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A continued Investigation of Air Quality in the Vicinity of Heathrow Airport. (November 2005 to December 2006)

Report to British Airways plc

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Executive summary

British Airways has previously undertaken dispersion modelling of aircraft emissions at Heathrow Airport. In order to compare modelling results with measurements, netcen (a division of AEA Technology Environment, at the time) was commissioned to undertake an extended study of air pollution concentrations across the airport, over a 12-month period, from October 2002 to October 2003.

As a result of this survey, a further 12 months of nitrogen dioxide (NO_2) monitoring was undertaken, at seven of the previously selected landside locations, between October 2003 and October 2004. These locations were in the commercial/residential areas to the north of the airport. A co-location site for bias-adjustment purposes was retained from the earlier survey and located at the London Heathrow 2 (LHR2) airside continuous monitoring trailer.

A further twelve months of indicative nitrogen dioxide monitoring was undertaken at these eight locations, from 2 November 2004 to 1 November 2005. For this period, the use of a second co-location site was suggested by AEA, in order to compare the resulting bias-adjustment factors. This was subsequently located at the Hillingdon **A**utomatic **U**rban and **R**ural **N**etwork (AURN) continuous air quality monitoring station. For this final report, a further indication of 2006 bias-adjusted concentrations has been presented. The ‘Imperial college ‘1 diffusion tube sampling location is located on a lamp post close to the Harlington continuous air monitoring site (now fully affiliated in to the A.U.R.N.)[not to be confused with the Harlington Footpath tube –exposure location]. Therefore, the 2006 results from these two locations have been treated as a further co-location opportunity. The resulting bias-adjustment factor, calculated from 11 ‘GOOD’ periods of tube data, was 0.59.

The final contract period of NO_2 monitoring, by AEA Energy & Environment, (formally netcen) has covered November 2005 to December 2006. From these measurements, the level of the LHR2-derived bias adjustment factor, obtained from the 2006 annual mean sampling period, is similar to that derived from the 2005 annual mean monitoring period, 0.56 (2006) and 0.61 (2005).

Using the LHR2-derived bias-adjustment factor, the resulting 12-month mean and 2006 annual mean NO_2 concentrations, at all the original eight locations, remain closely aligned with those from the previous sampling periods.

By applying the LHR2 2006 annual mean bias-adjustment factor, the 2006 annual mean NO_2 concentrations, measured at five of the nine Heathrow sampling locations, are likely to remain below the 40 µg.m^{-3} Air Quality Objective (AQO) level (after taking in to account the 95% Confidence Interval uncertainty of between ±3 µg m^{-3} and ± 6 µg m^{-3}, associated with the precision of the triplicate tubes).

The Shepiston Lane site, at 56 µg.m^{-3}; Neptune Road, at 54 µg.m^{-}3 and LHR2 site, at 55 µg.m^{-3} continue to present bias-adjusted annual mean levels of NO_2 above the 40 µg.m^{-3} AQO level. The Harlington site footpath remained close to the AQO level at 38 ± 4 µg m^{-3}. The expected uncertainty, associated with all quoted bias adjusted concentrations, should be in the range ± 25%. From the precision demonstrated in the results, the uncertainty was well within this requirement.

The LHR2 bias adjustment factor remains lower than might be expected from similar sites, at approximately However, the bias adjusted NO_2 concentrations, particularly from the Heathrow tube sites located away from major roads, were generally in good agreement with the defra Air Quality web site predicted 2006 NO_2 background concentrations, for these locations.

The reason for the relatively low LHR2 bias-adjustment factor remains unclear but may be associated with wind-effects at this exposed location and/or pollution spikes from vehicles in the immediate area, affecting the uptake of NO_2 within the diffusion tubes. Some investigative work has been undertaken, both at the LHR2 site and elsewhere, by AEA E&E, during 2006. However, this study, into possible procedural improvements to the use of NO_2 diffusion tubes, is not yet complete. Hence, no conclusions are possible, at this stage.

The level of the 2006 annual mean bias-adjustment factor, obtained from the additional co-location site at Hillingdon, differed from that gained from the LHR2 co-location site. However, fixing points were limited and although the location of the Hillingdon tubes were in the best practical position, they may not be ideal, being sited close to the hut wall (enabling safe access by the operator). Hence, the primary bias adjustment results are given from LHR2 and Appendix 2, presents the bias adjusted results from Hillingdon.

