Report

Air Pollution at Heathrow Airport: Annual Report for 2003

Report to Heathrow Airport Ltd

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Executive Summary

netcen (part of AEA Technology Environment) is undertaking air pollution measurements at Heathrow airport on behalf of Heathrow Airport Ltd. This report presents a summary and analysis of the data for 2003, the eleventh year of the monitoring programme. The aim of the programme is to monitor air pollution at the airport, to provide a reliable assessment in relation to current and proposed air quality standards and guidelines, and to determine any trends in air pollution concentrations over time.

During 2003, measurements of oxides of nitrogen (NO and NO_2), carbon monoxide (CO), PM_{10} particulate matter, benzene (by diffusion tubes) and a range of other hydrocarbon species (by grab samples) were undertaken. Monitoring continued at the old apron location (site LHR2), which has been used since 1993. A new site was established at Harlington in April 2003.

The UK Air Quality Strategy objectives for CO and for the NO_2 hourly average were achieved in 2003. The current UK Air Quality Strategy objectives were not met for the annual mean NO_2 concentration and the PM_{10} daily mean. However, it should be noted that the 40 $\mu g\ m^{-3}$ annual mean NO_2 concentration is widely exceeded in urban areas of the UK and that PM_{10} levels in London were generally higher in 2003 than in 2002.

Average concentrations of NO, NO_2, CO and PM_{10} at Heathrow were generally similar to, or slightly higher than those measured at other air pollution monitoring sites in London.

Peak NO and NO_2 concentrations at Heathrow were found to coincide with peaks at other monitoring sites in London and the south east. Hence, these are likely to be regionally based air pollution episodes. However, the highest PM_{10} concentration at Harlingron was due to a local agricultural source, as PM_{10} monitoring data at Heathrow and for elsewhere in London did not show the same characteristics.

The pattern of monthly averaged concentrations throughout the year shows that the concentrations of the primary pollutants NO and CO were highest in the winter months. Concentrations of NO_2 and PM_{10}, which have both primary and secondary components, were generally less variable than NO and CO throughout the course of the year. Although, on a monthly averaged basis, pollutant concentrations were generally highest in the winter months, statistics related to airport activity (passenger numbers and air traffic movements) were highest in July and August.

Annual average concentrations of PM_{10}, NO, NO_2 and CO were slightly higher in 2003, than in 2002. These trends in concentrations are consistent with those seen elsewhere in London and in the rest of the UK.Annual averaged passenger numbers and air traffic movements had shown a steady year on year increase. Passenger numbers were slightly lower in 2001 and 2002 than in 2000 but have increased in 2003.

The measured annual mean concentration of benzene at Heathrow LHR2 was lower than at the Marylebone Road site in central London and well below the current Air Quality Strategy objectives for benzene. For other hydrocarbon species, the grab samples indicated that Heathrow annual mean concentrations were also lower than at the Marylebone Road site in central London.

Data capture of 95% or more was achieved for oxides of nitrogen and PM_{10} during 2003 at LHR2. Data capture for CO was 93.2%.

Contents

Executive Summary

1 Introduction **2**

1.1 BACKGROUND 2

2 Pollutants Monitored and Monitoring Location **4**

2.1 POLLUTANTS MONITORED 4
2.1.1 Oxides of Nitrogen 4
2.1.2 Carbon Monoxide 5
2.1.3 Volatile Organic Compounds 5
2.1.4 PM_{10} Particulate Matter 5
2.2 LOCATION OF THE MONITORING SITE 6

3 Quality Assurance and Data Capture **8**

3.1 QUALITY ASSURANCE AND QUALITY CONTROL 8
3.2 DATA CAPTURE 9

4 Results and Discussion **10**

4.1 PRESENTATION OF THE RESULTS 10
4.2 TEMPORAL VARIATION OF THE POLLUTANT CONCENTRATIONS 15
4.3 PERIODS OF ELEVATED POLLUTANT CONCENTRATIONS 18
4.4 DISCUSSION OF DATA IN RELATION TO SOURCES 26
4.5 COMPARISON WITH PREVIOUS YEARS 27
4.6 COMPARISON WITH AIR QUALITY STANDARDS AND GUIDELINES 32
4.7 COMPARISON WITH OTHER SITES 35

5 Conclusions **38**

6 Acknowledgements **39**

7 References **39**

Appendices

APPENDIX 1 POLLUTION ROSES
APPENDIX 2 AIR QUALITY STANDARDS AND GUIDELINES
APPENDIX 3 MONITORING EQUIPMENT AND SITE LOCATIONS
APPENDIX 4 QUALITY ASSURANCE AND QUALITY CONTROL

1 Introduction

netcen (part of AEA Technology Environment) is undertaking air pollution measurements at Heathrow Airport and nearby Harlington on behalf of Heathrow Airport Ltd. This report presents a summary and analysis of the data for 2003, the eleventh year of the monitoring programme.

The aim of the programme is to monitor air pollution at the airport, to provide a reliable assessment in relation to current and proposed air quality standards and guidelines and to determine any trends in air pollution concentrations over time. It should be noted that the pollutants measured in this study will have originated from a variety of sources, both local and long range i.e. not all of these sources will be directly connected with the airport.

This report presents and summarises the fully validated and quality controlled dataset for the period 1st January to 31st December 2003. The pollutants monitored were as follows:

- oxides of nitrogen;
- carbon monoxide;
- volatile organic compounds;
- particulate matter (PM_{10});
- ozone.

The locations used for monitoring during this period were the sites LHR2 and Harlington (see Figure 1).

Monitoring data collected at Heathrow are compared with:

- relevant UK air quality guidelines and standards, including the Government's Air Quality Objectives set out in the Air Quality Strategy and Addendum[1];
- corresponding results from a selection of National air pollution monitoring sites;
- statistics related to airport activity; and
- air pollution data from previous years.

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

The Air Quality Strategy adopts standards which were published in the first and second European Community (EC) Daughter Directive[2,3] and/or previously recommended by the Expert Panel on Air Quality Standards (EPAQS)[4-8]. These standards have been adopted into UK law in the Air Quality Regulations 2000[9] and the Air Quality (Amendment) Regulations 2002 [10].

1.1 BACKGROUND

Heathrow Airport is the world's busiest international airport, handling over 60 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.

Data for 1993-2002 have been reported in previous Annual Reports[11-20]. This report presents and analyses the data for 2003. Data in this annual report have been fully subjected to the rigorous quality assurance and quality control procedures adopted by

netcen, to ensure data of the highest quality, accuracy and traceability to UK national measurement standards.

In addition to this report, Heathrow Airport Planning and Environment Department has access to provisional data from both Heathrow monitoring sites, and to National Monitoring Network sites operated by **netcen** on behalf of The Department for Environment, Food and Rural Affairs (defra) daily, via a telemetry link to the Air Pollution Database held at **netcen**. Data collected are also summarised on a 3-monthly basis and supplied both on disc and in the Quarterly Reports[21-24] to the Planning and Environment Department by **netcen**. Data supplied on a 3-monthly basis must also be regarded as provisional and subject to possible change by quality assurance and control procedures.

The air pollution and meteorological data are also supplied to the BAA Heathrow Noise and Air Quality Database and to the London Air Quality Network Data Managers.

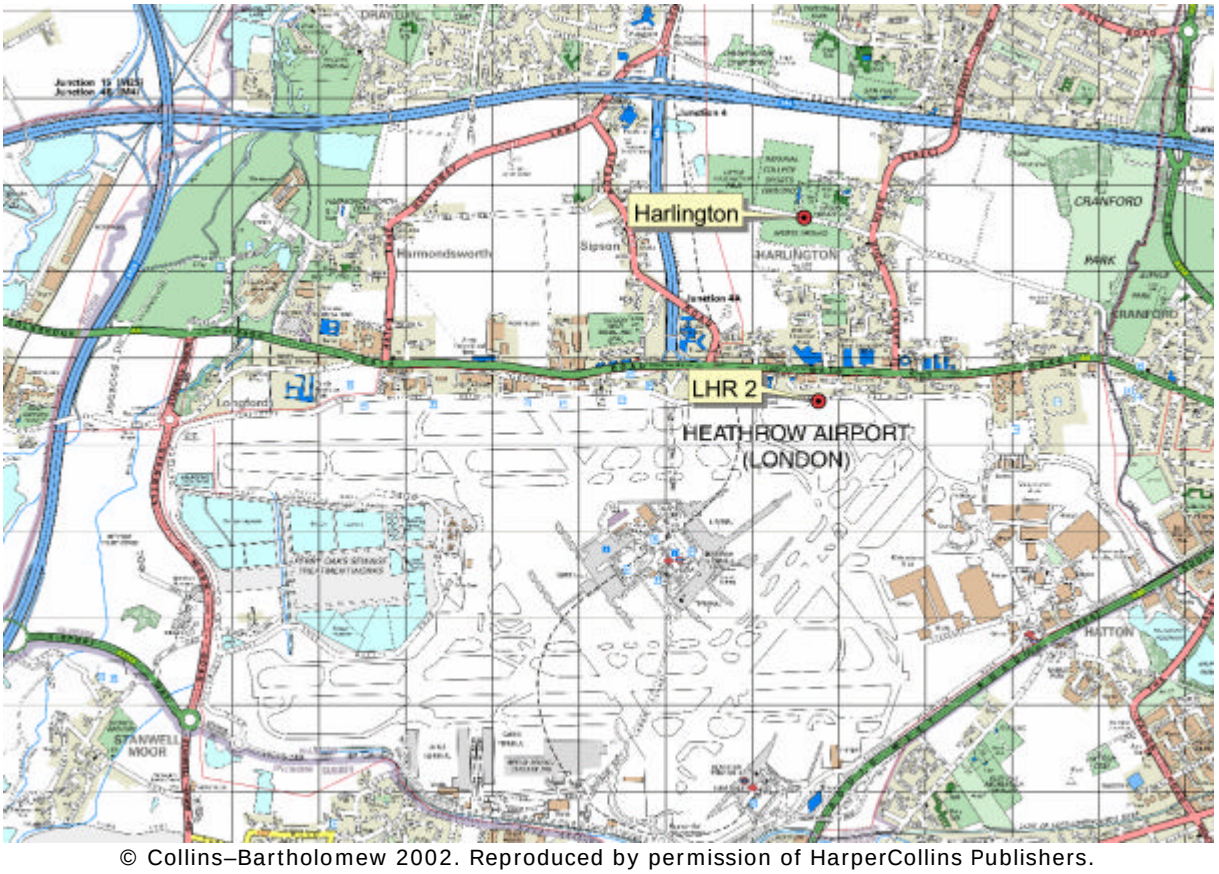

Figure 1. Location of the Heathrow Air Monitoring Sites LHR2 and Harlington

2 Pollutants Monitored and Monitoring Location

2.1 POLLUTANTS MONITORED

The monitoring programme concentrates on the pollutants which may be of concern in and around airports. These were identified by considering:

1. Those pollutants listed in the Air Quality Strategy which have significant health effects reported by EPAQS; and
2. Those pollutants which have significant emissions sources at Heathrow Airport.

The pollutants monitored are shown in Table 1 and described in the following section.

Table 1 Pollutants Monitored at Heathrow Sites

Site Location	netcen reference	Parameters monitored	Grid Reference
Old Apron	LHR2	NO_2, CO, $PM_{10,}$ VOCs	508400 176750
Harlington	Harl	NO_2, CO, $PM_{10,}$ Ozone	508299 177809

2.1.1 Oxides of Nitrogen

Combustion processes emit a mixture of oxides of nitrogen, primarily nitric oxide (NO) and nitrogen dioxide (NO_2), collectively termed NO_X. Major outdoor sources of NO_X in urban areas are fuel combustion in motor vehicles, power generation, heating plant and industrial processes. Based on 2001 data, in the UK, civil aircraft are estimated to contribute only approximately <0.3% to total UK emissions[25] of NO_X. However, such emission inventories only consider emissions up to a height of 1000m, the assumed height of the boundary layer. There will be emissions from aircraft above this height, but under most weather conditions they are unlikely to affect ground level concentrations. On and close to airports the contribution from aircraft and other airport-related sources is likely to be much more significant. The air pollution emissions and modelling work undertaken for the Terminal 5 Public Inquiry[26] indicated that, in 1993, aircraft sources accounted for 21-43% of annual average NO_X concentrations at a range of sites around the airport perimeter. The corresponding contribution from all airport sources was estimated to be 28-54%.

Automatic measurements of NO_X have been carried out at Heathrow since the current monitoring programme commenced in 1993. NO_x measurements have been carried out at Harlington since April 2003.

(i) NO

NO is described as a primary pollutant, being directly emitted from a range of mobile and stationary sources. Though NO is not known to have any harmful effects on human health, it undergoes oxidation in the atmosphere to form the secondary pollutant NO_2.

(ii) NO_2

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. Concentrations of NO_2 in the UK are regulated by the first European Community Daughter Directive[2]. The UK Department for Environment, Food and Rural Affairs (defra) has set air pollution bands for NO_2, which are used to describe air pollution

in Air Pollution Bulletins issued to the public. The Air Quality Strategy[1] sets out Objectives for NO_2 concentrations to be met by 31st December 2005 - an hourly mean concentration of 200 μgm^{-3} not to be exceeded more than 18 times and an annual mean of 40 μgm^{-3}.

2.1.2 Carbon Monoxide

Carbon monoxide (CO) is produced by the incomplete combustion of fossil fuels or organic material. Carbon monoxide has a strong affinity for haemoglobin, the oxygen-carrying substance in the blood. When oxygen is displaced by CO, it can progressively lead to oxygen starvation and severe acute health effects. Based on 2001 data, approximately 80% of the total UK emission of CO arises from motor vehicles, and emissions from civil aircraft only contribute approximately 0.1% to the UK total[25]. However, as with NO_X, such inventories only consider emissions up to 1000m. Defra has set air pollution bands for CO, which are used to describe air pollution in Air Pollution Bulletins issued to the public. The current Air Quality Strategy Objective is 10 mgm^{-3} as a maximum daily running 8-hour mean to be achieved by December 31st 2003. The Second EC Daughter Directive[3], sets a limit value for CO of 10 mgm^{-3} for the maximum running 8 hour average to be achieved by January 2005.

Automatic measurements of CO have been carried out at Heathrow since the current monitoring programme commenced in 1993. CO measurements have been carried out at Harlington since April 2003.

2.1.3 Volatile Organic Compounds

Volatile organic compounds (VOCs) include a very wide range of species which can be present either in the gaseous phase or associated with particulate matter. The major UK sources of total volatile organic compounds are road transport, solvent use and other non-combustion processes. However, individual species of volatile organic compounds may have different predominant sources. Based on 2001 data, civil aircraft are estimated to contribute <0.1% to total UK VOC emissions[25]. The Air Quality Strategy sets objectives which are to be achieved by December 31st 2003 for the carcinogenic compounds benzene and 1,3-butadiene, 16.25 μgm^{-3} and 2.25 μgm^{-3} respectively, measured as a running annual mean. In addition there is a benzene objective of 5 μgm^{-3} as an annual mean to be achieved by December 31st 2010 (England and Wales only).

A programme of volatile organic compound monitoring commenced at Heathrow Airport in April 1995. This consists of measurements of benzene (C_6H_6), toluene (C_7H_8) and xylene (C_8H_{10}) with diffusion tube samplers. These on-going measurements are supplemented by quarterly "grab samples" which are analysed for a wide range of hydrocarbon species, including 1,3 – butadiene (C_4H_6).

2.1.4 PM_{10} Particulate Matter

Airborne particulate matter varies widely in its physical and chemical composition, source and particle size. PM_{10} particles (the fraction of particulates in air of very small size (<10 µm)) are of major current concern, as they are small enough to penetrate deep into the lungs and so potentially pose significant health risks. Larger particles meanwhile, are not readily inhaled, and are removed relatively efficiently from the air by sedimentation. The principal source of airborne PM_{10} matter in European cities is road traffic emissions, particularly from diesel vehicles. Fine particles can be carried deep into the lungs where 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

In November 1994, a PM_{10} particle analyser was installed at the LHR2 site. Data for the first 6-months of operation of this analyser have been reported separately[27]. PM_{10} is now also monitored at the Harlington site. This extension to the monitoring programme reflects the current level of interest in particle concentrations. Based on 2001 data, less than

0.1% of UK total PM_{10} emissions are believed to originate from aircraft[25]. The Air Quality Strategy sets objectives based on 24-hour and annual mean gravimetric equivalent PM_{10} concentrations. The 24-hour mean of 50 μgm^{-3} is not to be exceeded more than 35 times per year by December 31st 2004, and an annual mean concentration of 40 μgm^{-3} must also be achieved by this date. Recently, additional objectives have been set for 2010 for England, Scotland, Wales, Northern Ireland and for London. However, as these new objectives have not been set in Regulations for England, they are not considered in this report.

