure 3-15 shows that highest concentrations of NO occurred under calm conditions. Such conditions allow 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 is also an association with lighter north-easterly winds, reflecting the location of the nearest roads and built-up area of Harlington.

Figure 3-16 shows that highest concentrations of NO₂ were associated with two sets of conditions: firstly, calm conditions and light winds from the north east (as for NO). These conditions bring pollutants from the nearest roads and the built-up area of Harlington. At higher wind speeds, there was a strong contribution from the south – the direction of the main airport buildings and runways. The signal from this direction was seen only for NO₂, not NO, indicating that the source is some distance away, allowing time for the emitted NO to be oxidised to NO₂.

Figure 3-17 (for PM₁₀) is based on “as measured” TEOM data, without VCM correction. It shows some similarity with the pollution rose for NO₂, in that highest concentrations occurred under calm conditions when emissions from nearby sources were able to build up. However, there was also a strong signal from a direction of approximately 070°, at a range of wind speeds. The direction of this source is slightly more to the east than for oxides of nitrogen: the source may be slightly different, perhaps with a contribution from industrial processes outside the airport perimeter (such as the gravel pit near Harlington). At higher wind speeds, there are also contributions from sources on bearings of approximately 180° (perhaps a source associated with the airport buildings and runways) and 315° (possibly from traffic on the M4 motorway spur.) This is a very similar pattern to that observed in recent years.

Figure 3-18, the pollution rose for PM_{2.5} shows a similar directional pattern to PM₁₀ at low wind speeds, suggesting the same sources are involved for both PM size fractions. However, unlike PM₁₀, the plot for PM_{2.5} shows less contribution from other directions at high wind speeds.

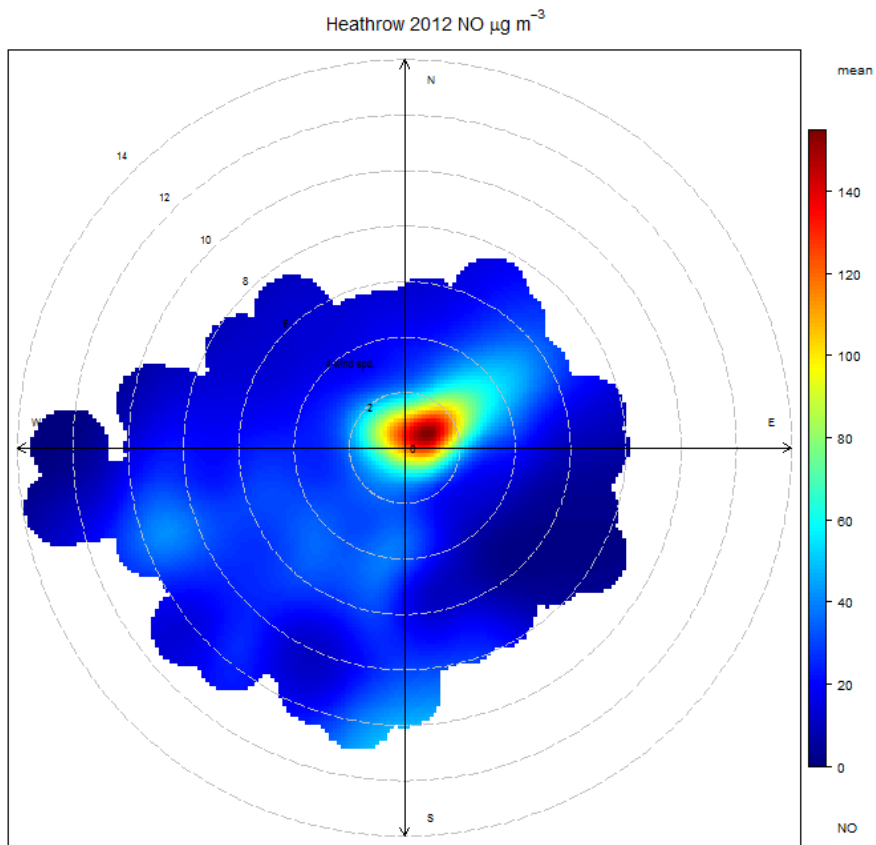


Figure 3-15 Pollution Rose for NO at LHR2

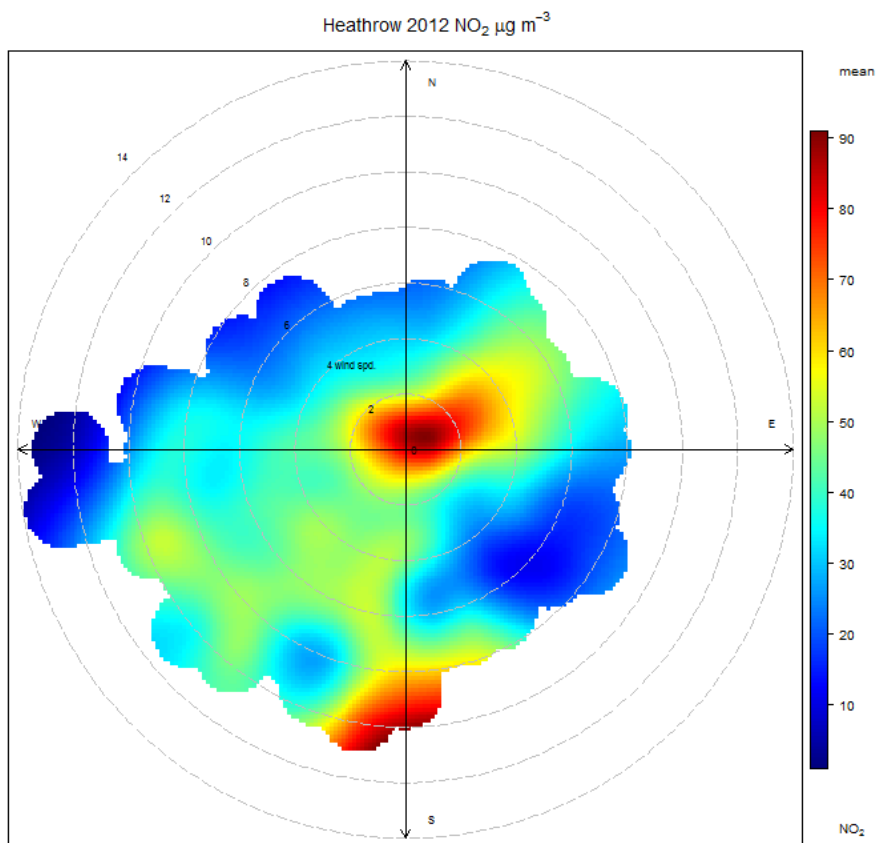


Figure 3-16 Pollution Rose for NO₂ at LHR2

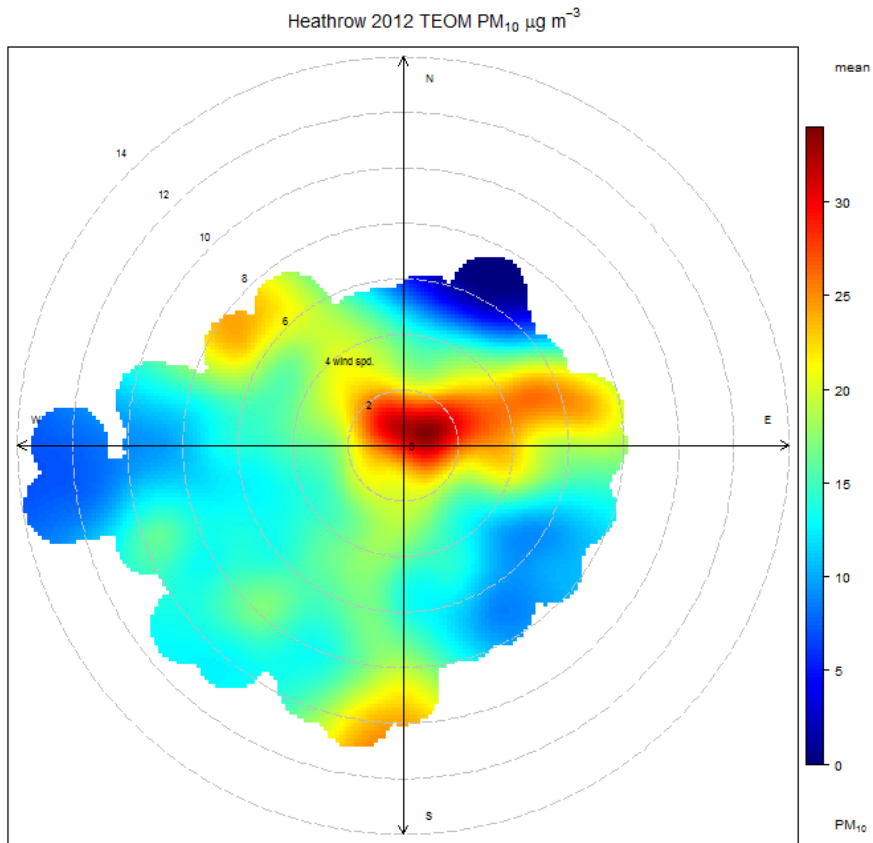


Figure 3-17 Pollution Rose for PM₁₀ at LHR2 (TEOM data as measured).