When the calculated Hillingdon bias adjustment factor of 0.79 was used, the 2006 annual mean NO_2 concentration for each sampling location was above the 40 $\mu g.m^{-3}$ Air Quality Objective/Limit Value level. (Even after taking in to account the 95% Confidence Interval uncertainty of up to ± 5 $\mu g\ m^{-3}$, associated with precision of the triplicate tubes).

The Objective limit for nitrogen dioxide, quoted as an **annual mean** concentration, is
40 $\mu g\ m^{-3}$ or 21 ppb.

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Appendices

1 Introduction

British Airways (BA) has undertaken dispersion modelling of aircraft emissions at Heathrow Airport. In order to compare modelling results with measurements, netcen (a division of AEA Technology Environment, at the time) was previously commissioned to undertake a 12-month study of air pollution concentrations, along a transect-line crossing the airport. This line extended into the residential areas to the north of the airport. The study measured indicative concentrations, from passive diffusion tubes, of both nitrogen dioxide and hydrocarbons during the period October 2002 to October 2003. AEA was subsequently re-commissioned (again, in collaboration with BA staff) to undertake continued surveys of nitrogen dioxide, at eight of the previously selected sites, between October 2003 to October 2004 and November 2004 to early November 2005.

For the 2004-05 contract, the tube exposure periods were harmonised with those of the U.K. Nitrogen Dioxide Diffusion Tube Survey. This continued into the final contract period, covering November 2005 to December 2006 (14 months). Passive nitrogen dioxide (NO_2) diffusion tubes (Appendix A) have continued to be used, supplied by the same laboratory as those used in the previous survey-periods. BA staff continued to visit the sites on a monthly basis to exchange the exposed tubes, returning them to AEA, for analysis by Harwell Scientifics Ltd. The results are summarised in Chapter 3 with full results in Appendix B. Examples of diffusion tubes are shown in Figure 1.

Nitrogen dioxide, is covered by the first European Union Air Quality Daughter Directive (1999/30/EC) and by the Air Quality Strategy Objectives, set by the UK Government. This Air Quality Strategy defines levels for air pollutants that must be met in the UK by specific dates. These are formally incorporated into English law by a number of UK Statutory Instruments detailed in Appendix E.

Figure 1: Diffusion Tubes for (left to right) SO_2, BTX and NO_2

The supply and analysis of the diffusion tubes was carried out by Scientifics Ltd, at Harwell. Scientifics has been awarded UKAS accreditation (Testing Laboratory No 0322) for this service.

The use of diffusion tubes is covered by the British Standard BS EN 13528:2001.

2 Methodology

For the final contract period, covering the 14 months from November 2005 to December 2006, both co-location-study sites, selected previously, were retained. This was in order to continue to assess any undue influence of local traffic, on the bias adjustment factor derived from the LHR2 continuous monitoring site (operated by AEA on behalf of BA) It is believed that this may have resulted in an unrepresentative bias adjustment factor. As a result, the exposure of triplicate tubes continued at the Hillingdon AURN station, a second locally sited continuous monitoring site. As a further means of assessing the possible level of bias-adjusted results, a third inter comparison has been included in this report. Due to the close proximity of the diffusion tubes exposed at the 'Imperial College 1' location and the now fully affiliated A.U.R.N.continuous NO_X monitor, at the Harlington air-monitoring site (within a few metres), the 2006 NO_2 results from these locations have been used to calculate a further "co-location" bias adjustment factor. The results from this are presented in Appendix 3.

For consistency with previous reports, the final 2005 to 2006 results from the LHR2 co-location site have continued to be used as the primary means of bias correcting both the 12-month and annual statistics from the Heathrow tube-monitoring sites. No further changes were made to the tube-only sampling locations, which remain the same as those used during the previous twelve months.

The NO_2 measurements from both the Hillingdon and Harlington AURN sites were taken from the defra UK National Air Quality Information Archive (http://www.airquality.co.uk/archive/index.php) and are presented in Appendix 2 and 3, respectively.