Defra has also set air pollution bands for $PM_{10,}$ measured with TEOM analysers, which are used to describe air pollution in Air Pollution Bulletins issued to the public. Latest studies indicate that PM_{10} measured by a gravimetric method will be a factor of 1.3 times higher than TEOM PM_{10} measurements – for further details see Appendix 3.

2.1.5 Ozone

Ozone (O_3) is not emitted directly into the atmosphere, but is a secondary pollutant produced by reaction between nitrogen dioxide (NO_2), hydrocarbons and sunlight. Whereas nitrogen dioxide (NO_2) acts as a source of ozone, nitrogen oxide (NO) destroys ozone acting as a local sink. For this reason, ozone levels are not as high in urban areas (where high levels of NO are 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". The air quality strategy objective for ozone is a daily running 8 hour mean of 100 μgm^{-3} not to be exceeded more than 10 times per year to be achieved by 31 December 2005. It should be noted that ozone is not included in the Regulations for the purpose of local air quality management.

A full discussion of the relevant air quality standards is given in Section 4.6 and a summary provided in Appendix 2. Ozone measurements have been carried out at Harlington since April 2003.

In summary, NO, NO_2, NO_X and CO concentrations have been monitored at Heathrow Airport since 1992. PM_{10}, benzene, toluene and xylene concentrations have been monitored since 1995, along with quarterly grab samples for a wide range of hydrocarbon species. A range of meteorological parameters has been monitored throughout: wind speed, wind direction and air temperature. NO_2, CO, $PM_{10,}$ and ozone are now monitored at the new Harlington site.

The equipment selected for the current monitoring programme is described in detail in Appendix 3.

2.2 LOCATION OF THE MONITORING SITES

Three factors influenced the selection of the LHR2 monitoring site; previous surveys indicating where highest concentrations were likely to be experienced, the prevailing wind direction, and the availability of a suitable and secure monitoring location. Data from the 1989/1990 monitoring study at Heathrow[28], in connection with the Terminal 5 development, clearly indicated that the area of highest NO_2 concentration was centred on the passenger terminals. However, the exposure of the public to air pollutants at the central terminal area is generally limited and it was considered more important to measure at a location more representative of the long-term exposure of residents in the surrounding area. The prevailing wind direction is from the south west and, hence, a site situated to the north east of the airport will be best placed to monitor air pollutants arising from the airport area. The area to the north east of the airport was therefore examined in order to determine a suitable site location.

The site falls into the category "other" as defined by the Defra Technical Guidance on air quality monitoring (LAQM TG (03)[29]), 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 location of the site is illustrated in Figure 1, Figure 2 is a photograph of the site and a detailed description is given in Appendix 2.

Figure 2. Heathrow LHR2 Air Quality Monitoring Site

The Harlington site 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 1 January 2004, the site is affiliated into the defra Automatic Urban and Rural Network. The site is classified as “Airport”. The location is illustrated in Figure 1, Figure 3 is a photograph of the site and a detailed description is given in Appendix 2.

Figure 3. Harlington Air Quality Monitoring Site

3 Quality Assurance and Data Capture

3.1 QUALITY ASSURANCE AND QUALITY CONTROL

In line with current operational procedures within the Defra Automatic Urban Monitoring Network, full intercalibration audits of the Heathrow air quality monitoring sites take place at the end of winter and summer. Full details of these UKAS accredited calibrations, together with our data validation and ratification procedures are given in Appendix 4. A summary of the intercalibration results for 2003 is presented in Table 2 below.

Table 2. Intercalibration Results

LHR2

	Accuracy %	Linearity %	Converter Efficiency
NO	+3.1	1.0000	-
NO_2	-3.5	0.9998	99%
CO	+0.3	1.0000	-
PM_{10}	+0.8	-	-

Harlington

	Accuracy %	Linearity %	Converter Efficiency
NO	-0.3	0.9981	-
NO_2	-1.1	0.9980	99%
CO	0.0	0.9980	-
O_3	+1.2	1.0000	-
PM_{10}	-0.7	-	-

In addition to instrument and calibration standard checking, the air intake sampling system was cleaned and all other aspects of site infrastructure were checked. Only one audit was undertaken in 2003, as a result of rescheduling them to coincide with the defra AURN programme. Future audits will be undertaken in winter and summer, as opposed to the previous spring autumn schedules.

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 can be summarised as follows:

Table 3. Estimated Accuracy and Precision of the Data Presented

	Precision	Accuracy
Nitric Oxide (NO)	±2.5 µg m^{-3}	±10%
Nitrogen Dioxide (NO_2)	±6.9 µg m^{-3}	±11%
Carbon Monoxide (CO)	±0.7 mg m^{-3}	±8%
Particles (PM_{10})	±4 µg m^{-3}	*

* accuracy of particle measurements cannot currently be assessed.

Wind speed and wind direction data from the measurements at the LHR2 site are checked by comparing against results from other nearby monitoring locations.

3.2 DATA CAPTURE

Overall data capture statistics for the monitoring sites at Heathrow and Harlington are given in Table 4.
As noted in the previous annual reports, the location of the site within a secure airside area leads to some additional delay in attending to faults once they are identified, because of security arrangements for access. A data capture rate of 90% or greater for ratified data is recommended in the Defra Technical Guidance LAQM (TG(03))[29].

3.2.1 LHR2

For all analysers, except CO, data capture during 2003 at LHR2 was 95% or greater. The data capture for CO was 93.2%. Apart from routine calibrations, servicing and audits, the only major loss of data occurred March 2003. There were up to 6 days of data lost during the period 21 – 27 March due to a power cut.

3.2.2 Harlington

The annual data capture statistics for Harlington are reduced as a result of the site commencing operation on 1 April 2003. As a result, a maximum annual data capture of 75% could be achieved at the site for NOx, CO and PM_{10} in this year. Monitoring of ozone at the site began in the middle of May, so a maximum annual data capture of 62% could be achieved for this pollutant. In April, 22 days of CO data were lost due to initial set up problems with the analyser. Apart from routine servicing, all other data losses were due to communications problems. Telemetry faults during July caused the following data losses:

- CO 10 days
- PM_{10} 16 days
- NO_2 15 days
- O_3 9 days

4 Results and Discussion

4.1 PRESENTATION OF THE RESULTS

The summary statistics for 1 January to 31 December 2003 at the LHR2 and Harlington sites are given in Table 4, and the time series of data for the full year are shown in Figures 4 and 5.

Measured concentrations of the majority of the gaseous pollutants (NO, NO_2, O_3 and VOCs) are reported in micrograms per cubic metre ($\mu g\ m^{-3}$). The exception is CO, which is reported in milligrams per cubic metre ($mg\ m^{-3}$).

PM_{10} is conventionally reported in units of $\mu g\ m^{-3}$, micrograms per cubic metre. In this report PM_{10} data are presented as measured (PM_{10} TEOM) or as the gravimetric equivalent (PM_{10} Grav.).

Conversion factors to other common units for air pollution concentrations parts per million (ppm) and parts per billion (ppb) are given below:

NO	1 ppb	=	1.25 $\mu g\ m^{-3}$
NO_2	1 ppb	=	1.91 $\mu g\ m^{-3}$
CO	1 ppm	=	1.16 $mg\ m^{-3}$
O_3	1 ppb	=	2.00 $\mu g\ m^{-3}$
C_6H_6 (benzene)	1 ppb	=	3.25 $\mu g\ m^{-3}$
C_7H_8 (toluene)	1 ppb	=	3.83 $\mu g\ m^{-3}$
C_8H_{10} (xylene)	1 ppb	=	4.41 $\mu g\ m^{-3}$
PM_{10} Gravimetric	= PM_{10} TEOM x1.3		

(at 20°C and 1atm pressure)

In this report, the mass concentration of NO_X has been calculated as follows:
$NO_X\ \mu g\ m^{-3}$ =(NO ppb+NO_2 ppb)*1.91.

This conforms with the requirements of the first Daughter Directive[2] and is also the convention generally adopted in air quality modelling.

Table 4. Basic Statistics of Air Pollution for Heathrow LHR2 and Harlington 1 January to 31 December 2003

LHR2						
POLLUTANT	**NO µg m^{-3}**	**NO_2 µg m^{-3}**	**NO_X µg m^{-3}**	**CO mg m^{-3}**	**PM_{10} TEOM**	**PM_{10} GRAV***
Number of hours Very High	-	0	-	0	0	-
Number of hours High	-	0	-	0	0	-
Number of hours Moderate	-	0	-	0	369	-
Number of hours Low	-	8359	-	8156	8048	-
Maximum 15-minute mean	861	224	1411	3.6	283	368
Maximum hourly mean	682	191	1236	3.3	208	270
Maximum running 8-hour mean	449	138	805	2.4	98	127
Maximum running 24-hour mean	277	118	525	1.5	72	94
Maximum daily mean	274	117	521	1.4	70	91
Average of hourly means	48	59	133	0.5	24	31
Data capture of hourly means	95.4 %	95.4 %	95.4 %	93.2 %	96.3 %	96.3 %

Harlington							
POLLUTANT	**NO µg m^{-3}**	**NO_2 µg m^{-3}**	**NO_X µg m^{-3}**	**CO mg m^{-3}**	**PM_{10} TEOM**	**PM_{10} GRAV***	**Ozone µg m^{-3}**
Number of hours Very High	-	0	-	0	47	-	0
Number of hours High	-	0	-	0	28	-	8
Number of hours Moderate	-	0	-	0	163	-	244
Number of hours Low	-	6040	-	5537	5207	-	5087
Maximum 15-minute mean	681	163	1177	4.2	2333	3033	208
Maximum hourly mean	630	145	1087	3.7	1792	2330	204
Maximum running 8-hour mean	449	116	790	2.5	958	1246	179
Maximum running 24-hour mean	272	99	510	1.8	339	441	126
Maximum daily mean	253	94	465	1.7	336	437	119
Average of hourly means	27	41	82	0.3	24	31	32
Data capture of hourly means	68.9 %	68.9 %	68.9 %	63.3 %	62.1 %	62.1 %	60.7

* PM_{10} in gravimetric units
NO_X mass units are NO_X as NO_2
All mass units are at 20'C and 1013mb

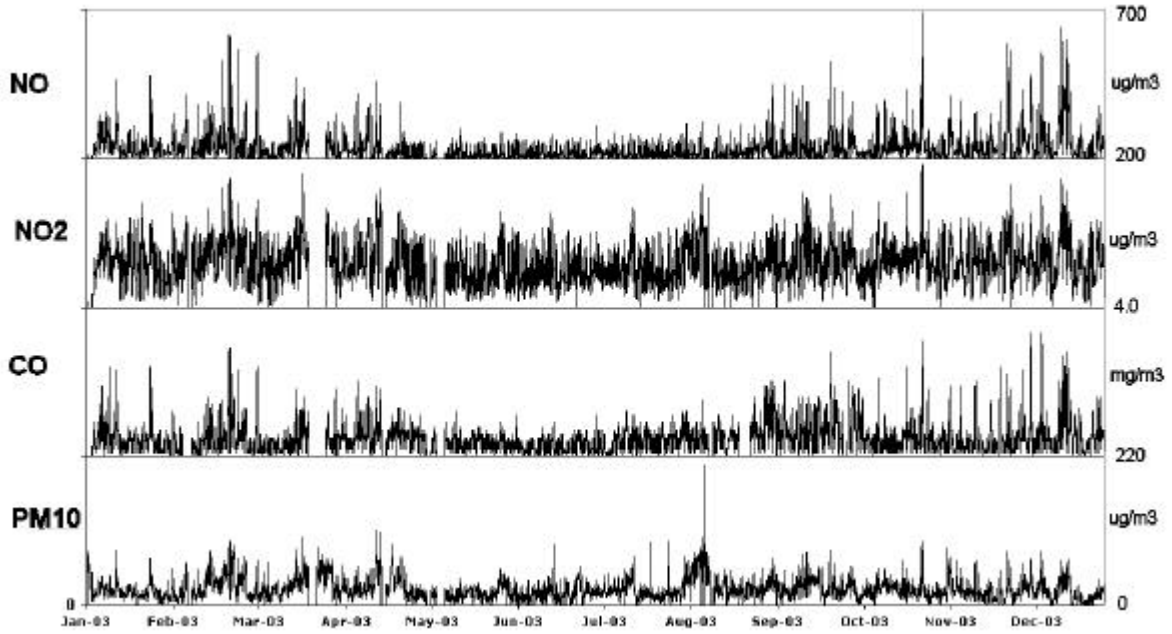

Figure 4. Time Series of Hourly Averaged Concentrations at LHR2 – 2003

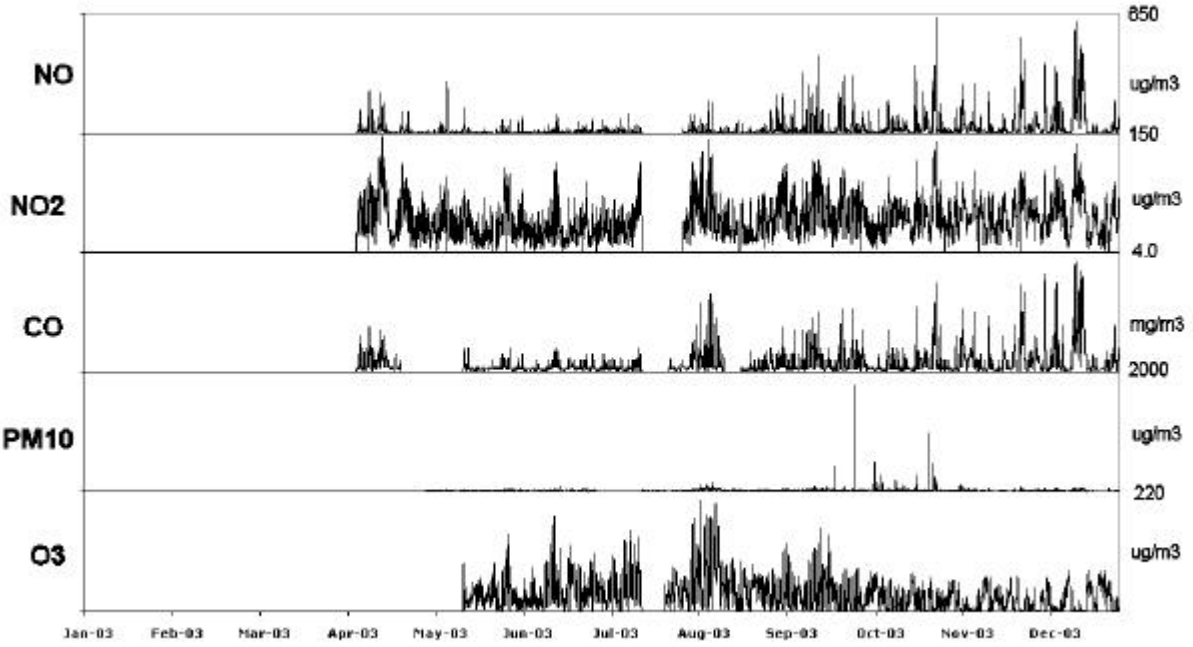

Figure 5. Time Series of Hourly Averaged Concentrations at Harlington – 2003

Table 5 shows the monthly averaged pollutant concentrations at LHR2 in 2003 (with a 75% data capture requirement for each month).

Table 5. Monthly Average Air Pollutant Concentrations at LHR2 and Harlington, 2003

	LHR2											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
NO µg m^{-3}	59	68	54	43	21	23	26	29	53	59	59	87
NO_2 µg m^{-3}	57	67	65	63	47	47	49	57	64	63	63	64
NO_X µg m^{-3}	147	171	148	128	79	82	89	102	146	153	154	197
CO mgm^{-3}	0.5	0.5	0.4	0.6	0.4	0.3	0.4	0.5	0.8	0.5	0.4	0.6
PM_{10} µg m^{-3} (TEOM)	21	31	30	29	17	18	21	31	27	23	21	21

	Harlington											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul***	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
NO µg m^{-3}				22	10	8		13	37	33	37	59
NO_2 µg m^{-3}				49	33	28		40	50	43	46	46
NO_X µg m^{-3}				83	48	41		61	107	94	103	138
CO mgm^{-3}						0.3		0.9	0.7	1	1.5	1.7
PM_{10} µg m^{-3} (TEOM)					17	18		30	36	31	20	20
Ozone µg m^{-3}						37		53	34	23	18	20

*Due to data losses caused by telemetry problems, insufficient data are available to calculate a valid monthly average for July.