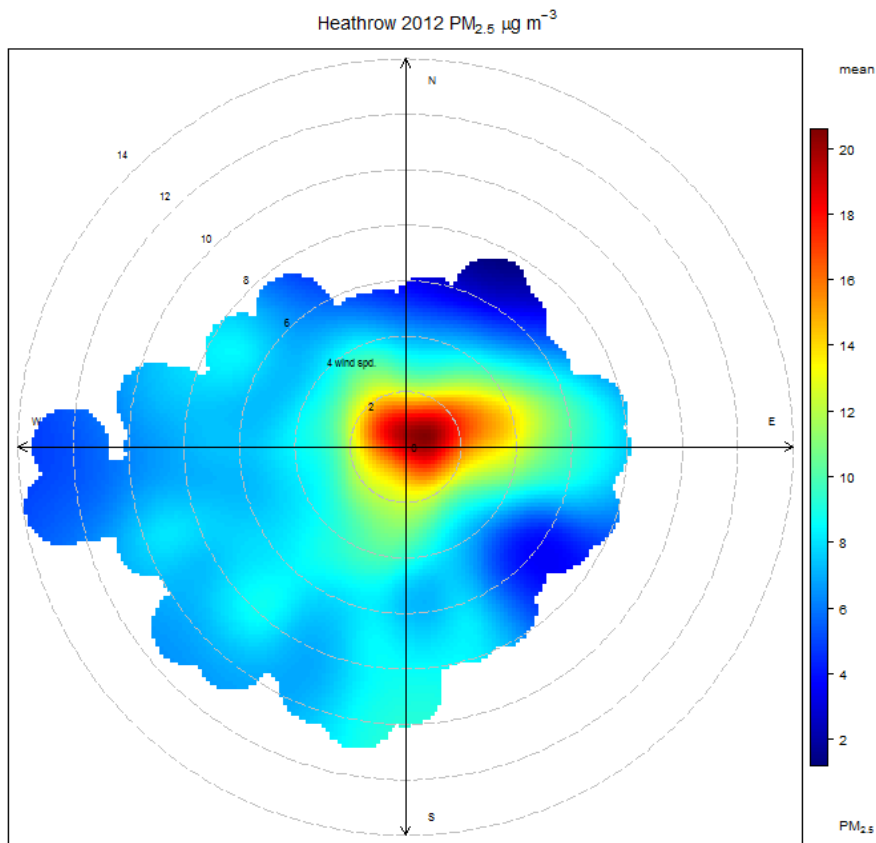


Figure 3-18 Pollution Rose for PM_{2.5} at LHR2

The pollution rose for ozone (Figure 3-19) is based on ozone concentration data from Harlington, combined with wind speed and direction data from the Heathrow LHR site. This should be treated as indicative only, as wind speeds at Harlington are likely to be lower on average than those at the very exposed LHR2 site. The pattern for ozone indicates that in 2012, as in 2011, higher ozone concentrations were associated with easterly wind directions.

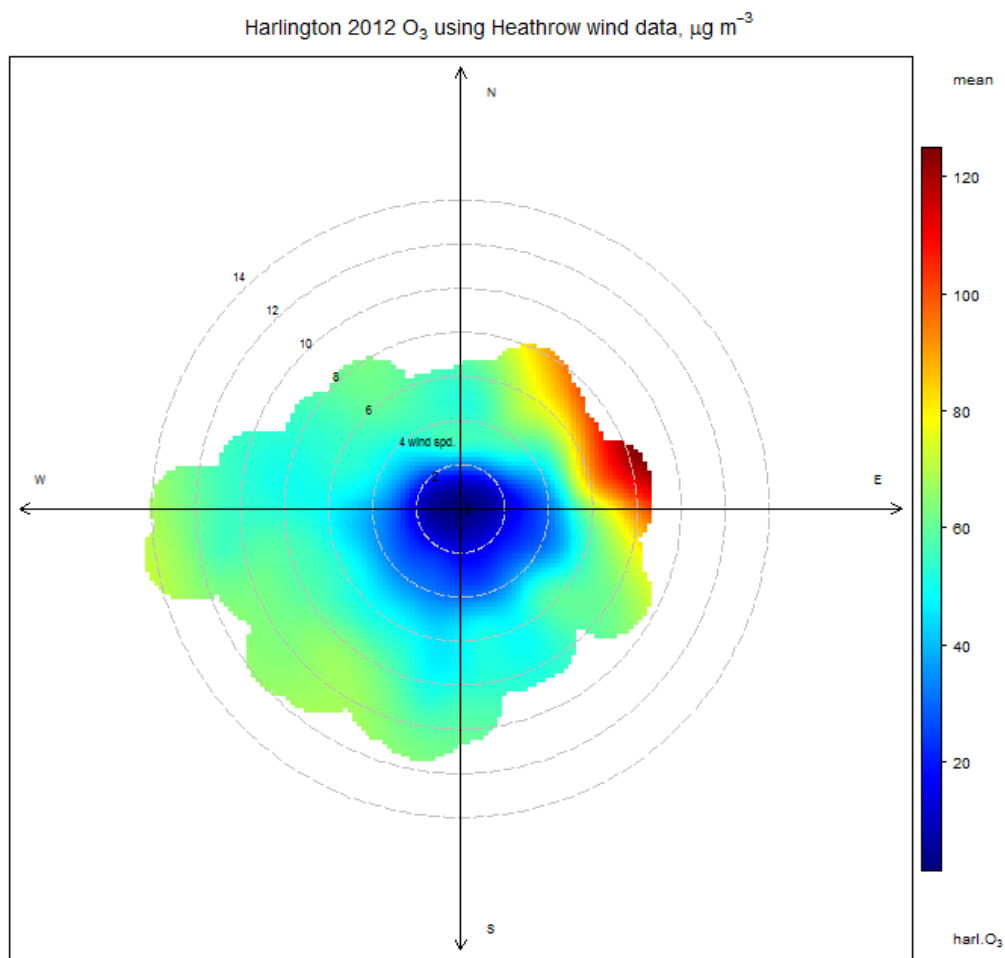


Figure 3-19 Pollution Rose for Ozone at Harlington (using LHR2 wind data)

3.8 Comparison with Other Sites in London

Annual mean pollutant concentrations at the four Heathrow sites are compared in Table 3-9 with those measured at other air quality monitoring sites in and around London, plus one rural site in the south of England. The sites selected 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 comparison purposes.

Table 3-9 Annual Mean Pollutant Concentrations at Other Sites

Site	NO ₂ µgm ⁻³	PM ₁₀ µgm ⁻³	PM _{2.5} µgm ⁻³	O ₃ µgm ⁻³
LHR2	48	25	11	-
Harlington	35	<i>18</i>	<i>13</i>	34
Green Gates	33	21	10	-
Oaks Road	30	22	10	-
London Bexley	29	-	<i>12</i>	-
London North Kensington	37	<i>20</i>	<i>15</i>	38
London Bloomsbury	55	<i>19</i>	<i>16</i>	27
London Marylebone Road	94	<i>31</i>	<i>21</i>	15
Harwell	10	<i>17</i>	<i>13</i>	55

All PM₁₀ and PM_{2.5} measurements at comparison sites have all been made with FDMS instruments rather than unmodified TEOMs. These are shown in *italics* in the table. All mass units are at 20°C and 1013mb.

The annual mean NO₂ concentration of 48 µg m⁻³ at LHR2 was between the corresponding measurements at the urban background London North Kensington site, and the city centre London Bloomsbury site – both of which are more affected by traffic - but still well below the London Marylebone Road annual mean. Annual mean NO₂ concentrations at Harlington, Green Gates and Oaks Road were higher than the annual mean at London Bexley, but below the annual mean at London North Kensington.