All sampling locations are in the commercial/residential areas to the North of the airport. The LHR2 'continuous' air quality monitoring trailer was located approximately 10 metres airside of the northern perimeter fence, in the vicinity of the Heathrow Visitor Centre. The Hillingdon AURN station was located in a residential area to the north west of the diffusion tube monitoring area. It was positioned a relatively short distance to the north of the M4 motorway and the results were assessed to determine whether the bias adjustment, applied to previous mean NO_2 concentrations, could be refined using this additional data. The Harlington site is located only a few meters from the lamp post supporting the Imperial College 1 diffusion tubes. Both the siste sample-inlet and tubes are located between two and three metres above ground level.

Triplicate diffusion tubes for nitrogen dioxide (NO_2) have continued to be exposed at monthly intervals at all locations.

Previously, the 2004 to 2005 report presented full 2005 annual mean concentrations for NO_2. Consequently, this report will concentrate on presenting the 2006 annual mean NO_2 concentrations i.e. covering the period January to December 2006. This will enable the comparison of the 2006 Heathrow results, with those from other locations and for comparison with the required UK Objectives and Limit Values.

2.1 Diffusion Tube Measurements

Diffusion tubes are passive sampling devices, which require no mains or battery power and are ideal for this type of survey, where an indication of nitrogen dioxide concentrations is required at a number of locations in the same area. Further details of diffusion tube samplers for NO_2 are provided in Appendix A. For this continued survey, triplicate NO_2 tubes were, again, deployed at each site, in order to maximise the reliability and accuracy of the data. In line with defra technical guidance on the use of diffusion tubes, tubes have also been co-located with continuous automatic NO_2 analysers, as described previously.

As indicated above, only one set of annual statistics is presented, covering the period January to December 2006.

The bias adjustment factor has been calculated primarily from the LHR2 data set. However, an upper and lower boundary of adjusted values is presented in Appendix 2, assuming that LHR2 could potentially provide an over-correcting bias-adjustment.

These factors have then been applied to the mean NO_2 concentrations, in line with the defra Technical Guidance on the use of diffusion tubes and the resulting data from longer survey-periods.

In the 2004 to 2005 Report, two data sets were presented. The November 2004 to October 2005 contract-period 12-month mean NO_2 concentrations were shown to be very similar to the 2005 annual mean concentrations. The bias adjustment factors for each 12- month period were almost identical, at 0.614 and 0.615, respectively.

For the monthly submission of the provisional data to BA, throughout 2006, all diffusion tube results continued to be re-scaled, using non-standard 'monthly' factors, derived from only the LHR2 co-location site. However, it should be noted that this is not the recommended approach for deriving the final bias-corrected concentrations, as detailed in the defra Technical Guidance document. Therefore, the 2006 annual data set has been processed according to the defra Technical Guidance.

Diffusion tube samplers are an indicative method of measurement. In terms of the EC Directive for NO_2 concentrations, indicative methods of measurement should be accurate to ±25%. The monitoring of NO_2 at the two automated sites was undertaken using a chemiluminescence analyser, which is defined as the European Union (EU) reference method of monitoring. Under the Directive, this reference method is required to have an accuracy of ±15%.

From the LHR2 co-location data and assuming an ideal analyser, the uncertainty associated with the bias corrected NO_2 concentration, ranges from ±6% to ±8%.

Table 1 shows a summary of the exposure dates for the final 14-month contract period

Table 1: Summary of Diffusion Tube Exposure Periods

Overall Period	Diffusion Tube Exposure Dates
37	1 Nov. to 29 Nov. 2005
38	29 Nov. to 3 Jan. 2006
39	3 Jan. to 31 Jan. 2006
40	31 Jan. to 28 Feb. 2006
41	28 Feb. to 4 Apr. 2006
42	4 Apr. to 2 May 2006
43	2 May to 31 May 2006
44	31 May to 27 Jun. 2006
45	27 Jun. to 24 Jul 2006
46	24 Jul. to 29 Aug. 2006
47	29 Aug. to 3 Oct. 2006
48	3 Oct. to 31 Oct. 2006
49	31 Oct. to 28 Nov. 2006
50	28 Nov. to 2 Jan. 2007

2.2 Monitoring Locations

For the 2005 to 2006 survey, the eight previously selected monitoring locations have been retained. The only addition has been the Hillingdon AURN station, included as a second co-location site. The tube-only sites are all located in the residential areas to the North east of the airport and are listed in Table 2. This also shows details of the LHR2 and Hillingdon AURN sites. Table 2 and Figure 2 summarise the continuing diffusion tube exposure locations.