Table 6 presents results of the benzene, toluene and xylene measurements by diffusion tube samplers and Table 7, the analysis of the quarterly grab samples.

Table 6. Benzene, Toluene and m+p Xylene concentrations LHR2, 2003

Date on	**Date off**	**Benzene µg m^{-3}**	**Toluene µg m^{-3}**	**m,p xylene µg m^{-3}**
19/12/02	6/02/03	1.6	3.8	2.4
6/02/03	7/03/03	1.5	2.5	0.7
7/03/03	31/03/03	2.8	8.4	4.4
31/03/03	25/06/03	0.6	2.5	1.6
18/07/03	5/09/03	0.8	3.3	2.1
29/10/03	05/12/03	0.3	1.2	0.8
05/12/03	19/12/03	2.4	8.0	5.8
	MEAN	**1.4**	**4.2**	**2.6**

Table 7. Concentrations of Hydrocarbon Species at LHR2, from Grab Sample Analysis, 2003

Hydrocarbon	Concentration, μgm^{-3}			
	07-Mar	18-Jul	28-Nov	Mean
ethane	1.4	0.6	5.1	2.4
ethene	0.7	0.2	2.1	1.0
propane	1.8	0.5	4.5	2.3
propene	1.8	0.3	2.4	1.5
iso-butane	0.6	0.3	2.3	1.1
n-butane	1.1	0.4	4.0	1.8
ethyne	1.8	0.3	5.2	2.4
trans-2-butene	1.1	0.3	0.2	0.5
1- butene	0.6	0.1	0.5	0.4
cis-2-butene	0.4	0.1	0.2	0.2
iso-pentane	0.5	0.7	2.8	1.3
n-pentane	0.2	0.3	0.7	0.4
1,3-butadiene	0.5	0.1	0.5	0.4
trans-2-pentene	0.0	0.2	0.1	0.1
cis-2-pentene	0.1	0.2	0.1	0.1
2-methylpentane	0.3	0.6	0.4	0.4
3-methylpentane	0.1	0.2	0.4	0.2
n-hexane	0.1	0.1	0.3	0.2
isoprene	0.2	0.9	0.1	0.4
n-heptane	0.2	0.2	0.2	0.2
benzene	1.3	0.4	1.0	0.9
toluene	1.4	0.7	2.4	1.5
ethyl benzene	0.4	0.3	0.4	0.4
meta & para xylene	1.2	0.7	1.4	1.1
ortho xylene	0.6	0.7	0.7	0.7
1,3,5-trimethyl benzene	0.2	0.1	0.1	0.1
1,2,4-trimethyl benzene	1.4	0.8	0.8	1.0
dodecane	0.2	0.4	0.1	0.2

The following sections discuss the data with reference to the following issues:

- Section 4.2 discusses temporal and seasonal variation of pollutant concentration during 2003;
- In Section 4.3, some periods of relatively elevated concentrations at Heathrow are examined in more detail;
- In Section 4.4, the data are analysed in conjunction with meteorological measurements in order to investigate possible pollution sources;
- Section 4.5 compares data for 2003 with that for previous years and with statistics related to airport activity;
- In Section 4.6, the measurements at Heathrow are compared with current UK air quality guidelines and standards; and
- Section 4.7 compares the 2003 Heathrow data with that obtained at other sites.

4.2 TEMPORAL VARIATION OF THE POLLUTANT CONCENTRATIONS

4.2.1 LHR2

Figure 6 shows the variation of monthly averaged pollutant concentrations during 2003 at LHR2. Concentrations of the primary pollutants NO and CO were highest in the winter months. Concentrations of NO_2, which has both primary and secondary components, were also highest in the winter months but with less variability than NO and CO throughout the course of the year. PM_{10} concentrations did not exhibit a distinct seasonal variation.

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

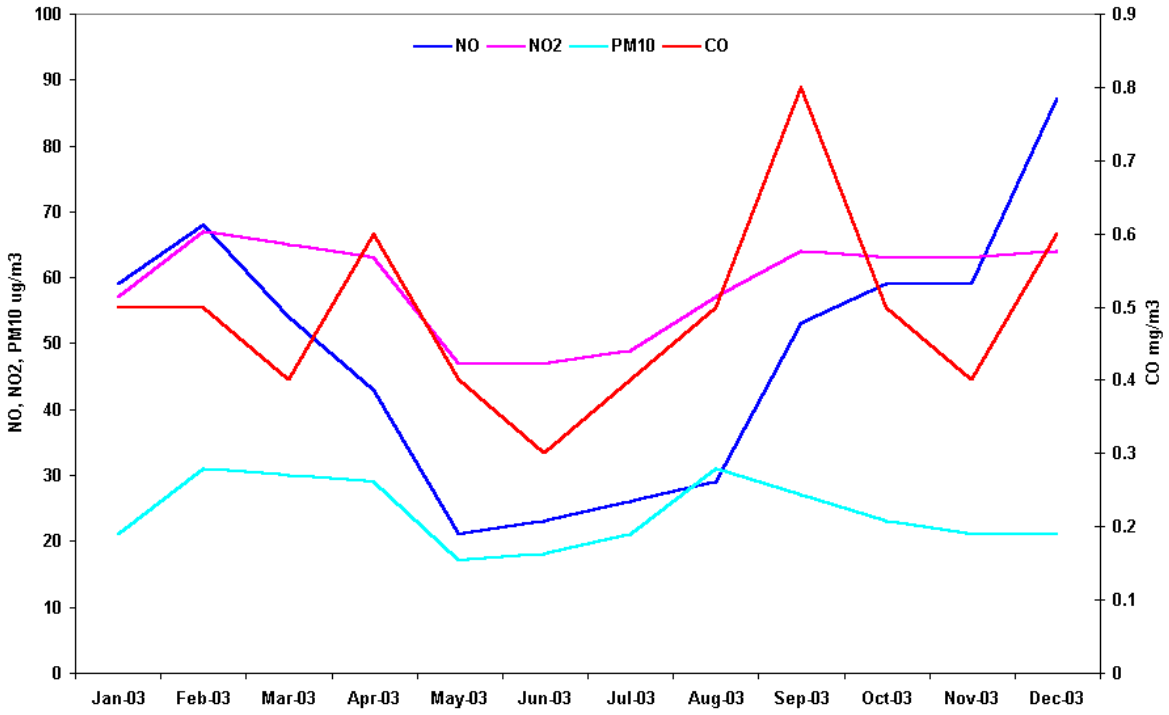

Figure 6. Seasonal variation of pollutant concentrations at Heathrow LHR2, 2003

The average variation of hourly concentrations throughout the day, at Heathrow, is shown in Figure 7. The curves for NO and CO show the classic typical daily cycle for these pollutants in urban areas. The distinct morning peaks probably arise from general rush-hour traffic emissions. Concentrations decrease during the middle of the day, with a much broader evening rush-hour peak commencing after 1600. For NO_2 and PM_{10} which have secondary components, the morning rush-hour peak is again visible, with the peak broader than for the primary pollutants. In the afternoon, concentrations of oxidising agents, particularly ozone, in the atmosphere tend to increase, leading to enhanced oxidation of NO to NO_2. For PM_{10}, emissions of sulphur dioxide and NO_X can react with other chemicals in the atmosphere to form secondary sulphate and nitrate particles, which can result in elevated levels of PM. In addition, the diurnal PM_{10} profile may be affected by the pattern of use of light and heavy-duty vehicles throughout the day.

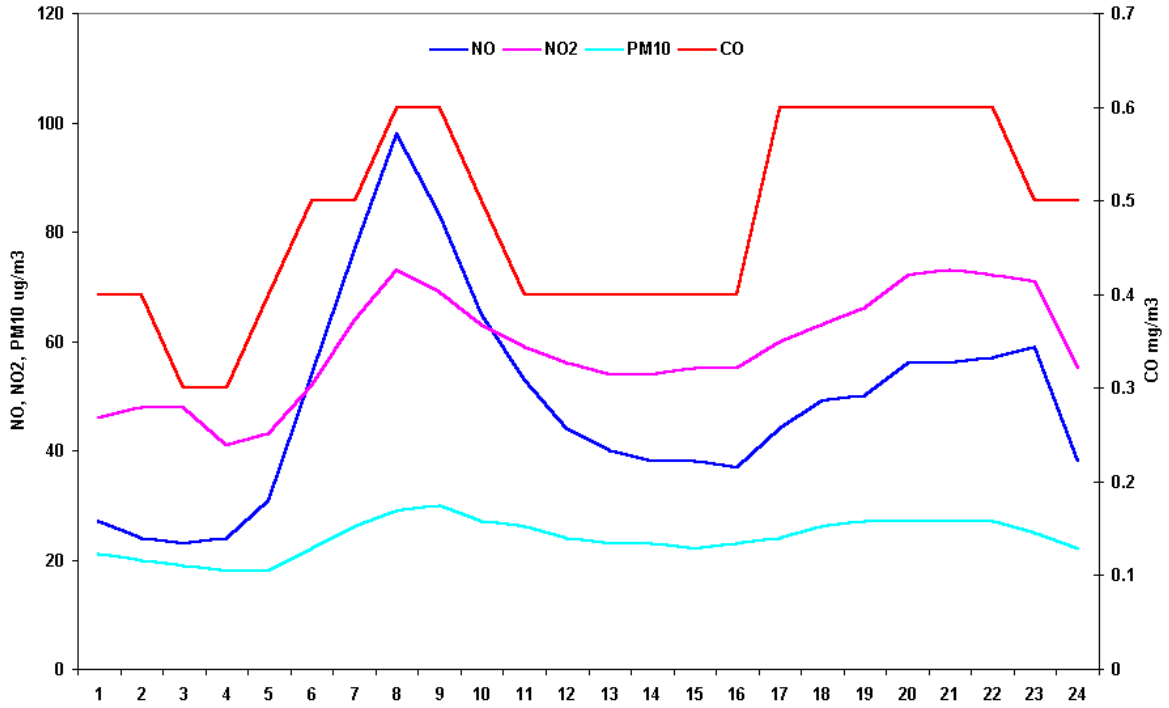

Figure 7. Diurnal variation of pollutant concentrations at Heathrow LHR2, 2003

4.2.2 Harlington

Figure 8 shows the variation of monthly averaged pollutant concentrations during 2003 at Harlington. The plot is presented without comment since there is less than a full years data available.

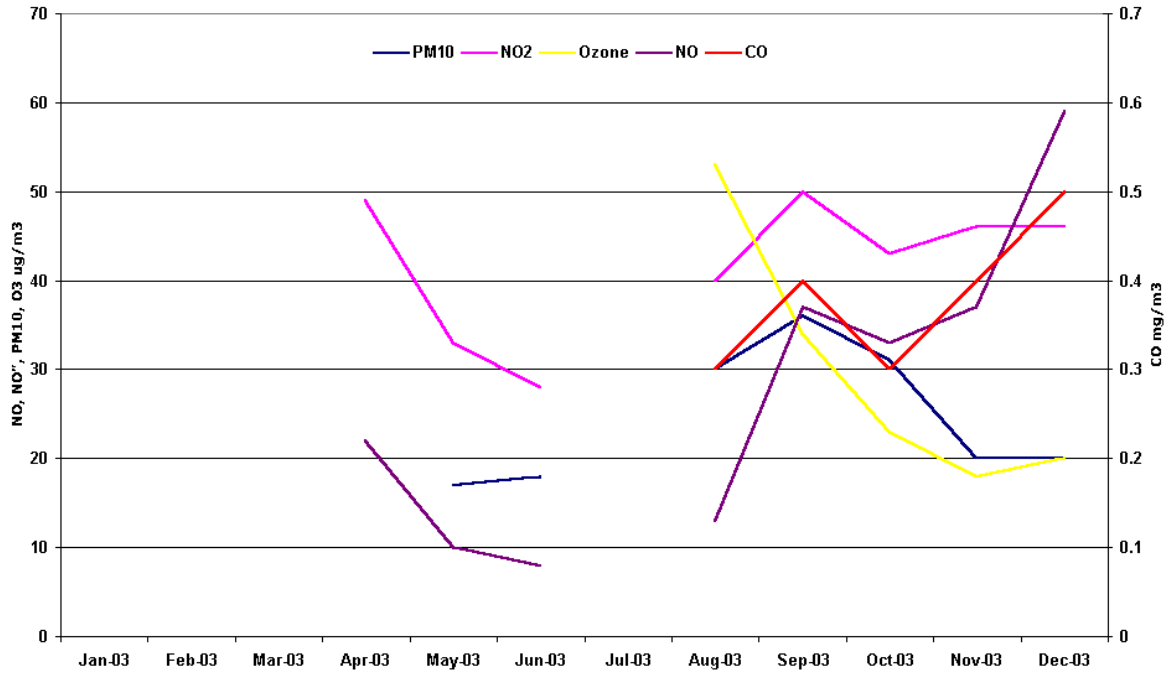

Figure 8. Seasonal variation of pollutant concentrations at Harlington, 2003

The average variation of hourly concentrations throughout the day, at Harlington, is shown in Figure 9. It should be noted that these curves are not based on a full years data and may not be representative of a typical year.

Patterns for NO, NO_2 and CO are similar to those for LHR2 but with lower overall concentrations. The pattern for PM_{10} show a more distinct afternoon peak than the plot for LHR2. This is probably influenced by the very high concentrations recorded during periods when nearby farm field were ploughed. The diurnal pattern for ozone which exhibits highest concentrations in the afternoon is typical for this pollutant.

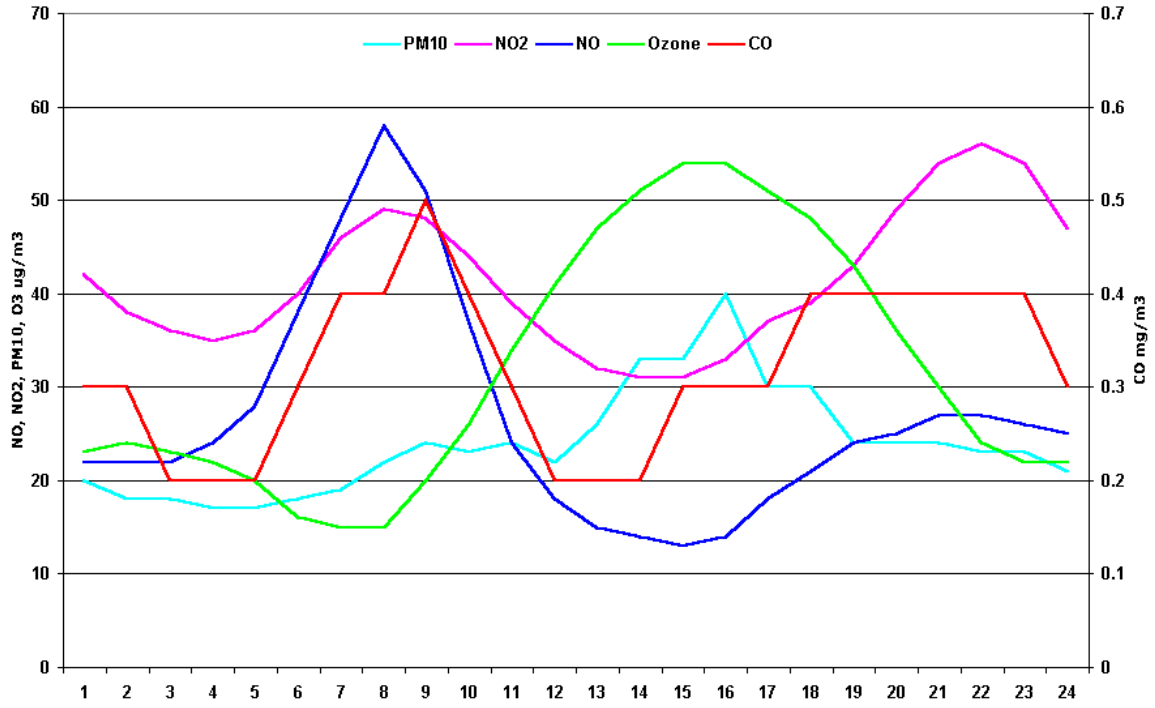

Figure 9. Diurnal variation of pollutant concentrations at Harlington, 2003

4.3 PERIODS OF ELEVATED POLLUTANT CONCENTRATIONS

Periods of elevated pollutant concentrations are reported regularly to Heathrow Airport Ltd in the Quarterly Summary reports. In this report, the most significant periods of high air pollution concentrations for the whole year are briefly reviewed, using the fully validated data set.