The annual mean PM₁₀ concentrations at Harlington, Green Gates and Oaks Road were comparable with those at London Bloomsbury and London North Kensington. LHR2 was slightly higher.

PM_{2.5} concentrations appear to show less variation: there was little difference between the annual mean concentrations of this parameter measured at LHR2, Harlington, Green Gates, Oaks Road, London Bexley, London North Kensington and the rural Harwell site.

Concentrations of ozone tend to be higher in rural areas, due to the chemistry of its formation: the annual mean O₃ concentration of 36 µg m⁻³ at Harlington is comparable with those measured at other suburban or urban background sites. As expected, it is higher than the annual mean at the city centre London Marylebone Road, and lower than the annual mean ozone concentration of 55 µg m⁻³ at the rural Harwell site.

3.9 Long-Term Changes in Pollutant Concentrations

LHR2 has been in operation for 20 years (having started up in 1993). The other three sites have all been in operation since 2002. 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, NO₂, PM₁₀, PM_{2.5} and O₃ are provided in table form in Appendix 3: they are illustrated below in a series of charts. Annual means are only shown for years in which data capture was at least 75%.

Figure 3-20 shows how annual mean concentrations of total NO_x have changed at the four sites, since the first site LHR2 came into operation. There was a clear decrease throughout the 1990s, although this appears to have levelled off to some extent. Annual mean NO_x at the other three sites also appears to have decreased slightly over the past decade, although there is clearly a lot of year-to-year fluctuation. There appears to have been a peak in 2007.

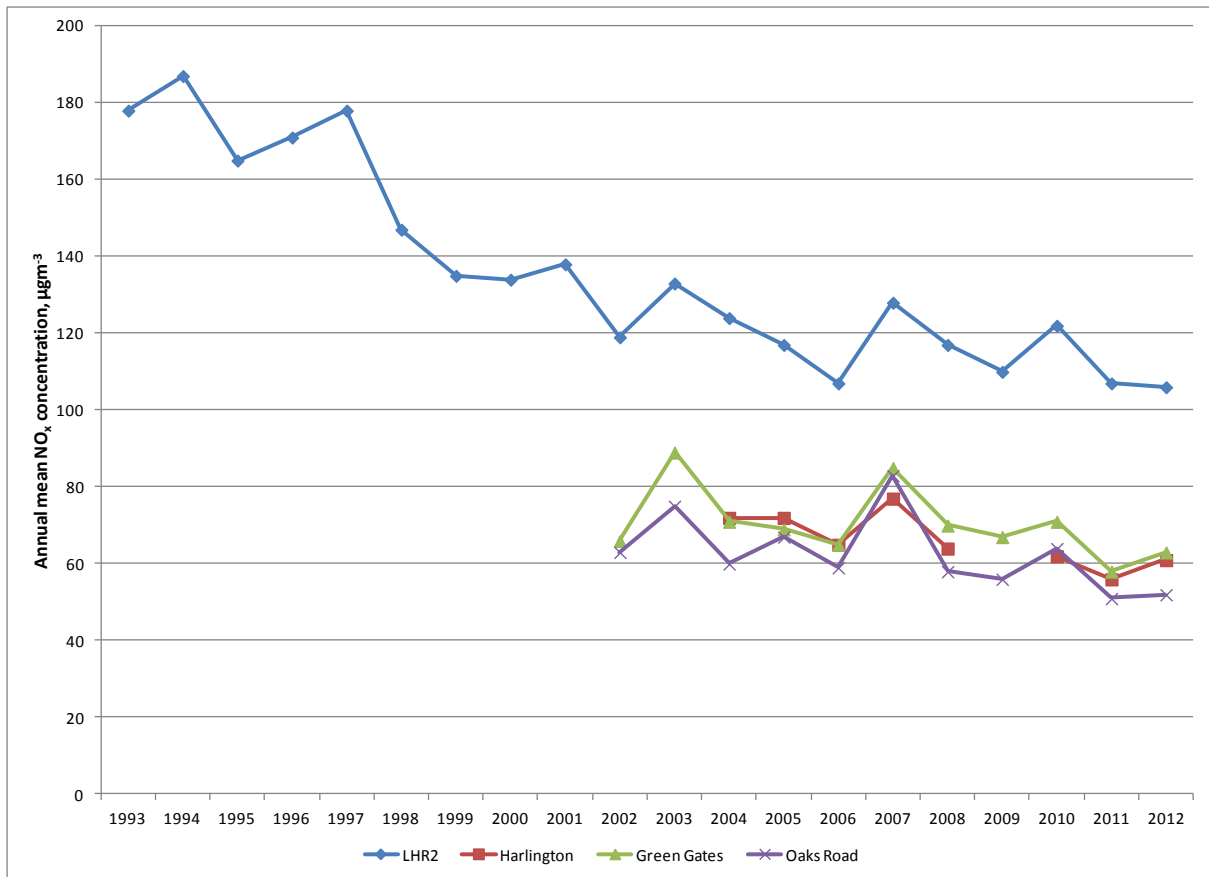


Figure 3-20 Time Series of Annual Mean NO_x

Trends in annual mean concentrations of NO are illustrated in Figure 3-21. The pattern is similar to that observed for total NOx.

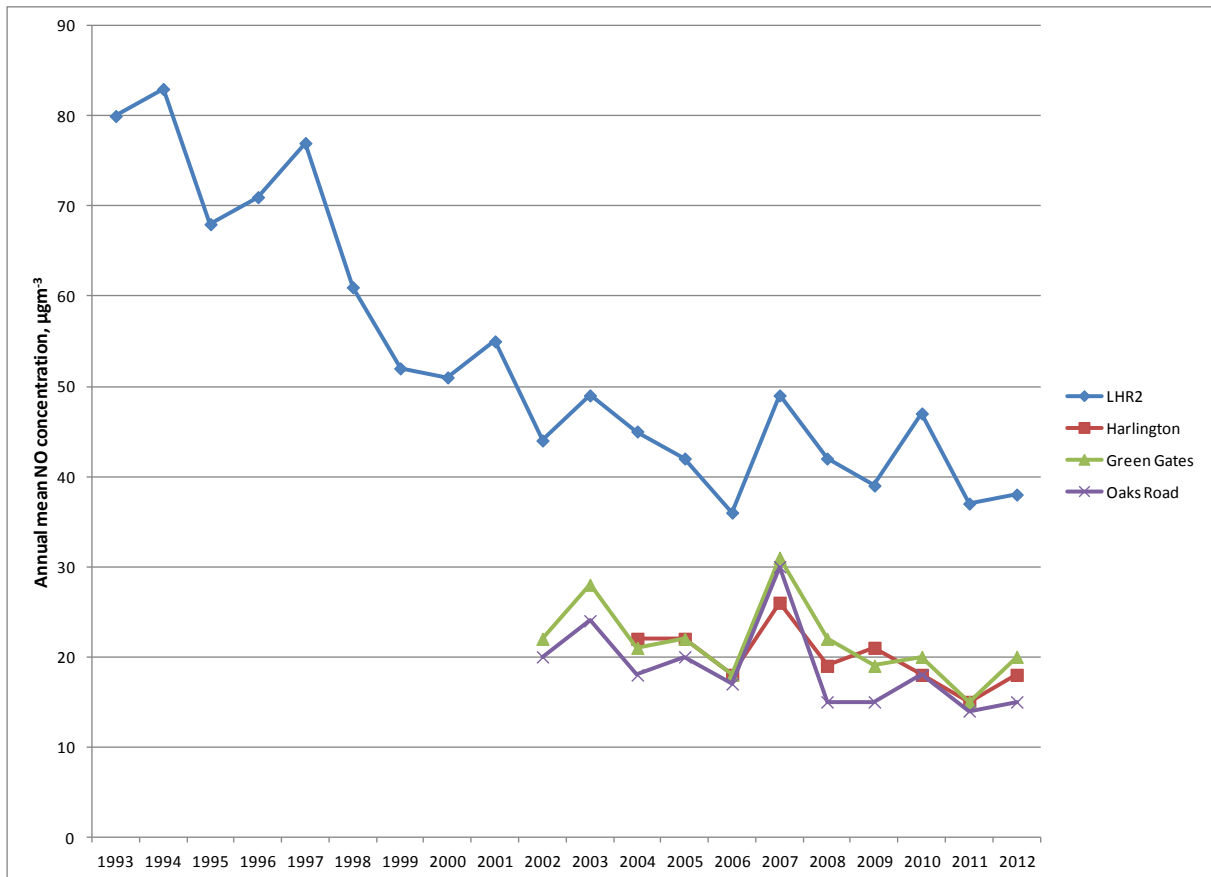


Figure 3-21 Time Series of Annual Mean NO

In the case of NO₂ (illustrated in Figure 3-22), there is less evidence of a clear year-on-year decrease in recent years. The graphs for both LHR2 and Harlington show a slight downward slope. Also, at LHR2, Green Gates and Oaks Road the annual means for 2012 were the lowest measured so far.