For this final report, 2006 results from the Harlington A.U.R.N. monitoring site have been used, as described previously, as further bias-adjustment data, linked with tube results from Imperial College 1.

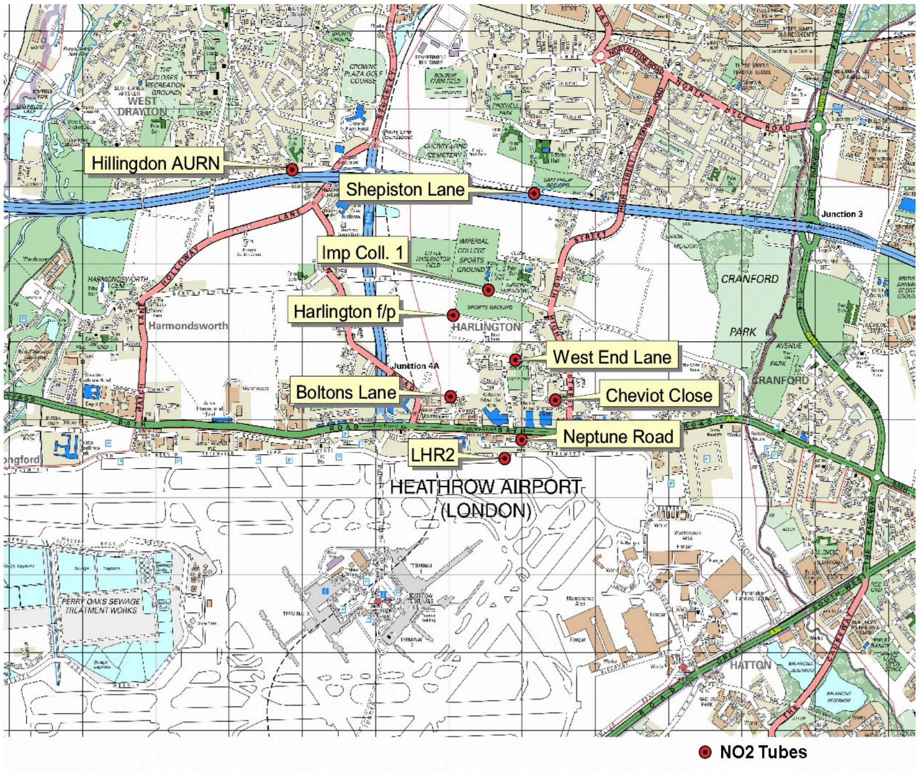
The tubes were supported in aluminium blocks, fixed at a height of approximately 2 metres where possible and using street-furniture or other available supports. Due to access and safety reasons, the Hillingdon tubes were not ideally positioned, being close to the wall of the monitoring hut.

Table 2: Monitoring Locations

Site	Easting	Northing	Comment
Shepiston Lane	508582	178453	Close to M4 motorway
Imperial College 1	508270	177831	Opposite sports ground
Harlington foot path	508030	177670	On f/p in centre of field
West End Lane	508455	177383	
Boltons Lane	508014	177147	
Cheviot Close	508728	177124	
Neptune Road	508496	176869	North of Northern perimeter
LHR2 *	508382	176749	Close to perimeter fence
Hillingdon AURN	506933	178607	Residential but close to M4.

* Denotes airside continuous monitoring trailer with co-located NO_2 tubes. The co-ordinates are indicative and reported to an accuracy of ±10 metres based on the operating instructions of the GPS system used at each of the sites.

Figure 2: Geographic Representation of the NO_2 Diffusion Tube Monitoring sites used in the 2004/05 Survey



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3 Results

Throughout the 2005 to 2006 survey period, results from the non-exposed ‘blank’ tubes were consistently low for legitimate tubes (i.e. where no obvious defect was apparent e.g. split cap) typically being close to, or below, the limit of detection (0.03µg NO_2). Therefore, no blank-adjustments, to the analytical results, were required. As a result of a change in cap design from the end of 2005, there were only two split end-caps, on Blank tubes, throughout the 14 months of sampling. These were both evident in the November 2005 set. The third tube from this set produced a value below the detectable limit.