Figure 4 shows that a period of elevated PM_{10} concentrations occurred in August 2003 at LHR2 and during September and October 2003 at Harlington. Elevated NO_2 and CO occurred during February and October at LHR2. There were no major episodes of high NO_2 concentrations either site. The highest hourly average NO_2 concentration of the year ($191\mu gm^{-3}$) occurred on 18 November at LHR2.

For the figures in this section, the following codes have been used to identify the monitoring sites:

LHR2	- Heathrow Airport	Harl	- Harlington
KC1[i]	- London North Kensington	HIL	- London Hillingdon
LH	- Lullington Heath	WL	- West London

(a description of these site locations is given in Section 4.7)

[i] North Kensington has been used instead of Bloomsbury due to the low data capture rates at Bloomsbury in 2003.

4.3.1 LHR2

NO, NO_2, CO and PM_{10} concentrations during the period 20 to 23 February

Figure 10 shows pollutant concentrations at LHR2 during the period 20 to 23 February 2003. The highest NO_2 (172µgm^{-3}), PM_{10}TEOM (93 µgm^{-3}) and CO (2.9 mg/m^3) concentrations during this period were recorded at 08.00 on the 21st February. High concentration peaks were also seen at other monitoring sites in London (Figure 11 shows concentrations measured at North Kensington) during the period. Hence this is a regional episode, rather than a local effect.

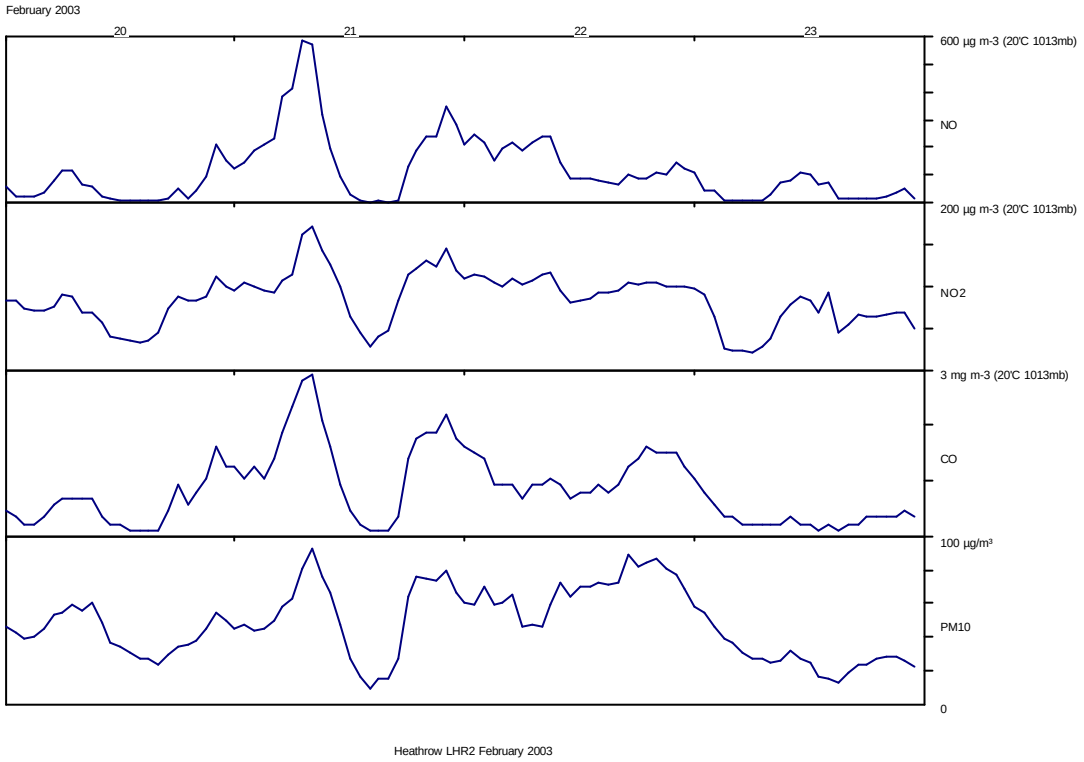

Figure 10. NO, NO_2, CO and PM_{10} concentrations at LHR2 during the period 20 to 23 February

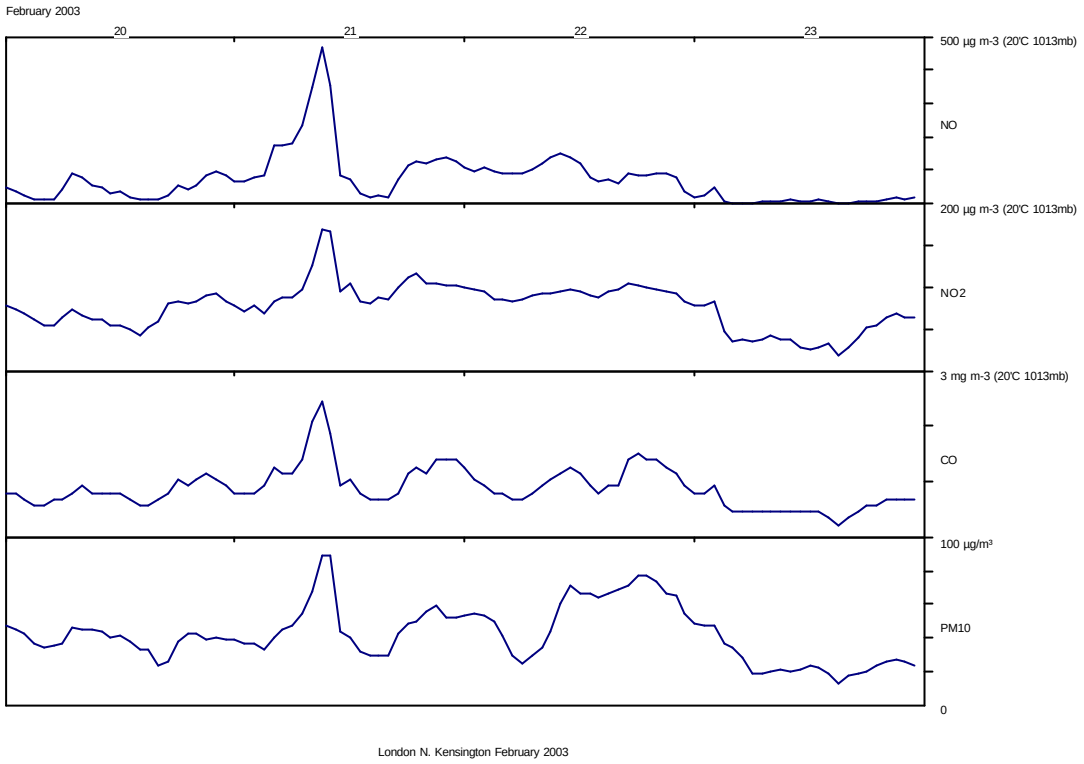

Figure 11. NO, NO_2, CO and PM_{10} concentrations at North Kensington during the period 20 to 23 February

PM_{10} Concentrations during the period 9 - 11 August 2003

The highest PM_{10}TEOM concentration (208 μgm^{-3}) measured at LHR2 during 2003 occurred on 10 August at 17:00 (Figure 12). Meteorological data show that the wind direction was variable and the speed was low (< $4ms^{-1}$) on that day. This was also the hottest day ever recorded in the UK (38.5°C), and the episode coincided with a major UK ozone episode.

Figures 13 and 14 show that elevated PM_{10} concentrations also occurred at other sites in London at approximately the same time. Peak PM_{10} concentrations in central London were similar to those seen at Heathrow and Harlington.

Hence, this was a regional scale episode probably due to an ozone pollution episode and poor dispersion of traffic emission in the light winds.

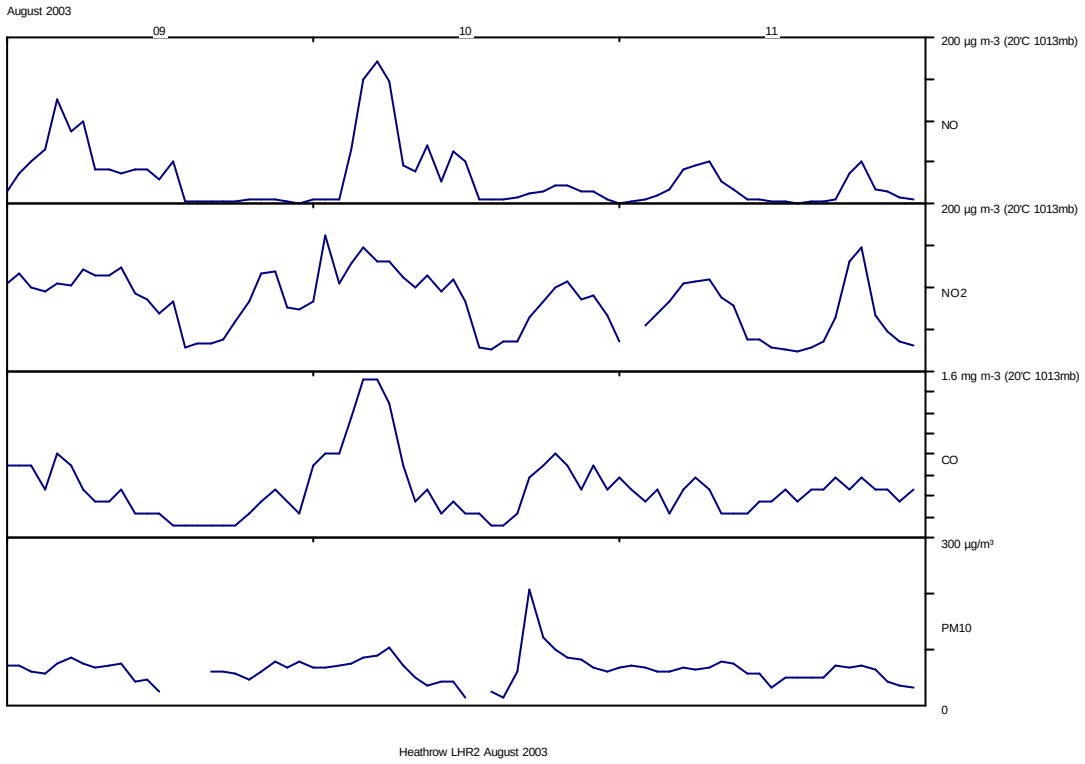

Figure 12. NO, NO_2, CO and PM_{10} concentrations at LHR2 during the period 9 - 11 August 2003

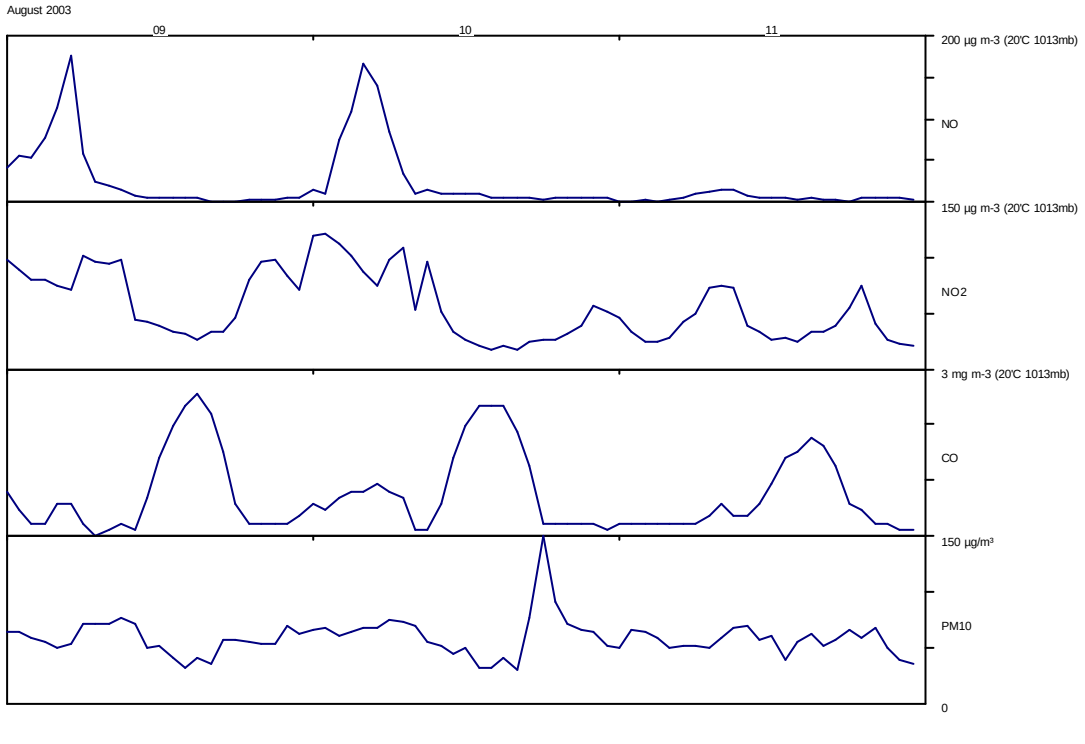

Figure 13. NO, NO_2, CO and PM_{10} concentrations at Harlington during the period 9 - 11 August 2003

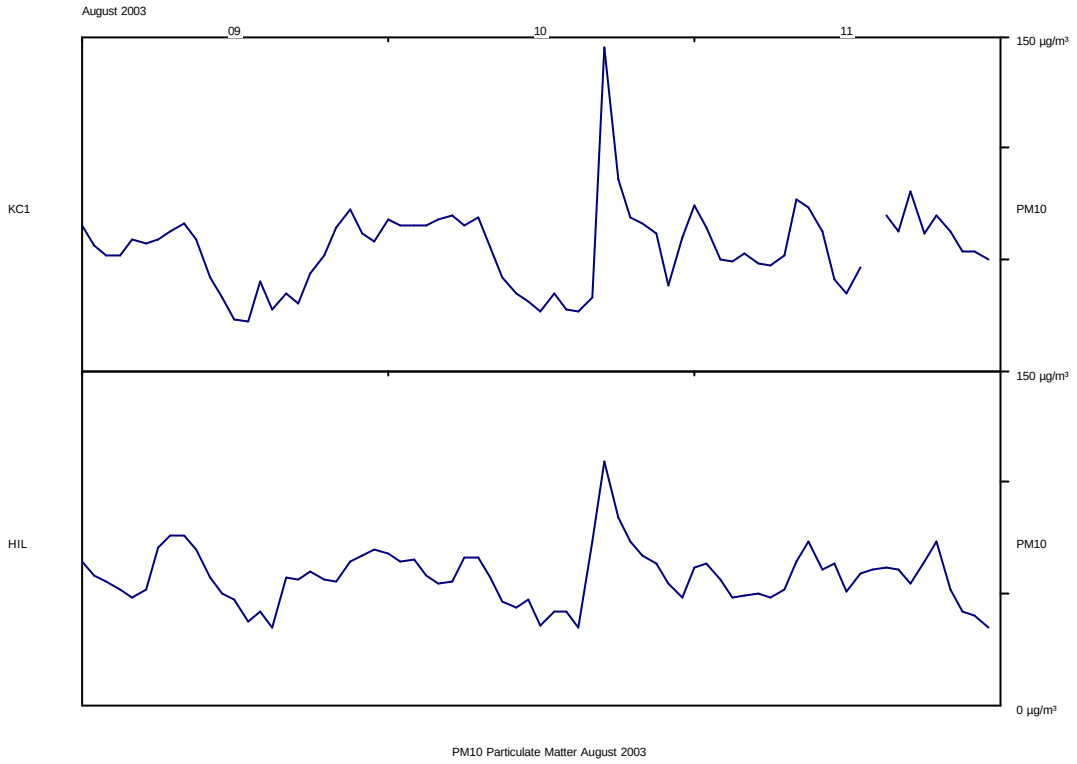

Figure 14. PM_{10} concentrations at North Kensington and Hillingdon during the period 9 - 11 August 2003

NO, NO_2, CO and PM_{10} concentrations during the period 26 to 29 October

Figure 15 shows pollutant concentrations at LHR2 during the period 26 to 29 October 2003. The highest NO (682 μgm^{-3}), NO_2 (191 μgm^{-3}) and PM_{10}TEOM (94 μgm^{-3}) concentrations during this period were recorded on the 28th October at 07.00. The highest CO (3.1 mg/m^3) concentration was recorded on the 27th October at 18.00. High concentration peaks were also seen at other monitoring sites in London (Figures 16 and 17 shows concentrations measured at Harlington and North Kensington) during the period. Hence this is a regional episode, rather than a local effect.