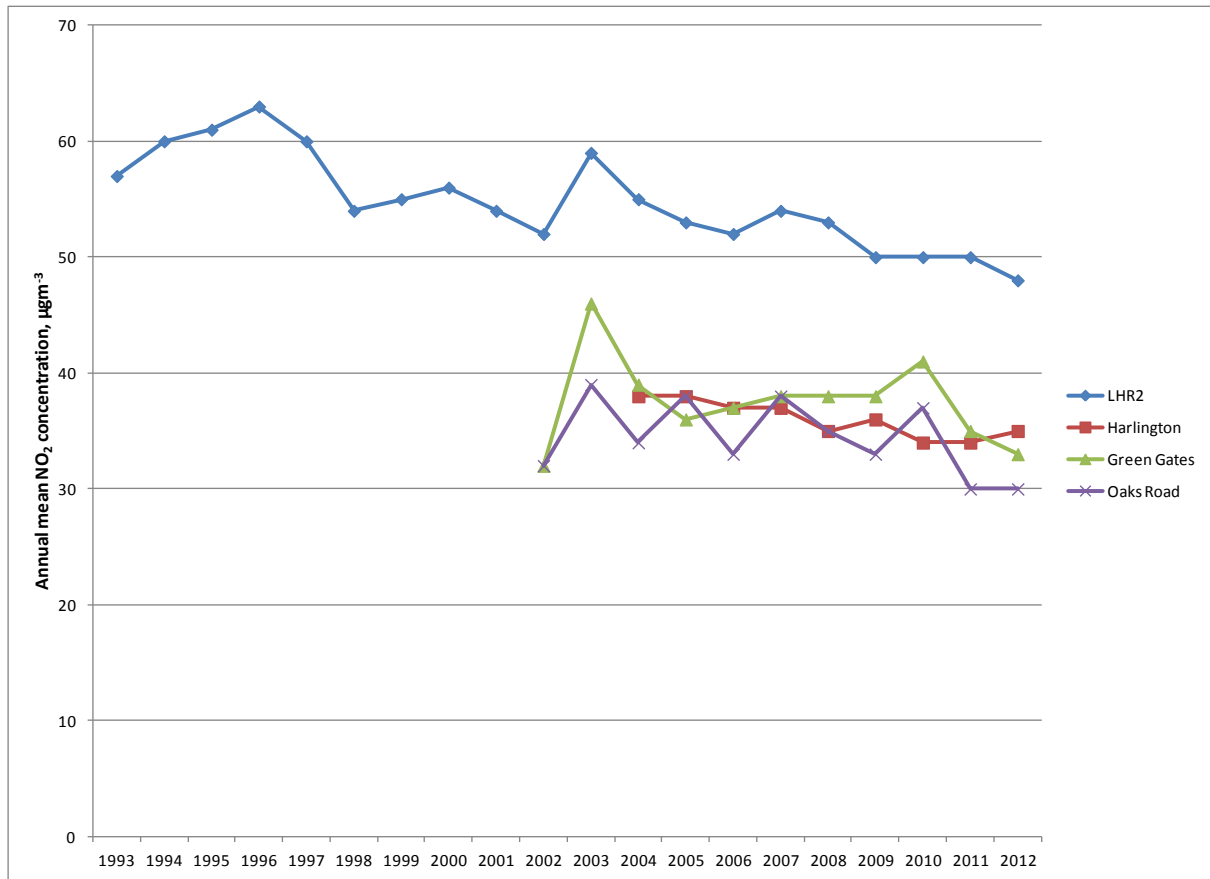


Figure 3-22 Time Series of Annual Mean NO₂

Figure 3-23 shows the annual mean concentration of NO₂ as a percentage of the total NO_x. Since the early 1990s, until around 2005, NO₂ has accounted for an increasing percentage of total NO_x at LHR2. There is also some indication of a general increase in the proportion of NO_x measured as NO₂ at the other three sites, although some years such as 2007 and 2012 are exceptions to this general pattern.

An increasing trend in the proportion of NO₂:NO_x ratio has been observed in the UK as a whole: the Air Quality Expert Group⁶ considers this may be due to an increase in the proportion of total NO_x emitted as NO₂ (due to increased proportion of diesel cars and increased fitting of catalytically regenerative particulate traps to buses).

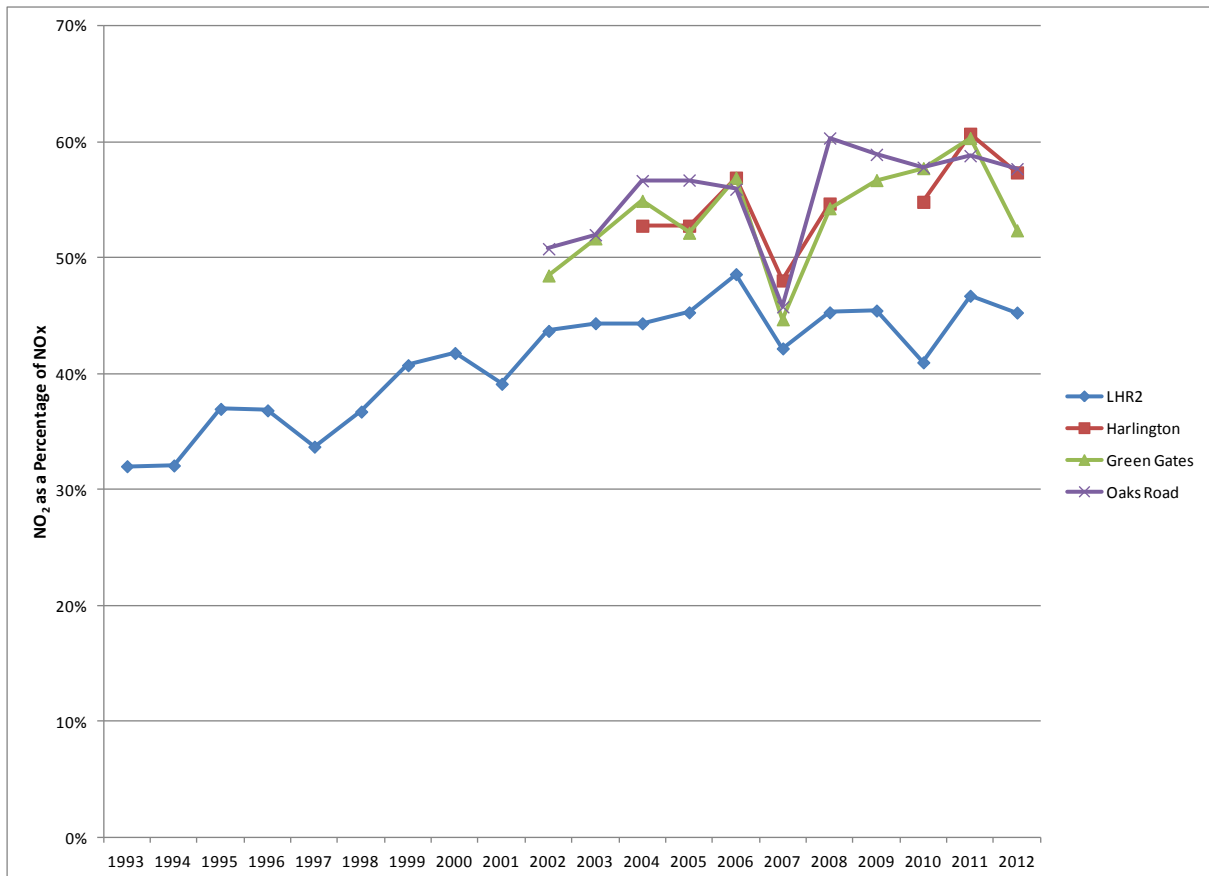


Figure 3-23 Time Series of NO₂ as a Percentage of Total NO_x

Figure 3-24 illustrates how annual mean PM₁₀ concentrations have changed since monitoring began in 1995.