There were no instances of split caps on exposed tubes, when returned to AEA, prior to analysis. However, one sampled tube from Neptune Road (May 2006 set) was lost during analysis.

Only three tubes were recorded as containing spiders’ webs. The results from these were very similar to the other tubes in the relevant triplicates. Hence, the individual results were not discounted. The overall data capture for the survey period was, therefore, well above 99%.

3.1 Diffusion Tubes – Bias Adjustment

The 2006 survey bias adjustment factor has been calculated following the Technical Guidance LAQM.TG (03) by which the average of the chemiluminescence results are compared to the average of the diffusion tube results from the co-location sites.

In order to maintain continuity with previous Heathrow diffusion tube monitoring results, the LHR2 continuous monitoring site was retained as the primary co-location site for the 2005-06 contract-period. Triplicate NO_2 tubes were exposed here in order to calculate the bias adjustment factor. This has been applied to the Heathrow diffusion tube 2006 annual mean concentrations, quoted within this report.

However, due to the fault with the LHR2 continuous NO_X monitor towards the end of 2006, which resulted in the deletion of part of the November 2006 NO_2 data and all December 2006 NO_2 data, it was decided to calculate the November 2005 to October 2006 LHR2 bias adjustment factor and apply this to the Heathrow 2006 annual mean diffusion tube results. As described in section 2.1, the bias adjustment factor derived from the November 04 to October 05 12-month period, was virtually identical to the standard annual mean factor, for 2005. Hence, the approach used was deemed acceptable.

Previous tube monitoring at LHR2, had indicated higher than expected period mean tube concentrations, compared to the mean chemiluminescence concentrations from equivalent periods. This may indicate the influence of an, as yet, unconfirmed factor, possibly the exposed nature of the tube-sampling site, being subjected to interference from wind. The proximity of both the northern perimeter road and runway may also be relevant. Consequently, the bias adjustment factors obtained from LHR2 (i.e. chemiluminescence mean concentration divided by the diffusion tube mean concentration) have been lower than might have been anticipated, at approximately 0.6.For the 2006 annual mean period, this factor was calculated as 0.56. Applying this to the mean diffusion tube concentration from each of the other sites may result in an over-correction.

In order to assist in assessing any possible over-correction, a second co-location site, was included for the 2004-05 contract-period. As indicated previously, this was at the Hillingdon AURN site, located a short distance away from the airport. The 2006 results from this additional site are presented in Appendix 2. As described previously, the 2006 results from two other sites were assessed, as a further indication of the likely level of bias-adjustment. After full ratification of the NO_2 data from the LHR2 automatic monitoring station, data from mid November 2006 to early January 2007 was deleted due to a fault with the chemiluminescence monitor. This was not picked up earlier due to a modem communication problem, with the site. The affect that this had on the NO_2 data capture rate, from the continuous analyser, is shown below;

- 12 months – January 2006 to December 2006 inclusive = 85%.
- 12 months – November 2005 to October 2006 inclusive = 98%.

As with the 2003 to 2004 annual report, the final dataset for this report has been compiled using the AEA E&E (formally netcen) NO_2 diffusion tube precision accuracy bias spreadsheet. This is available on the defra Air Quality website, as a standardised means of calculating the final data sets from NO_2 diffusion tube surveys in the U.K. The spreadsheet calculates annual or 12-month bias adjustment factors from the co-location-site data.

The spreadsheet did not screen diffusion tube data for outliers but was set to exclude data from the bias calculation if the coefficient of variance (C.o.V.) of the triplicate set was 20% or greater (this is an option within the spreadsheet). It will also exclude any data from a period where the comparative reference sampler data capture was below 75%. For LHR2, this applied to both the November and December 2006 chemiluminescence results, due to an NO_X instrument fault.

In a small number of cases, the C.o.V. was above 20% due to one obvious outlier within the triplicate results. In these instances, the decision was taken to discard the outlying result and use a mean of the remaining pair. If the spread of results was fairly even across the triplicate results, the original condition of excluding the result from this triplicate, as a 'poor' result, was upheld. In this way, the data set was used to its maximum potential.