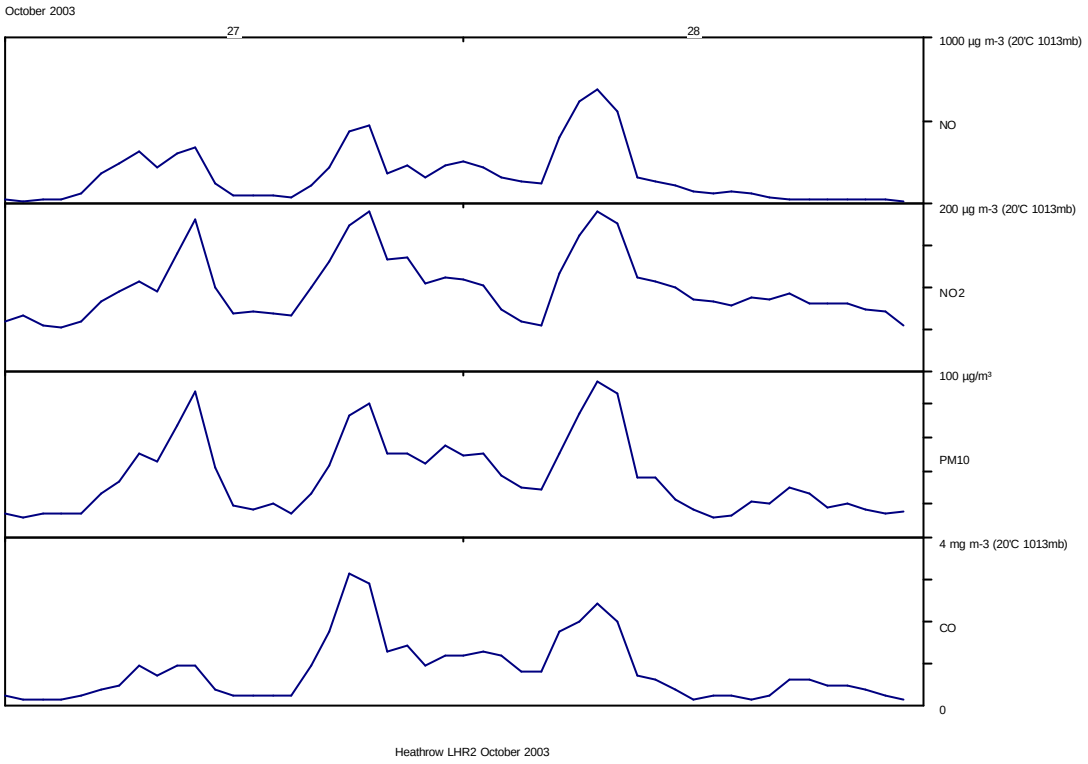

Figure 15. NO, NO_2, CO and PM_{10} concentrations at LHR2 during the period 26 -29 October 2003

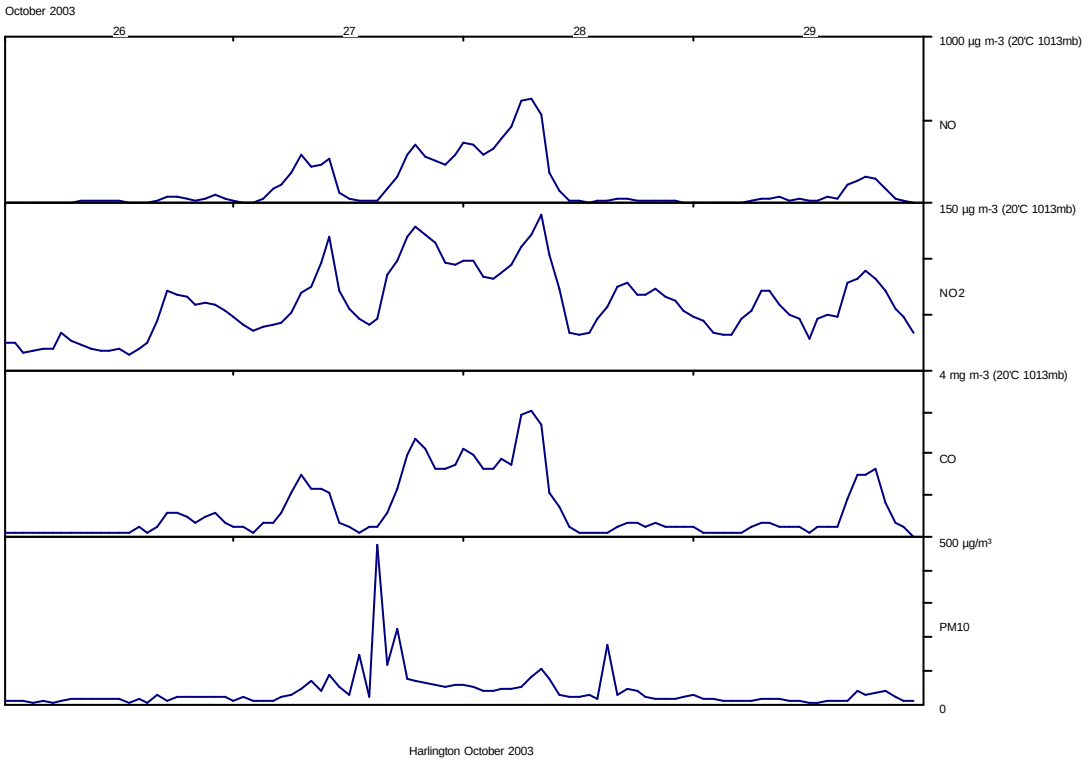

Figure 16. NO, NO_2, CO and PM_{10} concentrations at Harlington during the period 26 -29 October 2003

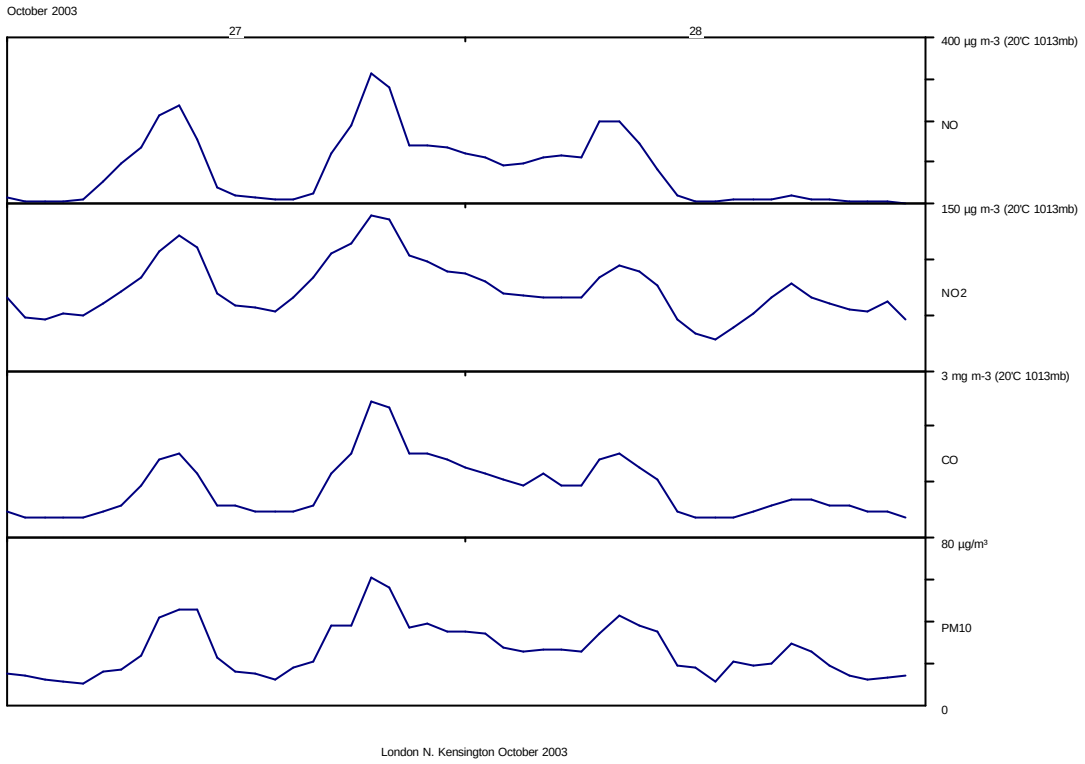

Figure 17. NO, NO_2, CO and PM_{10} concentrations at North Kensington during the period 26 - 29 October2003

4.3.2 Harlington

PM_{10} Concentrations at Harlington during September and October 2003

The highest PM_{10} TEOM concentration (1792 μgm^{-3}) measured at Harlington during 2003 occurred on 29 September at 13:00 (Figure 18). There were elevated PM_{10} concentrations recorded at Harlington throughout September and October 2003. These high concentrations were investigated and shown to be due to ploughing activity in nearby fields.

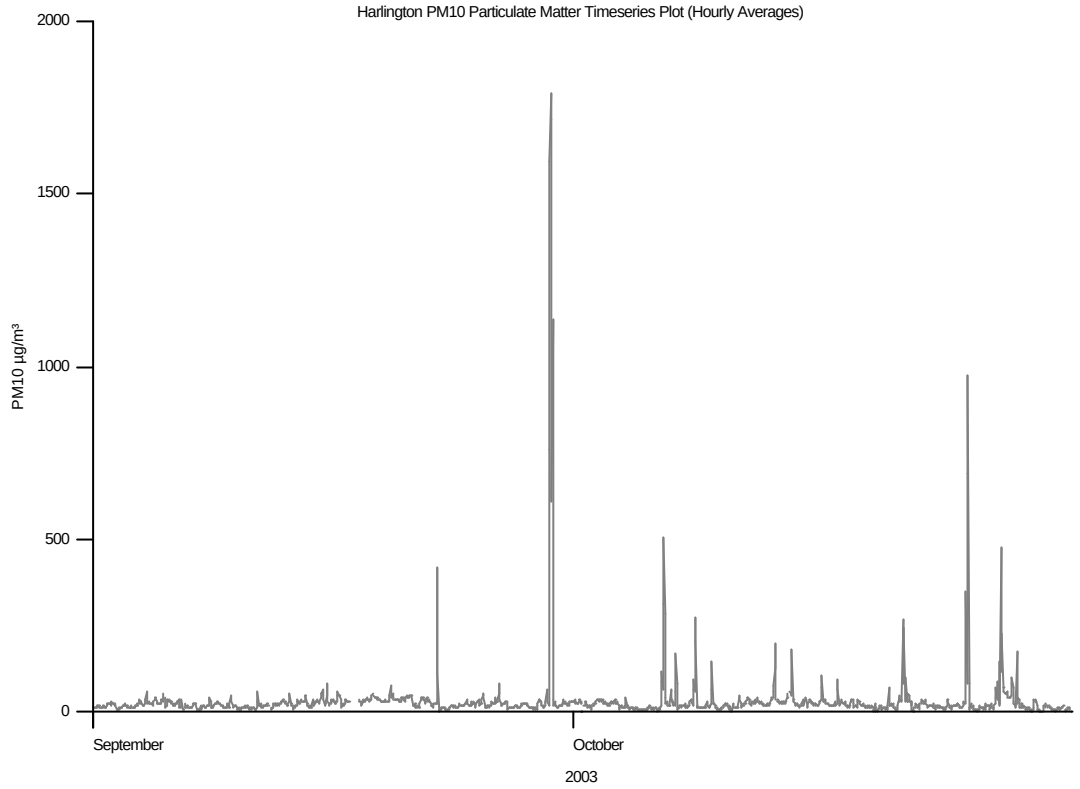

Figure 18. PM_{10} concentrations at Harlington during the September and October 2003

Ozone concentrations during the period 1 to 15 August

Figure 19 shows ozone concentrations at Harlington during the period 1 to 15 August 2003. The highest O_3 (204 μgm^{-3}) concentration during this period was recorded on the 6th August at 14.00. High concentration peaks were also seen at other monitoring sites in London (Figure 19 also shows concentrations measured at Hillingdon and North Kensington) during the period. Hence this is a regional episode due to the very high temperatures recorded during this period, rather than a local effect.

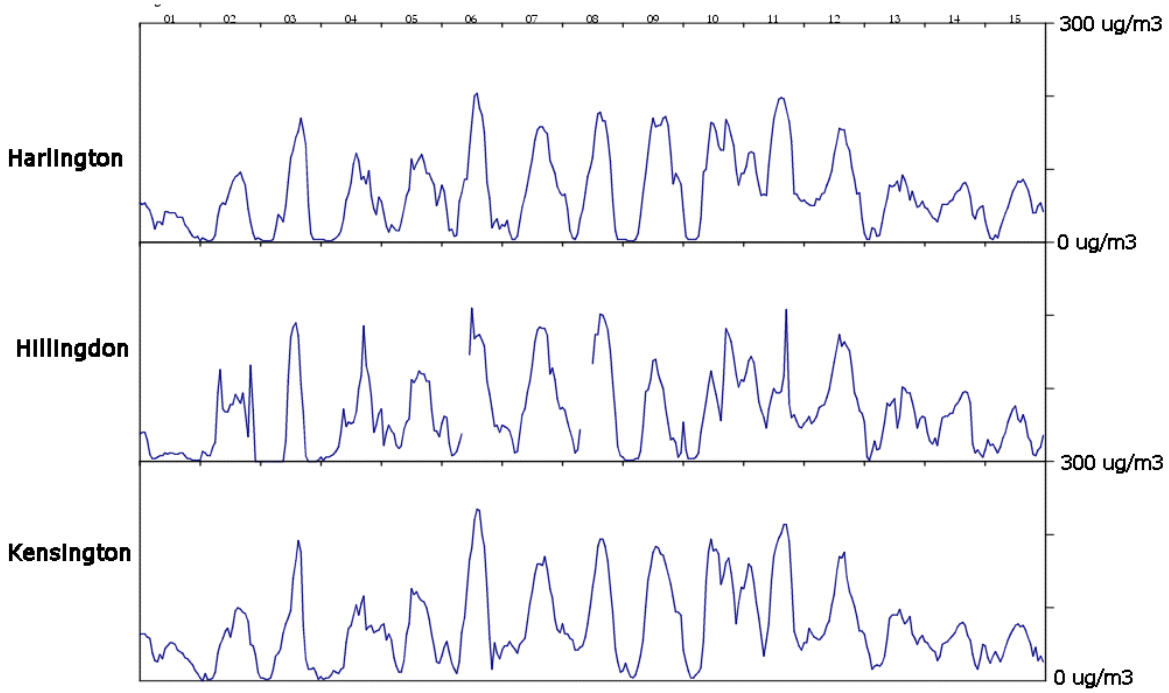

Figure 19. O_3, concentrations at Harlington, Hillingdon and North Kensington during the period 1 -15 August 2003

4.4 DISCUSSION OF DATA IN RELATION TO SOURCES

In this section, air pollutant concentrations measured at Heathrow are analysed in relation to wind speed and direction as well as in relation to statistics reflecting airport activity such as passenger numbers and aircraft movements. Meteorological measurements are not currently made at Harlington.

Appendix 1 shows wind speed, wind direction and pollution rose plots for LHR2. The wind velocity rose indicates average wind speed for wind directions recorded in each of 16 sectors of 22.5° each, and the wind direction rose indicates the percentage of time wind was recorded from each particular direction. The pollution rose plots relate air pollution measurements to wind direction. These plots show the average pollutant concentrations during periods when the wind was recorded in each of the 16 direction sectors. Due to the difficulty of defining a wind direction when wind speeds are very low, the pollution rose plots do not include data for which the recorded wind speed was less than 0.1 ms^{-1}.

The wind speed pattern shows the highest wind speeds generally occur when the wind is from a south-westerly direction, and the wind direction rose confirms the prevailing wind direction measured at Heathrow in 2003 to be south-westerly.