Earlier reports in this series, for years up to and including 2010, have assessed long-term changes on the basis of the annual mean as measured by the TEOM, multiplied by a factor of 1.3. This was formerly used as an indicative estimate of gravimetric equivalent. However, the use of this factor is no longer recommended: the VCM should be used instead, wherever possible.

Therefore, in reports for 2011 onwards, the annual mean PM₁₀ data for previous years have been retrospectively VCM-corrected, as far back in time as possible. The earliest year for which this has been possible is 2004 (in most areas, 2006 is the earliest year for which VCM correction can be done: in London there were a small number of FDMS monitors in place from 2004). Figure 3-24 shows VCM-corrected data from 2004 onwards. For years prior to this, uncorrected TEOM data are shown.

There is no clear trend: VCM-corrected PM₁₀ concentrations appear to have increased in 2010 and 2011, after a number of years in which they had been falling. The 2011 annual mean for Harlington is shown despite low data capture (58%) and should be interpreted with caution.

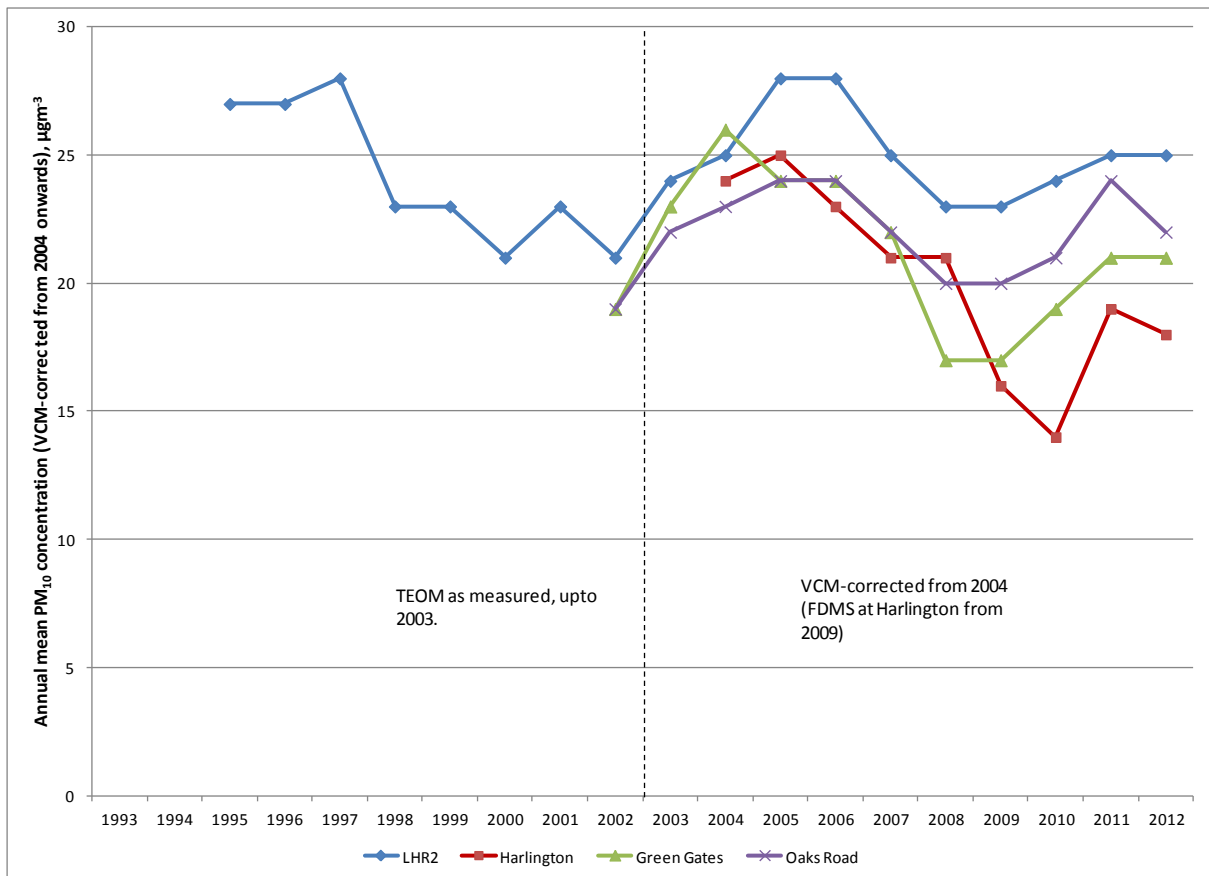


Figure 3-24 Time Series of Annual Mean PM₁₀ (TEOM until 2003, VCM-corrected TEOM from 2004 onwards.)

Figure 3-25 shows how annual mean concentrations of $PM_{2.5}$ have changed over time. Only Green Gates and Oaks Road have the minimum of five years' data needed to assess long-term trends. Both sites' data indicate that concentrations of this particulate fraction around Heathrow are decreasing. However, the changes year-on-year are small.

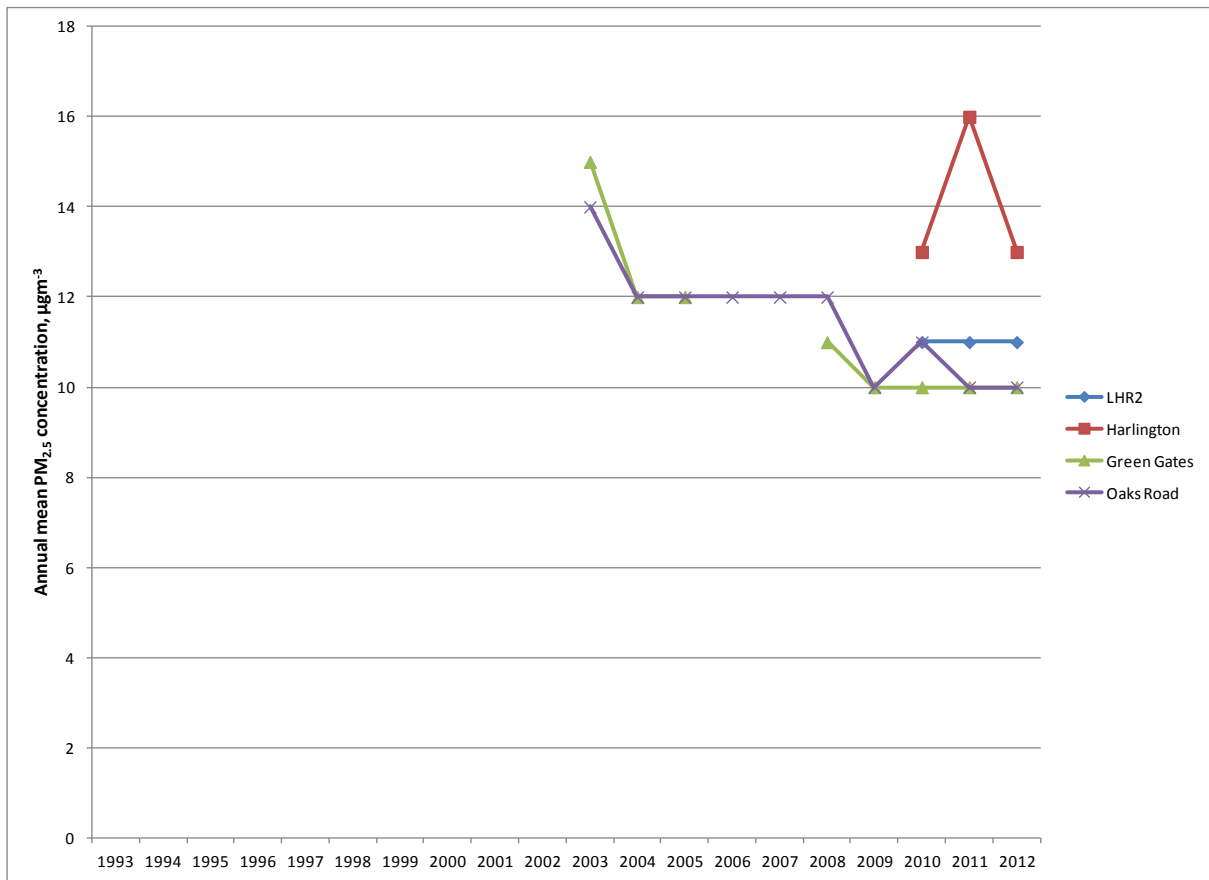


Figure 3-25 Trends in Annual Mean $PM_{2.5}$

Ozone is only measured at one of the sites – Harlington. As illustrated in Figure 3-26 there is no clear upward or downward trend in annual mean ozone concentration at this site. (There is a possible hint of a slight general upward trend but with considerable variation from year to year).