This approach was similar to that used in the 2004 Report but differs slightly from that used in the previous 2003 report, where outlier-identification was achieved via the application of the Dixons Q test when the C.o.V. was above 10%. The current method accepts all triplicate data with a C.o.V below 20% irrespective of the fact that the data may fail the Q-test.

A resume of the spreadsheet is given in Appendix D. Table 3 shows the LHR2 diffusion tube and continuous analyser data used for the 2005-2007 bias adjustment calculations.

Table 3: NO_2 data from the co-location site at LHR2

Overall period number	Tube 1 ($\mu g.m^{-3}$)	Tube 2 ($\mu g.m^{-3}$)	Tube 3 ($\mu g.m^{-3}$)	Mean (S) ($\mu g.m^{-3}$)	CoV (%)	Precision Check	Analyser ($\mu g.m^{-3}$)	Data Capture (%)	Data Ratification Status
37	112	111	115	113 (2.4)	2	Good	62	90	R
38	185	102	92	93 (9.0)	10	Good	58	97	R
39	88	59	99	82 (20.8)	25†	Poor	57	99	R
40	93	82	99	91 (9.0)	10	Good	61	99	R
41	87	98	108	98 (10.5)	11	Good	55	99	R
42	78	86	113	92 (18.1)	20†	Poor	52	99	R
43	89	103	115	102 (12.8)	12	Good	50	97	R
44	82	79	87	82 (4.1)	5	Good	52	99	R
45	84	95	115	98 (15.8)	16	Good	55	99	R
46	80	75	78	77 (2.6)	3	Good	44	99	R
47	76	90	74	80 (8.3)	10	Good	45	99	R
48	95	86	95	92 (4.9)	5	Good	45	99	R
49	121	133	131	128 (6.8)	5	Good	-	-	D
50	137	136	131	134 (2.8)	2	Good	-	-	D

S – Standard Deviation. R – Fully ratified automatic data. † - A duplicate mean concentration was used in the calculation of the 12-month bias correction factor. D – Data deleted due to problem with NO_2 monitor from mid November 2006 to end December 2006.

For reference, the bias-adjustment factor obtained from the LHR2 co-location study, for the monitoring period of November 2005 to October 2006 was 0.57. The November 2004 to October 2005 factor was 0.614, compared to 0.602 for the 2003-04 contract-period.

The equivalent bias-adjustment factors for the 2005 and 2006 annual mean periods were 0.615 and 0.56, respectively.

The Air Quality Consultants (AQC) spreadsheet, providing historical 'mean bias adjustment factors' from numerous analytical laboratories throughout the UK, is available via the Defra Air Quality web site. The 2006 bias adjustment factor of 0.73, derived by Harwell Scientifics, is quoted as a guide only, The AQS 'Laboratory bias adjustment' spreadsheet can be found at the following web address; http://www.airquality.co.uk/aqm/review/questions.html, under the 'R & A support' option.

3.2 Diffusion tube Results – Data Handling

In order to maximise the benefits of all the available data, the compilation of this report was deferred until the 2006 LHR2 chemilumunescence data had been ratified. This has enabled the calculation of 2006 bias adjusted annual mean concentrations, which will also enable the comparison of the data with the Objectives and Limit Values for NO_2 and results from other long-term NO_2 diffusion tube surveys. These are typically reported as annual mean concentrations.

All individual monthly NO_2 diffusion tube results are given in Appendix 1. The mean, standard deviation and coefficient of variation for each monthly set have been calculated. The final data was calculated using the defra Technical Guidance procedures. The bias-adjusted 12-month mean NO_2 concentrations from the diffusion tubes, exposed at each location, are shown in Table 4, which also shows the 95% confidence interval associated with each concentration.

The previous report, No. 2157, covered the contract-period 2nd November 2004 to 1st November 2005. However, the report also presented the full 2005 annual mean statistics. Therefore, this current report will concentrate on the data available for the 2006 annual mean period.