The pollution rose patterns for the primary pollutants, nitric oxide and CO, are similar at LHR2, reflecting a common source. The highest concentrations are generally associated with winds from a north-easterly direction. This implies that there is a significant contribution from motor vehicles on the perimeter road, or possibly from those on more distant, busier, roads. The northerly wind direction also coincides with lower wind speeds on average, therefore also encouraging the build-up of primary pollutant emissions. As previously found, the NO_2 rose is more even, reflecting the more complex chemistry of this pollutant – slightly higher concentrations are recorded when the wind direction is north - easterly.

The PM_{10} pollution rose identifies highest concentrations when the wind blows from an easterly or northerly direction, and lowest concentrations when the direction is from the south-west. The PM_{10} pollution rose showed similar characteristics during 2002. Though PM_{10} has a wide variety of primary and secondary pollutant sources, traffic is still a major component hence the general similarity with the pattern for NO_X and CO.

4.5 COMPARISON WITH PREVIOUS YEARS

Table 8 presents a summary of the data for the years 1993 - 2003 at LHR2. Table 8 also shows trends in passenger numbers and aircraft movements at Heathrow Airport.
The table shows that both peak and average concentrations of NO, NO_2, CO and PM_{10} were slightly higher in 2003 compared to 2002. This is in line with pollutant concentrations measured nationally which were higher in 2003 than in 2002 due to elevated temperature and low wind speeds fro much of the year.

The steady increase in passengers and air traffic movements up to 2000 does not show any apparent correlation with pollutant concentrations. There are likely to be many possible reasons for this, including:

- Changes in aircraft emissions (including combustion modifications and new engine types);
- Changes in vehicle and other emissions (affecting both airport and UK vehicle traffic fleet emissions generally, including increased use of catalytic converters); and,
- Meteorological factors.

However, it is beyond the scope of this report to investigate these further.

Two Defra air pollution monitoring sites in London have operated for the same period (1993-2003), West London and London Bloomsbury[ii]. West London NO_2 concentrations have decreased steadily since 1997 with downward trend of about 2 μgm^{-3} per year, whereas at London Bloomsbury there has been a less significant decrease up to 1999 but a more rapid decease since that date. Nationally, the UK NO_2 Diffusion Tube survey shows that, averaged over all urban areas in the UK, NO_2 concentrations have remained reasonably stable at roadside locations and decreased slightly at urban background areas during the period 1993-2003. Hence, results from the Heathrow site are consistent with the national picture, and are not closely related to passenger numbers and aircraft movements.

Figures 20 and 21 show how air pollution concentrations at Heathrow relate to airport activity. Figure 17 shows monthly statistics for number of passengers and air traffic movements (ATM's) averaged over the period 1998 – 2003. Table 8 shows that, in general, both of these parameters show an increase.

[ii] NO_2 data capture at the London Bloomsbury site was 67.8% for 1993.

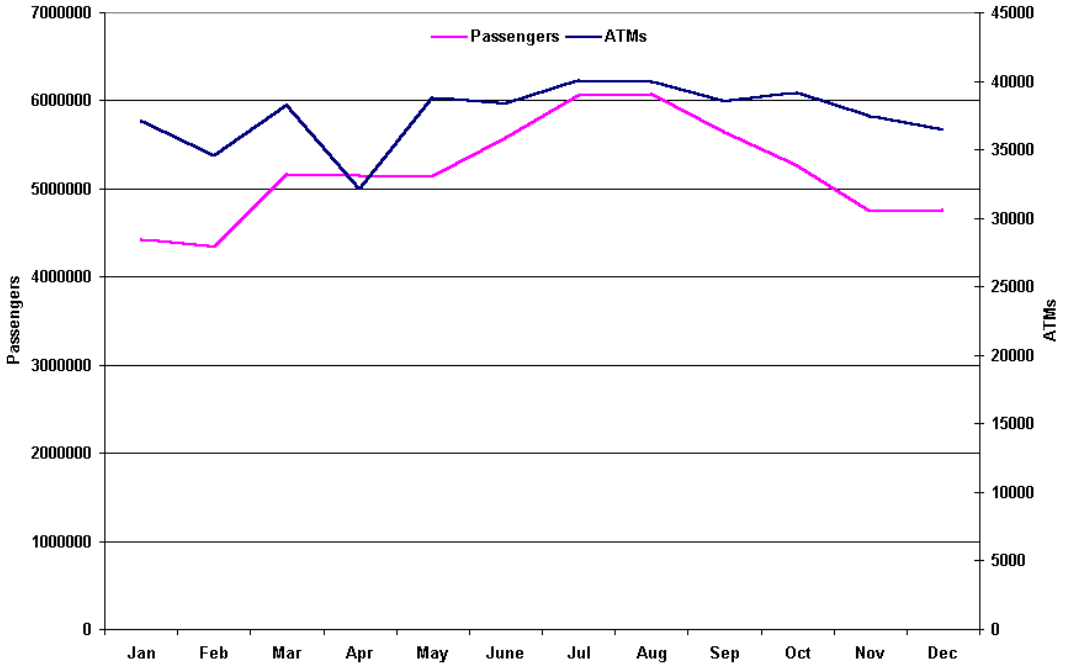

Figure 20. Monthly data for Passengers and Air Traffic Movements, 1998 - 2003

Figure 21 below shows corresponding monthly statistics of air pollutant measurements. As discussed in Section 4.2, these also show a seasonal distribution, particularly for the primary pollutants such as NO and CO, but in this case, the peak is in the winter months rather than the summer, unlike passenger numbers and ATMs.

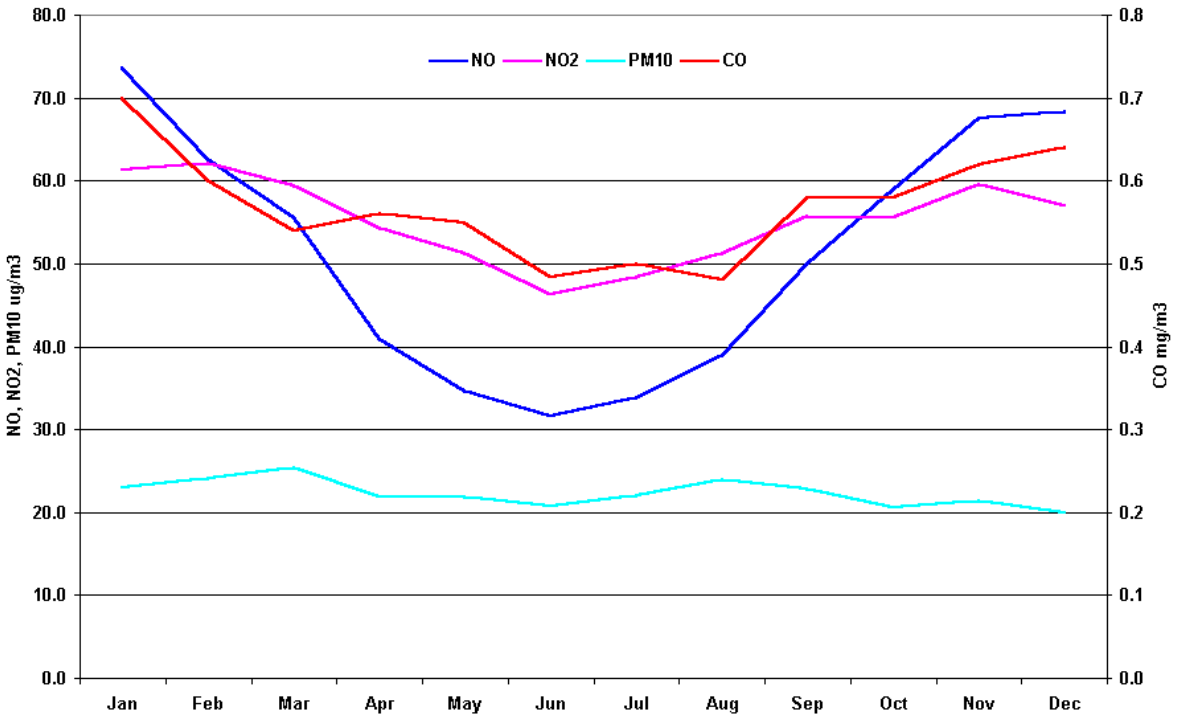

Figure 21. Monthly average air pollution data LHR2, 1998 - 2003

Hence, it is clear from this simplistic analysis that the profile of air pollutant concentrations measured at Heathrow throughout the year is influenced much more by general meteorological factors than by airport activity.

Figure 22 shows a plot of the daily mean NO_2 and PM_{10} concentrations over the complete period of monitoring at LHR2, 1992 – 2003. The figure shows graphically the general reduction in both peak and average concentrations for NO_2. The plot for PM_{10} shows a similar trend, though less distinct.

Table 8. Comparison of 2003 Data at Heathrow Airport (LHR2) with Previous Years

Pollutant	Parameter	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
NO	Mean	80	83	68	70	78	61	53	51	55	43	48
	Max	1109	1593	963	1324	1313	873	726	760	618	582	682
NO_2	Mean	57	61	61	63	59	53	55	57	53	52	59
	Max	216	288	357	428	267	180	388	174	153	138	191
CO	Mean	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.7	0.5	0.4	0.5
	Max	7	14.6	8.1	13.5	11.1	4.2	5.1	7.4	5	3.7	3.3
PM_{10}	Mean			27	27	28	23	23	21	23	21	24
	Max			493	152	243	102	113	140	217	148	208
Number of Passengers		47.6	51.4	54.1	55.7	57.8	60.3	62.0	64.3	60.4	63.0	63.2
Number of ATMs*		0.39	0.41	0.42	0.43	0.43	0.44	0.45	0.46	0.46	0.46	0.46

- ATM = Air Traffic Movement

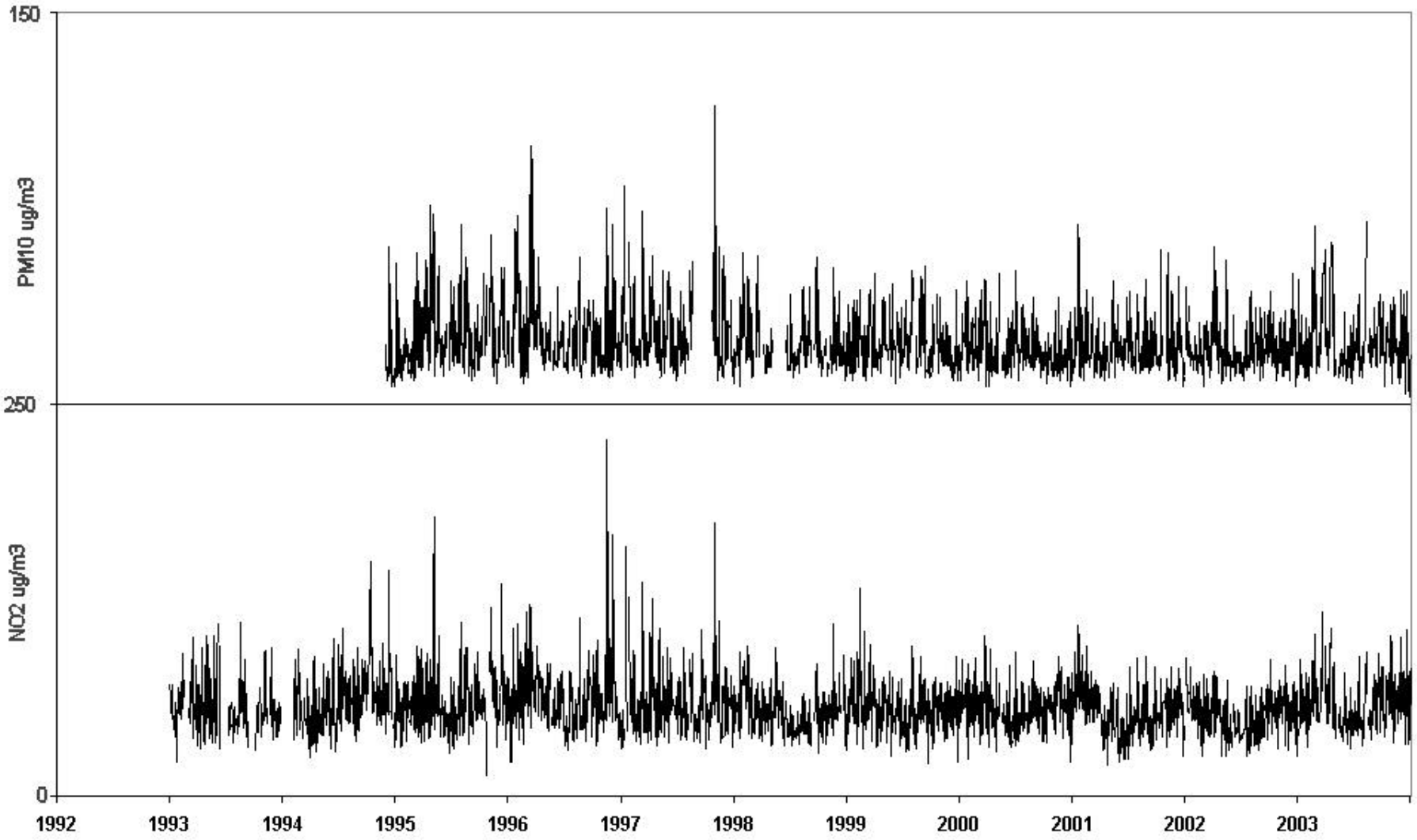

Figure 22. Daily mean NO_2 and PM_{10} TEOM Concentrations, Heathrow LHR2, 1992 - 2003

4.6 COMPARISON WITH AIR QUALITY STANDARDS AND GUIDELINES

In January 2000, the UK Government published the current Air Quality Strategy containing air quality objectives for five of the pollutants measured at Heathrow Airport (benzene, 1,3-butadiene, carbon monoxide, nitrogen dioxide and PM_{10} particulate matter). Revised air quality objectives were issued in the Air Quality (Amendment) Regulations 2002.

The objectives are based on the first and second EC Daughter Directive and/or the recommendations made by the UK independent Expert Panel on Air Quality Standards (EPAQS). The objectives provide policy targets by outlining what the Government considers current measures should deliver. In addition, Defra has defined Air Pollution Bands for NO_2, CO and PM_{10}. NO is not thought to be harmful to health at concentrations experienced in the ambient environment and there are no air quality standards or guidelines for this pollutant.

Defra air pollution bands for NO_2, CO and PM_{10} assign data to the categories LOW, MODERATE, HIGH, or VERY HIGH, depending on the magnitude of concentrations over a specified averaging period. These descriptors are used for pollutant concentrations measured at National Monitoring Network sites throughout the UK, when presented on the World Wide Web, TELETEXT or the Air Quality Information Line service.

The specific objectives which are compared with the pollutant concentrations monitored at LHR2[iii] are as follows:

NO_2	200 μg m^{-3} hourly mean not to be exceeded more than 18 times per year to be achieved by December 31st 2005 40 μg m^{-3} annual mean to be achieved by December 31st 2005.
CO	10 mg m^{-3} maximum running 8-hour mean to be achieved by December 31st 2003.
PM_{10}	50 μgm^{-3} gravimetric 24-hour mean not to be exceeded more than 35 times per year by December 31st 2004 40 μg m^{-3} gravimetric annual mean to be achieved by December 31st 2004
Benzene	16.25 μg m^{-3} running annual mean to be achieved by December 31st 2003. 5 μg m^{-3}annual average to be achieved by 31 December 2010
1,3-butadiene	2.25 μg m^{-3} running annual mean to be achieved by December 31st 2003.

Full details of the air quality standards and objectives used for analysis of Heathrow Airport monitoring data are summarised in Appendix 2.

Note that, in addition there are also new PM_{10} strategy objectives for 2010 for England, Scotland, Wales and Northern Ireland. However, as yet these have not been included in the UK Regulations and therefore comparison of PM_{10} monitoring data from Heathrow with the new objectives is not made in this report. Details of these new objectives are also provided in Appendix 2.

[iii] The Harlington data were not compared with the strategy objectives since insufficient data were collected in the monitoring period.

Table 9 shows how air pollution data at the Heathrow airport monitoring site LHR2 compare with these various air quality standards and guidelines.