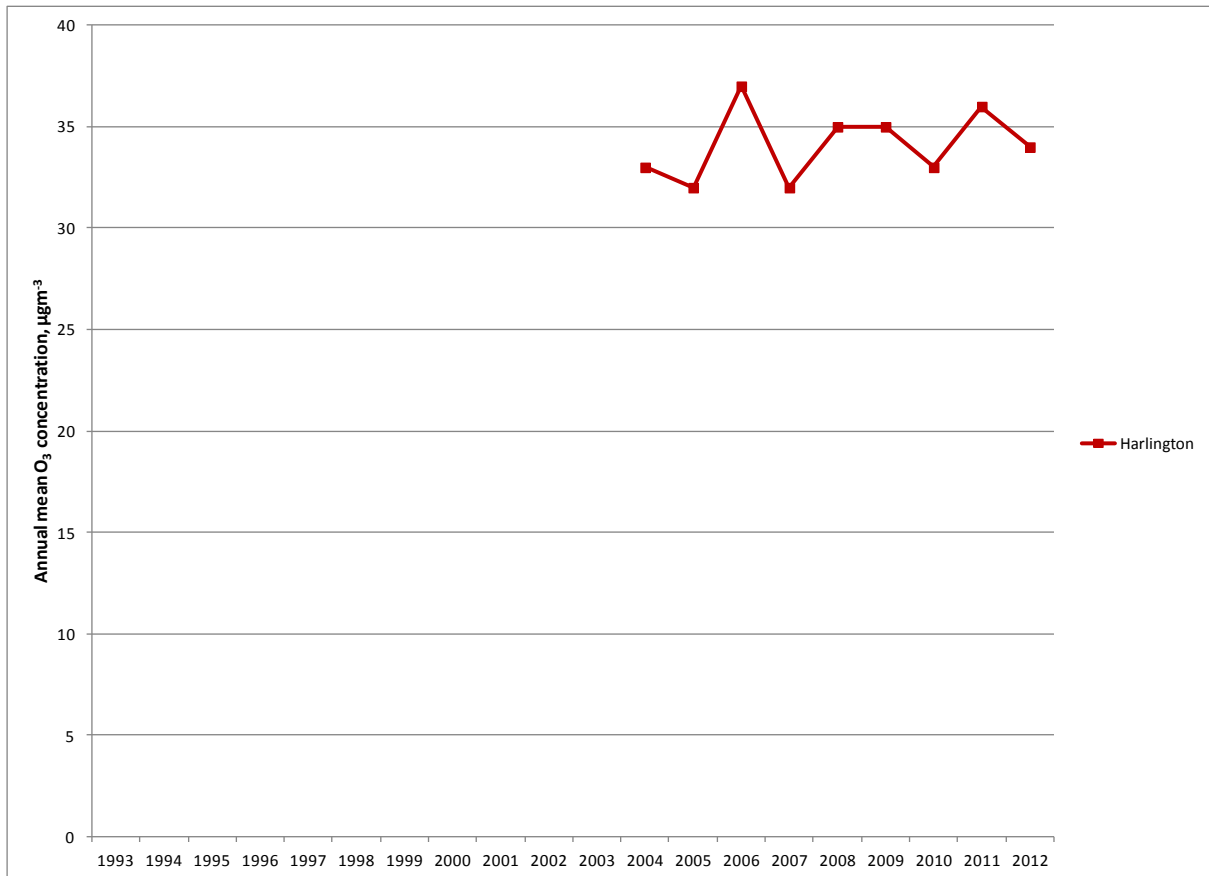


Figure 3-26 Trends in Annual Mean Ozone at Harlington

3.10 Relationship with Airport Activity

Figure 3-27 shows daily mean aircraft transport movements (ATMs) for each month during 2012. ATMs remained relatively constant throughout the year, with a slight increase in summer. This is a typical pattern, observed in most previous years (though not in 2010, when volcanic eruptions disrupted flights during the spring).

By contrast, ambient concentrations of oxides of nitrogen and particulate matter measured at the four Heathrow sites are typically higher in winter and lower in summer. This pattern has been observed consistently in previous years.

It is important to note that emissions from the airport (and associated sources such as road traffic) are an important contributor to local concentrations of NO₂ and PM₁₀. However, this illustrates how the seasonal variation in ambient pollutant concentrations around the airport is driven by meteorological factors rather than variation in local emissions.

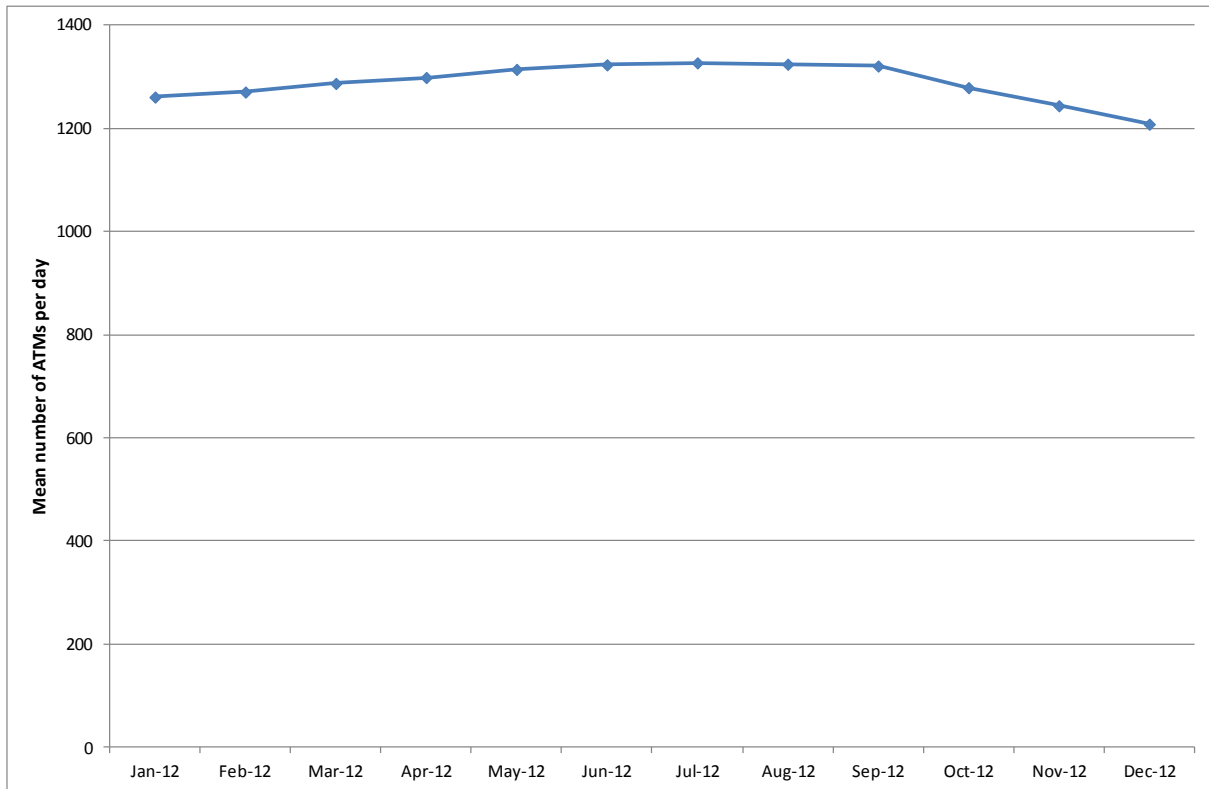


Figure 3-27 Average number of Transport Movements per Day at Heathrow, 2012

It is also useful to look for relationships between long-term trends in airport activity and pollutant concentrations. Figure 3-28 shows annual mean NO_x concentrations at the four monitoring sites, together with annual total air transport movements (ATMs). In 2012, the total number of air transport movements at Heathrow was the slightly lower than in 2011 (when ATMs peaked after several years in which they had fallen). There does not appear to be any obvious relationship between the year-on-year changes in ATMs and local ambient concentrations of NO_x.