Table 9. Comparison with Air Quality Standards and Guidelines – Heathrow LHR2

1st January - 31st December 2003

(i) Nitrogen Dioxide

Banding	**Number of Hours**
VERY HIGH	0
HIGH	0
MODERATE	0
LOW	8359
Air Quality Strategy	**Exceedences**
Annual mean > 40 µg m^{-3}	1
Hourly mean > 200 µg m^{-3}	0

(i) Carbon monoxide

Banding	**Number of Hours**
VERY HIGH	0
HIGH	0
MODERATE	0
LOW	8156
Air Quality Strategy	**Exceedences**
Running 8-hour mean > 10 mg m^{-3}	0

(iii) PM_{10}

Banding	**Number of Hours**
VERY HIGH	0
HIGH	0
MODERATE	369
LOW	8048
Air Quality Strategy	**Exceedences**
Daily mean > 50 µg m^{-3}	39
Annual mean > 40 µg m^{-3}	0

Nitrogen Dioxide
There were no hours above the air quality objective of 200 μg m^{-3} (up to 18 hours per year are allowed). However, the annual average NO_2 concentration (59 μg $m^{-3)}$ was above the annual average objective of 40 μg m^{-3}, which is to be achieved by the end of 2005. (This objective is widely exceeded in urban areas of the UK). No hours of VERY HIGH, HIGH or MODERATE air pollution were recorded during 2003 according to the defra air pollution bands.

Carbon Monoxide
The CO UK Air Quality Objective for the end of 2003 was achieved. No hours of VERY HIGH, HIGH or MODERATE air pollution were recorded during 2003 according to the defra air pollution bands.

PM_{10}
There were 39 days exceeding the PM_{10} Air Quality Strategy objective for 2004 (50 μg m^{-3} as a daily mean based on gravimetric equivalent PM_{10} data). Up to 35 days per year are allowed therefore the objective was not achieved. PM_{10} concentrations were generally higher in 2003 than 2002 due to the hot dry summer. The annual mean objective of 40 μgm^{-3} based on gravimetric equivalent data was not exceeded. The gravimetric equivalent PM_{10} concentration was calculated by multiplying the value measured with the TEOM by a factor of 1.3. There were no hours of HIGH or VERY HIGH air pollution levels recorded according to the defra air pollution bands.

Benzene
The average benzene concentration recorded using BTX diffusion tubes for 2003 was 1.4 μgm^{-3}. This is well below the Air Quality Strategy Objective (16.25μgm^{-3}) for 2003 for benzene, and the new air quality objective (5μgm^{-3}) for 2010. In line with monitoring of benzene throughout the UK, benzene concentrations are seen to have decreased to about 50% of their previous level due to the reduction in the benzene content of petrol at the end of 1999.

For 1,3-butadiene, the measurements at LHR2 have only been undertaken with two short duration grab samples. Hence, these measurements cannot be considered as providing a reliable annual average concentration. However, these measurements show a ratio of 1,3-butadiene to benzene of approximately 0.4. Based on an annual average benzene concentration of 1.4 μgm^{-3}, from the diffusion tube monitoring, this would indicate an annual average 1,3-butadiene concentration of about 0.6 μgm^{-3}, which is well within the UK Air Quality Strategy Objective for 1,3-butadiene of 2.25μgm^{-3}.

Considering these results together with the data for previous years (1993-2002), it can be seen that none of the air quality standards, objectives or guidelines for CO has been exceeded since monitoring commenced at Heathrow Airport.

No NO_2 concentrations have been recorded in the defra HIGH air pollution band over the 11-year monitoring period and only 17 in the MODERATE band. The defra annual mean objective for NO_2 has been exceeded in each of the ten years.

Since PM_{10} monitoring started in 1994, PM_{10} concentrations have been recorded in the defra VERY HIGH air pollution band on 42 occasions and 238 in the HIGH band. However, there were no PM_{10} particle concentrations recorded as HIGH or VERY HIGH during 2003.

4.7 COMPARISON WITH OTHER SITES

Tables 10 and 11 show how data measured at the Heathrow site LHR2 in 2003, compared with corresponding measurements made at other National Air Quality Monitoring Network stations operated by netcen, for Defra, during the same period. The locations and site descriptions of the national sites used are given below:

London Hillingdon	TQ193653	Suburban residential area approximately 30 metres from the M4 motorway.
London North* Kensington	TQ240817	The site is located within the grounds of a school. The surrounding area is mainly residential.
West London	TQ251788	Located in a municipal depot in a partially residential area in Earl's Court, bounded on all sides by major roads. 90m from Warwick Road.
Lullington Heath	TQ538016	Rural site on a high plateau 5km from the South Coast. Immediate area is English Nature heathland. CO is not measured at this rural site.

*The London North Kensington site has been used in this report instead of London Bloomsbury site since less than 75 % data were available for Bloomsbury in 2003.

Comparison of Harlington data with measurements made at other sites is not valid since insufficient data are available for the year.

Table 10 summarises the comparison of period averages at the different sites and Table 11 shows the ratios of the annual average concentrations recorded at Heathrow in 2003 to corresponding measurements at the national monitoring sites.

The ratios of annual average concentrations for NO, NO_2, CO and PM_{10} during 2003 at LHR2, to those measured at other monitoring sites in south-east England, follow a similar pattern to previous years. NO concentrations at LHR2 were higher than at the West London and similar to the monitoring site at London Hillingdon. NO_2 concentrations at LHR2 were higher than those in central London. CO concentrations at LHR2 were slightly higher than West London and similar to the London Hillingdon and North Kensington sites. Average PM_{10} concentrations at LHR2 were similar to London North Kensington and London Hillingdon.

At LHR2, the relatively high NO concentration compared to CO, may indicate a contribution from aircraft emissions for which, particularly at take-off, NO_X emissions are generally high and CO emissions generally low. An increase of temperature and pressure within the engine permits more atmospheric nitrogen and nitrogen within the fuel to be oxidised forming oxides of nitrogen. As the power increases, the air to fuel ratio becomes richer in nitrogen and the air is exposed for a shorter time at higher temperatures. In addition, at lower power settings substantial quantities of hydrocarbons and carbon monoxide are produced due to incomplete oxidation of the fuel.

The calculated ratios for comparisons with the rural monitoring site at Lullington Heath on the South Coast need to be treated with caution, because of the low numbers involved, particularly for NO. However, data for 2003 and previous years show that NO_2

concentrations at the urban background sites in London and at LHR2 to be 3 - 4 times higher than the rural background concentration for South East England.

Table 10. Comparison of measurements at Heathrow LHR2 with other National Monitoring Sites 1st January to 31st December 2003

	Pollutant	NO $\mu g\ m^{-3}$	NO_2 $\mu g\ m^{-3}$	CO $mg\ m^{-3}$	PM_{10} TEOM $\mu g\ m^{-3}$
Heathrow LHR2	Mean	48	59	0.5	24
	Max	682	191	3.3	208
London Hillingdon	Mean	49	54	0.5	23
	Max	800	199	9.3	116
London North Kensington	Mean	19	44	0.5	145
	Max	470	195	3.4	22
West London	Mean	24	55	0.4	
	Max	433	186	2.6	
Lullington Heath	Mean	1.8	12.5		
	Max	63.2	89.3		

Table 11. Ratios of Annual Average Concentrations

Heathrow Ratios	NO	NO_2	CO	PM_{10}
London Hillingdon	1.0	1.1	1.0	1.0
London North Kensington	2.5	1.3	1.0	1.0
West London	2.0	1.1	1.3	-
Lullington Heath	37	4.7	-	-

Benzene and 1,3-butadiene concentrations measured in this study can be compared with measurements made in London as part of the UK Hydrocarbon monitoring network (though these measurements are made with continuous automatic analysers rather than with diffusion samplers, as at Heathrow). The only automatic hydrocarbon monitoring station in operation in London during 2003 was Marylebone Road. Since this is a roadside station, hydrocarbon levels can be expected to be significantly higher than those measured at background sites in Heathrow. Table 12 shows that concentrations in Marylebone Road London for benzene were 3.3 μgm^{-3} and for 1,3-butadiene 0.6 μgm^{-3}. Hence, the annual average benzene concentration at Heathrow (1.4μgm^{-3}) and the estimated concentration of 1,3-butadiene (0.6 μgm^{-3}) are lower than at roadside sites in London.

It is not appropriate to make a direct comparison of the short duration hydrocarbon grab samples at Heathrow, with annual average concentration at other national monitoring sites, as these are the product of averaging many continuous measurements. However, a generalised comparison is illustrative. Annual average concentrations at a roadside site in London Marylebone Road are given in Table 12.

Examination of Tables 7 and 12 shows that the concentrations measured in the grab samples at Heathrow are lower than to those measured at the roadside in London.

Table 12. Annual Average Hydrocarbon Concentrations for 2003 at London Marylebone Road

	Concentration μgm^{-3}
ethane	9.3
ethene	5.5
propane	6.0
propene	2.9
iso-butane	6.8
n-butane	11.7
ethyne	4.2
trans-2-butene	0.9
1- butene	0.8
cis-2-butene	0.6
iso-pentane	14.2
n-pentane	3.7
1,3-butadiene	0.6
trans-2-pentene	0.9
cis-2-pentene	0.5
2-methylpentane	4.7
3-methylpentane	2.9
n-hexane	1.5
isoprene	0.4
n-heptane	0.9
benzene	3.3
toluene	13.6
ethyl benzene	2.6
meta & para xylene	9.3
ortho xylene	3.2
1,3,5-trimethyl benzene	1.2
1,2,4-trimethyl benzene	3.5

5 Conclusions

This report describes data for the eleventh year, 2003, of the air pollution monitoring programme at Heathrow Airport. During 2003, monitoring of oxides of nitrogen, carbon monoxide, PM_{10} and a range of hydrocarbon species has been undertaken at a site on the Old Apron (LHR2). A new monitoring station was established at Harlington in April 2003.

The following conclusions have been drawn from the data available:

5.1 LHR2

Annual average concentrations for 2003, for the Heathrow LHR2 site were as follows;

NO	48 μg m^{-3}
NO_2	59 μg m^{-3}
NO_X ($NO + NO_2$)	133 μg m^{-3}
CO	0.5 mg m^{-3}
PM_{10}	24 μg m^{-3} (TEOM data)
	31 μg m^{-3} (gravimetric equivalent data)
Benzene	1.4 μg m^{-3}
1,3-butadiene	0.6 μg m^{-3} (estimated from grab samples)

- Data capture for NO_X and PM_{10} was >95%;
- The data were compared with measurements in other areas of London and the UK. NO, NO_X, CO and PM_{10} concentrations were generally similar to, or slightly higher, than those measure in Central London. Benzene and 1,3-butadiene concentrations were lower than at roadside sites in Central London;
- The current UK Air Quality Strategy objectives were not met for the annual mean NO_2 concentration and the PM_{10} daily mean. However, it should be noted that the 40 μg m^{-3} annual mean NO_2 concentration is widely exceeded in urban areas of the UK and that PM_{10} levels in London were generally higher than in 2002;
- The pattern of monthly averaged concentrations throughout the year shows that highest concentrations for primary pollutants (NO and CO) were recorded during the winter months. Concentrations of NO_2 and PM_{10}, which have both primary and secondary components, were generally less variable than NO and CO throughout the course of the year;
- The diurnal pattern of concentrations is similar to that observed at other urban monitoring sites with the peak concentrations coinciding with the morning rush hour period;
- Although, on a monthly average basis, pollutant concentrations were generally highest in the winter months, statistics related to airport activity (passenger numbers and air traffic movements) were highest in July and August;
- Annual averaged passenger numbers and air traffic movements have shown a steady year on year increase up to 2000 when there was a decrease. Passenger numbers have increased from that point and passenger numbers in 2003 were just below the 2000

level. Air pollutant concentrations do not show any significant correlation with statistics related to airport activity; and,

5.2 HARLINGTON

Average concentrations for 2003, for the Harlington site were as follows;

NO	27 μg m^{-3}
NO_2	41 μg m^{-3}
NO_X (NO + NO_2)	82 μg m^{-3}
CO	0.3 mg m^{-3}
PM_{10}	24 μg m^{-3} (TEOM data)
	31 μg m^{-3} (gravimetric equivalent data)
Ozone	32 μg m^{-3}

Since the data capture for the year was less than 75%, it is not possible to draw any conclusions for annual averages or compliance with the Air Quality Strategy

6 Acknowledgements

The assistance of members of the Planning and Environment Department, in particular Carrie Harris and Jo Smith, is gratefully acknowledged.

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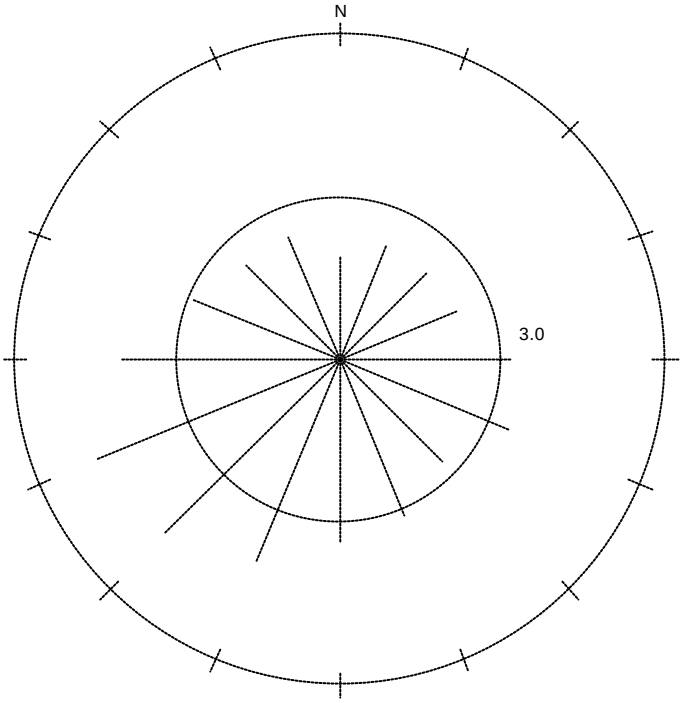
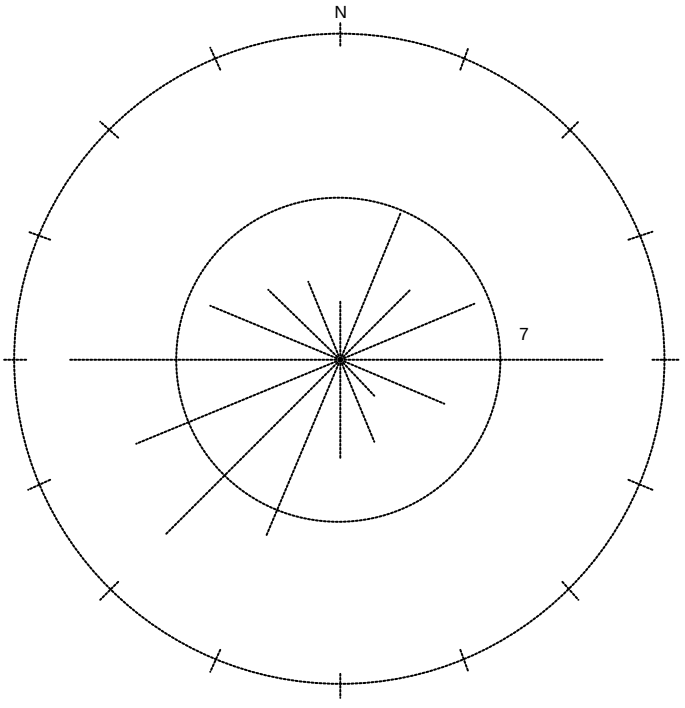
Appendix 1
Pollution Roses

Figure 6. Wind and Pollution "Roses" for Heathrow LHR2, 2003



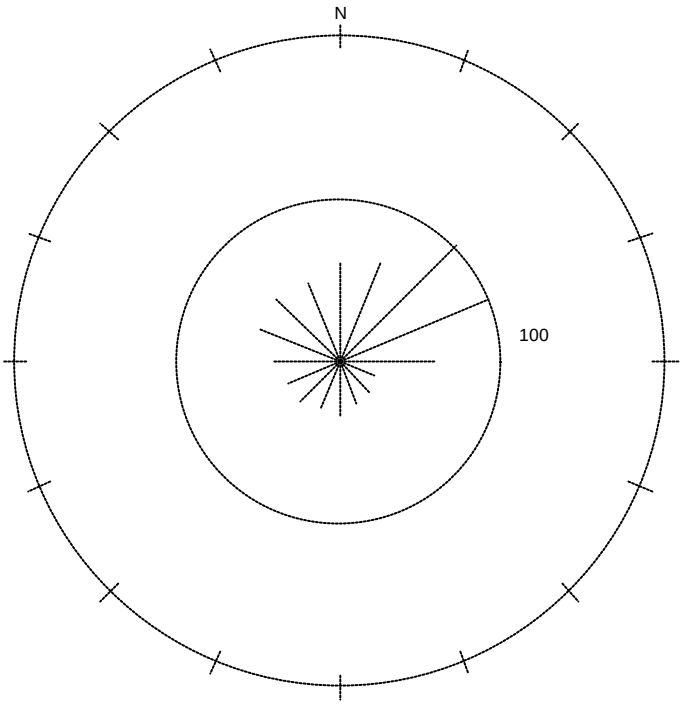
Heathrow LHR2 Wind Speed Rose : 01/01/2003 to 31/12/2003