Figure 3-29 shows the same comparison for PM₁₀. Annual mean PM₁₀ varies much more than can be accounted for by changes in air traffic movements. Again, this does not mean that the airport is not a major contributor to local ambient PM₁₀. It simply indicates that the variation in ambient PM₁₀ concentrations from one year to the next is also dependent on other factors.

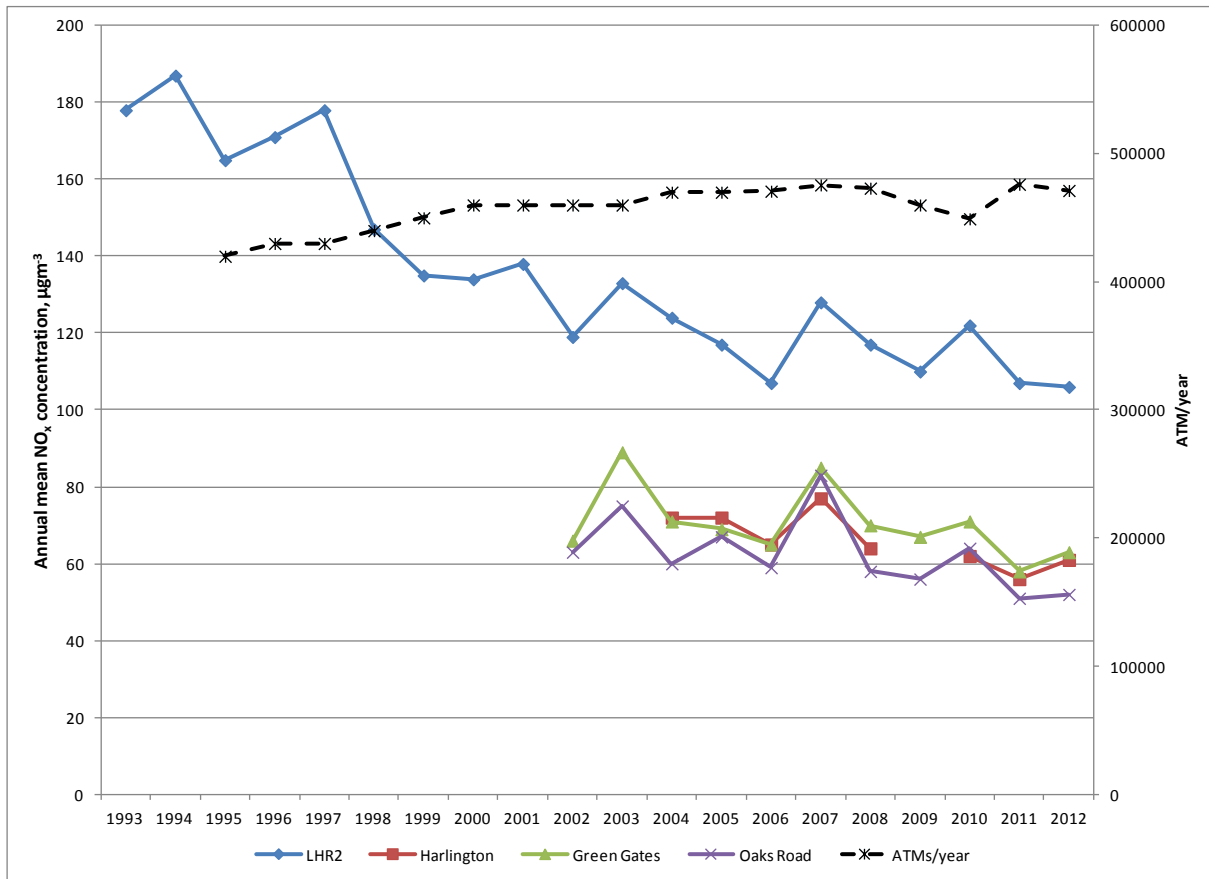


Figure 3-28 Time Series of Annual ATM and Annual Mean NOx Concentration

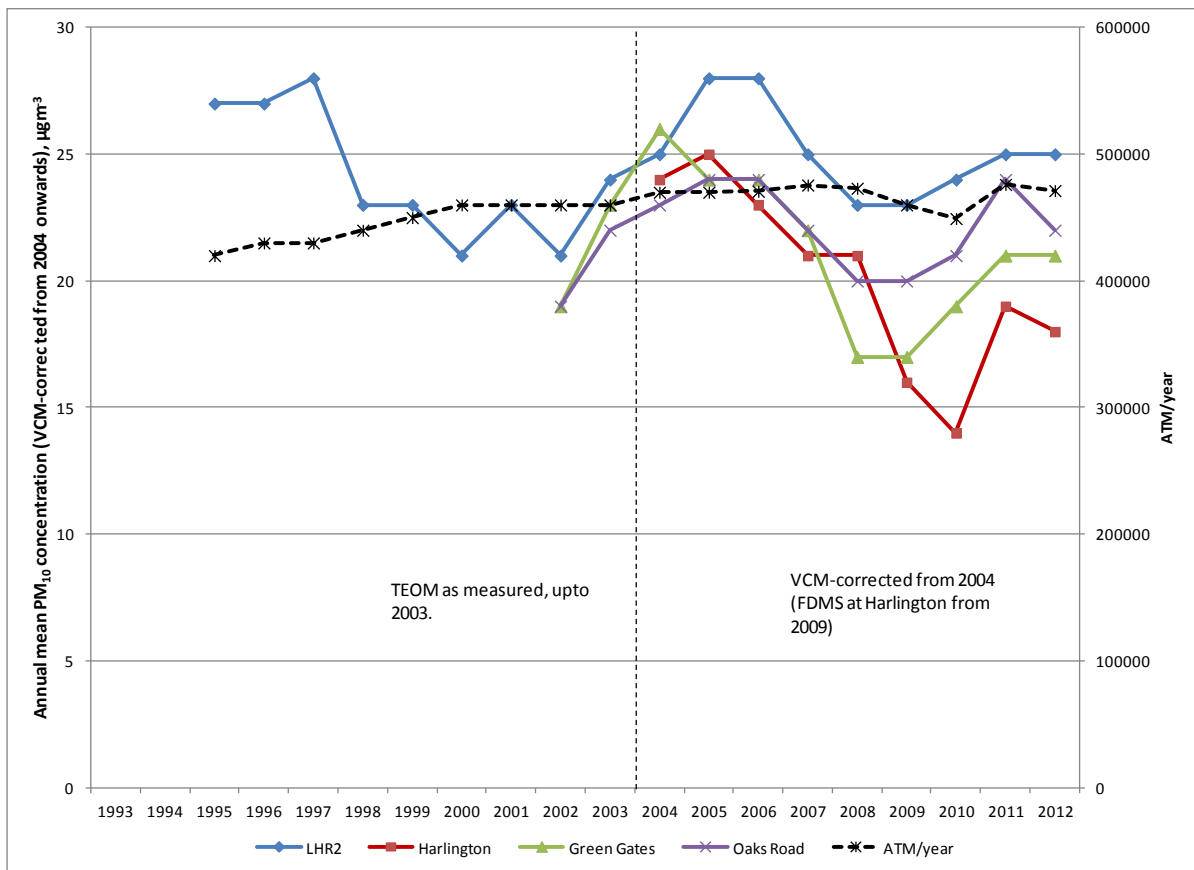


Figure 3-29 Time Series of Annual ATM and Annual Mean PM₁₀ Concentrations

4 Conclusions

Oxides of nitrogen and particulate matter (as PM₁₀ and PM_{2.5}) were monitored throughout 2012 at four sites around Heathrow Airport (LHR2, London Harlington, Green Gates and Oaks Road). Ozone was also measured at Harlington, and benzene was also indicatively monitored using diffusion tubes at LHR2. The conclusions of the 2012 monitoring programme are as follows:

1. Data capture of at least 90% was achieved for all pollutants monitored at LHR2, Green Gates and Oaks Road. This target was achieved at Harlington for all pollutants except PM₁₀, for which the data capture was 84%. The cause of most of the lost data was an equipment fault during May and June.
2. Oxides of nitrogen were monitored at all four sites. No sites exceeded the AQS Objective of 200 µg m⁻³ for hourly mean NO₂ on any occasion during 2012 (18 exceedances per calendar year are permitted).
3. One site, LHR2, exceeded the annual mean AQS Objective of 40 µg m⁻³ for NO₂ in 2012, with an annual mean of 48 µg m⁻³. LHR2 has consistently exceeded this objective since monitoring began. This site is close to the main areas of airport activity, also to the perimeter roads and associated parking areas. The EU limit values and AQS objectives do not actually apply at LHR2, because there is no public exposure. The other three sites met this objective.
4. All four sites met the AQS objective for 24-hour mean PM₁₀. Where measurements were made using the TEOM instrument, the PM₁₀ data were converted to gravimetric equivalent using the King's College Volatile Correction Model (VCM).
5. All four sites met the annual mean AQS objective of 40 µg m⁻³ for PM₁₀, 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 5 days during 2012: this is within the permitted maximum of 10 days per calendar year. (Harlington has exceeded the objective before; most recently in 2006, 2008, 2009 and 2011).
7. Diffusion tube measurements at LHR2 indicate that this site met the AQS objective for benzene.
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 and NO₂ exhibited higher concentrations during the winter months. PM₁₀ and PM_{2.5}, which have both primary and secondary components, showed a much less pronounced seasonal pattern but were also generally slightly higher in the winter. Ozone levels were highest during the 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, NO₂ and PM coincided with the morning and evening rush hour periods, and levels of ozone peaked in the early afternoon.
10. Numerous periods of elevated PM₁₀ concentration (daily mean concentration in the Defra "Moderate" band or higher) occurred throughout January to March 2012. As in previous years, other urban background monitoring sites in London and the South East showed a similar pattern of elevated PM₁₀ concentrations during the above periods. This indicates that the higher concentrations measured at Heathrow were reflecting regional variations in PM₁₀ concentration, rather than any emission sources specific to the airport.
11. Ozone concentration (measured at Harlington only) went into the "Moderate" band on six days in late May: these were also seen at other sites throughout London and the south of England and were regional rather than local events.

12. Meteorological measurements at LHR2 allowed the effect of wind direction to be investigated. Bivariate plots of NO concentration and wind data showed that concentrations of the primary pollutant NO at LHR2 were typically highest in calm conditions, indicating that the main sources of NO were nearby. The pattern was similar for NO₂, but also with an apparent contribution from the direction of the main airport buildings and runway area at higher wind speeds. The patterns for PM₁₀ and PM_{2.5} showed contribution from sources on a bearing of approximately 070° at a range of wind speeds. In the case of PM₁₀ there were also contributions from the south and the north-west at higher wind speeds.
13. Annual mean concentrations of pollutants at the four Heathrow sites in 2012 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. A less pronounced decrease is also observed in annual mean concentrations of NO₂ and PM₁₀, which have both primary and secondary components. However, the proportion of total NO_x measured as NO₂ has increased.
15. Neither seasonal patterns, nor long-term trends, in pollutant concentration at the Heathrow sites showed any obvious relationship to monthly or 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.

5 Acknowledgements

Ricardo-AEA would like to thank Rachel Thomas, Luke Cox and Spencer Thomas of Heathrow Airport Ltd for their assistance with this work.

6 References

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Appendices

Appendix 1: Quality Assurance and Quality Control

Appendix 2: Daily Air Quality Index Bandings

Appendix 3: Annual Mean Pollutant Concentrations 1993-2012

Appendix 1 – 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. 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. Ricardo-AEA's audit calibration procedures are UKAS accredited to ISO 17025. These procedures are documented in Ricardo-AEA's AURN QA/QC manual, available at: http://uk-air.defra.gov.uk/reports/cat13/0910081142_AURN_QA_QC_Manual_Sep_09_FINAL.pdf.

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

All air pollution measurements are reviewed on a daily basis, at Ricardo-AEA, by experienced staff. 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 to checking the data, the results of the daily automatic instrument calibrations 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, or occasionally the chart recorder record, to produce as complete as possible a data record.

Finally, the data are re-examined on an annual basis, when information from the 6-monthly intercalibration audits can be incorporated. After completion of this process, the data are fully validated and finalised, for compilation in the annual report.

Appendix 2 – Daily Air Quality Index Bandings

The air quality index and bandings were updated in January 2012. The table below shows the new bandings, in use during 2012, the period covered by this report.

Air pollution bandings and description.

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.

Boundaries between index points for each pollutant.

Band	Index	O ₃	NO ₂	SO ₂	PM _{2.5}	PM ₁₀
		Daily max 8-hr 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)
	1	0-33	0-66	0-88	0-11	0-16
Low	2	34-65	67-133	89-176	12-23	17-33
	3	66-99	134-199	177-265	24-34	34-49
	4	100-120	200-267	266-354	35-41	50-58
Moderate	5	121-140	268-334	355-442	42-46	59-66
	6	141-159	335-399	443-531	47-52	67-74
	7	160-187	400-467	532-708	53-58	75-83
High	8	188-213	468-534	709-886	59-64	84-91
	9	214-239	535-599	887-1063	65-69	92-99
Very High	10	240 or more	600 or more	1064 or more	70 or more	100 or more

Appendix 3 – Annual Mean Pollutant Concentrations 1993- 2012

Table A3.1 Annual Mean Concentrations of NO_x, µg^m⁻³

	LHR2	Harlington	Green Gates	Oaks Road
1993	178			
1994	187			
1995	165			
1996	171			
1997	178			
1998	147			
1999	135			
2000	134			
2001	138			
2002	119		66	63
2003	133		89	75
2004	124	72	71	60
2005	117	72	69	67
2006	107	65	65	59
2007	128	77	85	83
2008	117	64	70	58
2009	110	-	67	56
2010	122	62	71	64
2011	105	56	58	51
2012	106	63	61	52

Table A3.2 Annual Mean Concentrations of NO, $\mu\text{g m}^{-3}$

	LHR2	Harlington	Green Gates	Oaks Road
1993	80			
1994	83			
1995	68			
1996	71			
1997	77			
1998	61			
1999	52			
2000	51			
2001	55			
2002	44		22	20
2003	49		28	24
2004	45	22	21	18
2005	42	22	22	20
2006	36	18	18	17
2007	49	26	31	30
2008	42	19	22	15
2009	39	21	19	15
2010	47	18	20	18
2011	37	15	15	14
2012	38	18	20	14

Table A3.3 Annual Mean Concentrations of NO₂, µgm⁻³

	LHR2	Harlington	Green Gates	Oaks Road
1993	57			
1994	60			
1995	61			
1996	63			
1997	60			
1998	54			
1999	55			
2000	56			
2001	54			
2002	52		32	32
2003	59		46	39
2004	55	38	39	34
2005	53	38	36	38
2006	52	37	37	33
2007	54	37	38	38
2008	53	35	38	35
2009	50	36	38	33
2010	50	34	41	37
2011	50	34	35	30
2012	48	33	33	30

Table A3.4 Annual Mean Concentrations of PM₁₀, µgm⁻³

	LHR2	Harlington	Green Gates	Oaks Road
1995	27 (35)			
1996	27 (36)			
1997	28 (36)			
1998	23 (30)			
1999	23 (29)			
2000	21 (27)			
2001	24 (29)			
2002	21 (28)		19 (25)	19 (25)
2003	24 (31)		23 (30)	22 (29)
2004	25	24	26	23
2005	28	25	24	24
2006	28	23	24	24
2007	25	21	22	22
2008	23	21	17	20
2009	23	16	17	20
2010	24	14	19	21
2011	25	-	21	24
2012	25	18	21	22

Yellow shading indicates TEOM (as measured) with TEOM x 1.3 in brackets.

Aqua shading indicates VCM-corrected TEOM data.

Orange shading indicates FDMS data (from April 2009) at Harlington.

Table A3.5 Annual Mean Concentrations of $PM_{2.5}$, $\mu g m^{-3}$

	LHR2	Harlington	Green Gates	Oaks Road
2003			15	14
2004			12	12
2005			12	12
2006			-	12
2007			-	12
2008			11	12
2009			10	10
2010	11	13	10	11
2011	11	16	10	10
2012	11	13	10	10

Table A3.6 Annual Mean Concentrations of O₃, µgm⁻³

	LHR2	Harlington	Green Gates	Oaks Road
2004		33		
2005		32		
2006		37		
2007		32		
2008		35		
2009		35		
2010		33		
2011		36		
2012		34		

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