Windspeed Threshold set at 0.1 m/s



Heathrow LHR2 Wind Direction Rose : 01/01/2003 to 31/12/2003

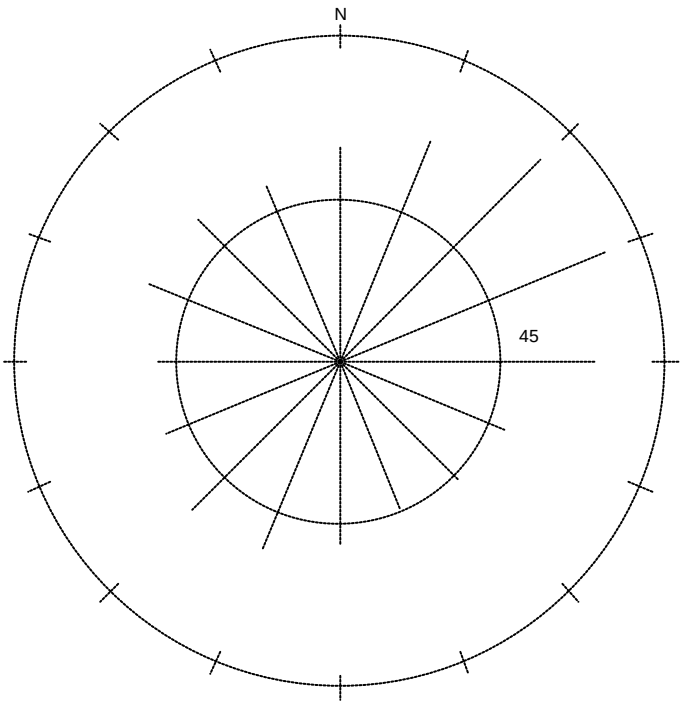
Windspeed Threshold set at 0.1 m/s



200 µg m-3 (20'C 1013mb)

Heathrow LHR2 Nitric Oxide Rose : 01/01/2003 to 31/12/2003

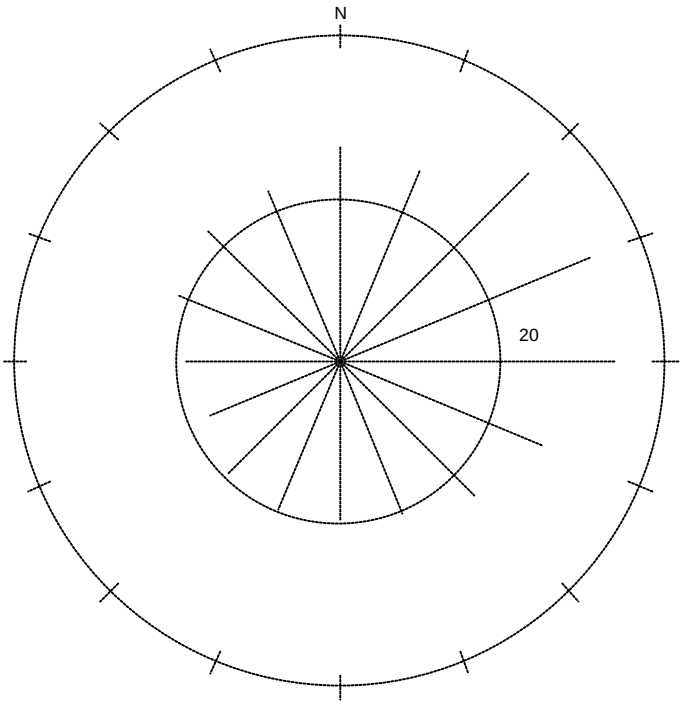
Windspeed Threshold set at 0.1 m/s



90 µg m-3 (20'C 1013mb)

Heathrow LHR2 Nitrogen Dioxide Rose : 01/01/2003 to 31/12/2003

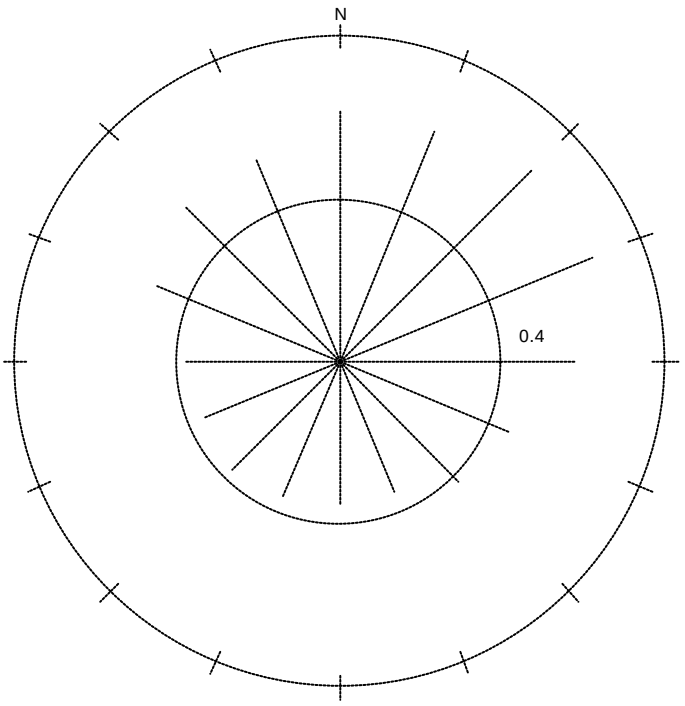
Windspeed Threshold set at 0.1 m/s



40 µg m-3 (20'C 1013mb)

Heathrow LHR2 PM10 Particulate Matter Rose : 01/01/2003 to 31/12/2003

Windspeed Threshold set at 0.1 m/s



0.8 mg m-3 (20'C 1013mb)

Heathrow LHR2 Carbon Monoxide Rose : 01/01/2003 to 31/12/2003

Windspeed Threshold set at 0.1 m/s

Appendix 2
Air Quality Standards and Guidelines

AIR QUALITY STANDARDS AND GUIDELINES

Defra air quality bands

Band	Ozone µg/m³	Nitrogen Dioxide µg/m³	Sulphur dioxide µg/m³	Carbon monoxide mg/m³	PM_{10} (TEOM) µg/m³
	8 hourly or hourly mean*	hourly mean	15-minute mean	Running 8-hour mean	Running 24-hour mean
LOW	<100	<287	<266	<11.6	<50
MODERATE	100-179	287-572	266-531	11.6-17.4	50-74
HIGH	180-359	573-763	532-1063	17.5-23.1	75-99
VERY HIGH	360 or more	764 or more	1064 or more	23.2 or more	100 or more

* For ozone, the maximum of the 8 hourly and hourly mean is used to calculate the banding value

Air Quality Strategy 2000 objectives and objectives in the 2003 Addendum prescribed in regulations for the purposes of local air quality management

Pollutant	Objective	Concentration measured as	Date to be achieved by
Benzene	16.25 µg/m³ (5 ppb)	Running annual mean	31 December 2003
Benzene (apart from Scotland and Northern Ireland)	5 µg/m³ (1.54 ppb)	Annual average	31 December 2010
1,3-Butadiene	2.25 µg/m³ (1 ppb)	Running annual mean	31 December 2003
Carbon monoxide (apart from Scotland)	10 mg/m³ (8.6 ppm)	Maximum daily running 8-hour mean	31 December 2003
Lead	0.5 µg/m³	Annual mean	31 December 2004
	0.25 µg/m³	Annual mean	31 December 2008
Nitrogen dioxide	200 µg/m³ (105 ppb) not to be exceeded more than 18 times per year	1 Hour mean	31 December 2005
	40 µg/m³	Annual mean	31 December 2005
Particles (PM_{10})	50 µg/m³ not to be exceeded more than 35 times per year	24 Hour mean	31 December 2004
	40 µg/m³	Annual mean	31 December 2004
Sulphur dioxide	266 µg/m³ (100 ppb) not to be exceeded more than 35 times per year	15 Minute mean	31 December 2005
	350 µg/m³ (132 ppb) not to be exceeded more than 24 times per year	1 Hour mean	31 December 2004
	125 µg/m³ (47 ppb) not to be exceeded more than 3 times per year	24 Hour mean	31 December 2004

Pollutant	Objective	Concentration measured as	Date to be achieved by
Scotland			
Particles (PM_{10})	50 µg/m^3 not to be exceeded more than 7 times per year	24 Hour mean	31 December 2010
	18 µg/m^3	Annual mean	31 December 2010
Carbon monoxide	10 mg/m^3 (8.6 ppm)	Running 8-hour mean	31 December 2003
Scotland and Northern Ireland			
Benzene	3.25 µg/m^3	Running annual mean	31 December 2010
Additional PM_{10} Objectives in the Air Quality Strategy Addendum			
PM_{10} England and Wales (apart from London)	50 µgm^{-3} gravimetric not to be exceeded more than 7 times per year	24-hour mean	December 31st 2010
	20 µg m^{-3} gravimetric	annual mean	December 31st 2010
PM_{10} London	50 µgm^{-3} gravimetric not to be exceeded more than 10 times per year	24-hour mean	December 31st 2010
	23 µg m^{-3} gravimetric	annual mean	December 31st 2010

Notes:
µg/m^3 - micrograms per cubic metre
mg/m^3 - milligrams per cubic metre
ppb – parts per billion.

Appendix 3 Monitoring Equipment And Site Locations

Monitoring Equipment and Site Locations

Monitoring Equipment

Continuous automatic analysers for monitoring NO, NO_2, CO, PM_{10} and ozone were selected, in order to 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, NO_2	chemiluminescence with ozone
CO	infra red absorption, gas filter correlation
PM_{10}	tapered element oscillating microbalance
O_3	ultra-violet absorption

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 netcen. The data are then converted to concentration units and averaged to hourly mean concentrations.

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

The TEOM monitoring method uses a 50^{o}C heated sample inlet in order to prevent moisture from contaminating the filter. Many studies have shown that this elevated temperature results in the loss of volatile and semi-volatile components of PM_{10}. Secondary particles such as ammonium nitrate for example, are known to evaporate below 50^{o}C. Current Government advice is that in order to convert the TEOM results to a gravimetric equivalent measurement a factor of 1.3 needs to be applied.

The PM_{10} analyser cannot be calibrated in the same way as the gas analysers and these data are scaled using the results of the 6-monthly checks described in Section 3.1. In these checks, the flow rate through the analyser is measured and the mass determination checked with pre-weighed filters.

Up to September 2002, wind speed and direction were monitored at LHR2 by a sensitive, lightweight anemometer and windvane system mounted on a 4m mast. For improved reliability of operation, this system was replaced with a sonic anemometer system in September 2002. Air temperature is recorded with a thermocouple thermometer, mounted in a radiation screen on the mast.

All of the air monitoring equipment is housed in a mobile air conditioned trailer unit, with the meteorological equipment mounted externally (As photographed on the front cover of this report).

Benzene, toluene and xylene are measured using diffusion tube samplers, which are exposed for monthly periods at the LHR2 site.

The sampler used for hydrocarbon monitoring in this survey was the Perkin Elmer tube packed with Chromosorb 106 absorbent. The top of the tube is sealed with a Swagelok cap and the diffusive end fitted with a diffusion cap during sampling.

Following thermal desorption and analysis on a gas chromatograph, the concentrations of benzene, toluene and xylene for each sample were determined using the formula:

$$C\,(\text{ppm}) = \frac{(F - B) * 1000}{U * t}$$

where:

U	is the diffusive uptake rate in ng ppm^{-1} min^{-1}
t	is the exposure time in minutes
F	is the mass of species present in the actual sample tube in μg
B	is the system analytical blank

The system blank is the amount of species present after the absorbent has been purged by three analysis cycles. The uptake rates (in ng ppm^{-1} min^{-1}) used in this study were: Benzene: 1.6, Toluene: 1.9, m+p Xylene: 2.1.

In addition, a range of hydrocarbon species are monitored with quarterly grab samples. Every 3-months, 3 grab samples of air from the LHR2 site are collected in 1.6 litre deactivated stainless steel bottles. Prior to collection, ambient air is flushed through the bottles for at least 5 minute then each bottle is filled, over a period of about 30 seconds, to a pressure of 3 Bar using a metal bellows pump. The air samples are returned to AEA Technology for gas chromatograph analysis. Concentrations of a range of 25 hydrocarbon species are determined by reference to traceable analytical standards.

Site Locations

The Heathrow Airport LHR2 monitoring site is located on an area of the old apron between the northern runway and the northern perimeter road. The grid reference of the site is TQ 084767 and has been called LHR2. Monitoring at this location commenced in December 1992.

Initially, the site was approximately 170 m from the runway edge and 30 m from the road edge. On 21 December 1994, the site was moved approximately 5m closer to the runway so that the perimeter fence could be moved to allow widening and repositioning of the perimeter road. Following completion of the work on the perimeter road, the site is now 17m from the kerb.

The monitoring site at Lapwing Sports ground, used during the Terminal 5 air quality study, was considered as a monitoring location for the present study, but rejected because the area around this site is now used for car parking and hydrocarbon measurements would be significantly influenced by localised evaporative emissions from parked vehicles.

The location of LHR2 is shown in Figure 1. A photograph of the site is shown in Figure 2.

The London Harlington site 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 the order of 300m from the western edge of Harlington.

The location of Harlington is shown in Figure 1. A photograph of the site is shown in Figure 3.

Appendix 4
Quality Assurance and Quality Control

Quality Assurance and Quality Control

netcen 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.

All gas calibration standards used for routine analyser calibration are certified against traceable primary gas calibration standards at the Gas Standards Calibration Laboratory at netcen. 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.

The calibration of the analysis of the BTX diffusion tubes is undertaken using both commercially available and gravimetrically prepared standards. A stock calibration solution of benzene, toluene and xylene is made up gravimetrically and diluted to working strength. A known quantity of this solution is injected onto glass wool in a Chromosorb 106 tube. A standard is run at the start of the batch and after every 10 samples in order to check the stability of the analyser. The mean of standards throughout the batch provides a calibration factor for use that day. If variation in standard response across the batch is greater than 10%, the reason for the variability is investigated. A blank tube is run to check baseline levels and eliminate possible carryover from standards.

The grab samples are analysed at AEA Technology on a gas chromatograph-flame ionisation detection system. The instrument uses a porous layer open tube (PLOT) Al_2O_3 column with temperature and flow rates optimised for best resolution. Each day the analyser is calibrated with a 27 component mixture which is traceable to national measurement standards.

Verification of calibration and instrumental techniques is achieved by regular participation in EU intercalibration exercises. In the last such exercise, AEA results were generally within 10% for C_2-C_6 compounds and within 15% for $>C_6$ compounds.

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 principle 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. Our audit calibration procedures for NO_X and CO are UKAS accredited.

In line with current operational procedures within the DEFRA Automatic Urban Monitoring Network, 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 on a daily basis, at netcen, by experienced staff. Data are compared with corresponding results from National Monitoring Network 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

(see Appendix 2) are examined to identify any possible instrument faults. Should any faults be identified or suspected, arrangements are made for netcen 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 for the quarterly report.

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.

Following these 3-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 below.

Estimated Accuracy and Precision of the Data Presented

	Precision	**Accuracy**
Nitric Oxide (NO)	±2.5 µg m^{-3}	±10%
Nitrogen Dioxide (NO_2)	±6.9 µg m^{-3}	±11%
Carbon Monoxide (CO)	±0.7 mgm^{-3}	±8%
Particles (PM_{10})	±4 µg m^{-3}	*

* accuracy of particle measurements cannot currently be assessed.

Wind speed and wind direction data from the measurements at the LHR2 site are checked by comparing against results from other nearby monitoring locations.