3.3 NO_2 diffusion tube results (3rd Jan 06 to 2nd Jan 07)

An instrument fault affected the LHR2 continuous NO_X monitor throughout November and December 2006. As a result, the NO_2 data-capture for 2006 dropped to 85%. The diffusion tube bias adjustment factor has, therefore, been calculated from only eight periods of acceptable data – two periods were also discounted from the spreadsheet calculations because the C.o.V. was above 20%. The resulting bias adjustment factor was 0.56.

As a confirmation of validity of the derived bias adjustment factor, the equivalent factor was calculated from the LHR2 November 05 to October 06 data set, during which, the data-capture was 98%. The resulting factor was 0.57, very close to the value used to adjust all the 2006 tube data. This is also consistent with the similarly closely matched factors, quoted in the 2005 report, derived from the November 2004 to October 2005 period and the 2005 annual mean period.

Where the individual monthly triplicate diffusion tube data for a site had a coefficient of variance greater than 20% the monthly mean was excluded from the monitoring period/annual mean calculations. However if there was a clear pairing of tube results, the mean of these two results is shown in the data tables presented in Appendix 1. Table 4 gives the number of monthly data points excluded from the overall mean calculation, for each site.

Table 4: Triplicate tube mean concentrations excluded from final 2006 calculations.

Site	Excluded Monthly-Means -	Site	Excluded Monthly-Means -
Shepiston Lane	1	Cheviot Close	0
Imperial College 1	1	Neptune Road	1
Harlington Footpath	0	LHR2	1
West End Lane	1	Hillingdon AURN	0
Boltons Lane	1	-	-

Table 5 and Figure 3 present NO_2 results for the monitoring period 3rd January 2006 to 2nd January 2007, essentially, the 2006 annual mean period.

Table 5: 2006 mean NO_2 concentrations

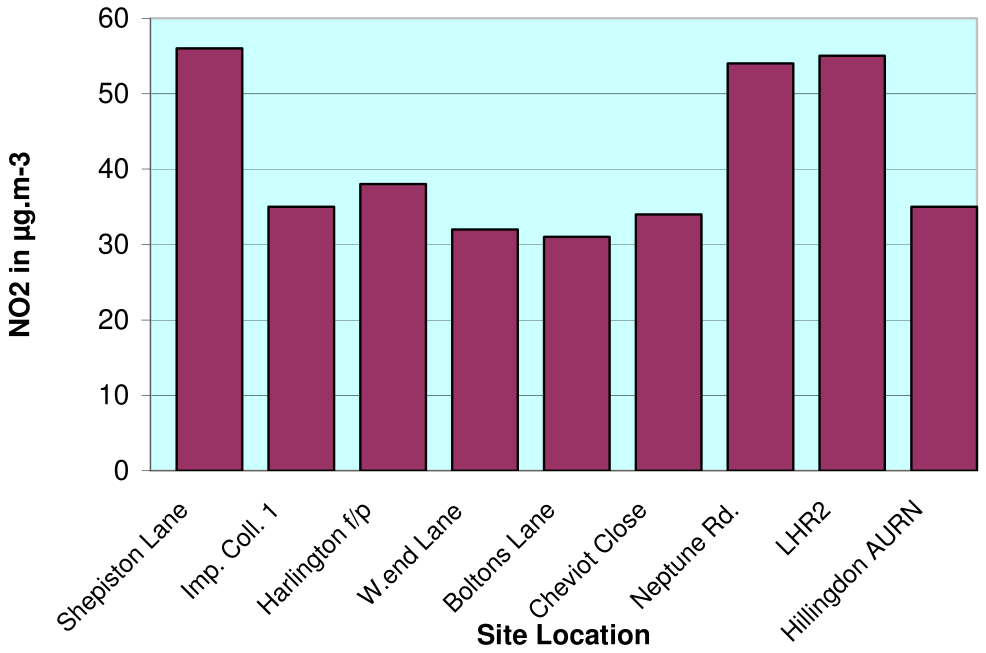
Site	Defra A.Q. Archive† predicted 2006 NO_2 background ($\mu g.m^{-3}$)	Non-adjusted 2006 mean NO_2 ($\mu g.m^{-3}$)	2006 bias adjusted mean NO_2 ($\mu g.m^{-3}$)
Shepiston Lane	31	101	56 ± 5
Imperial College 1	35	62	35 ± 4
Harlington Footpath	35	67	38 ± 4
West End Lane	35	57	32 ± 3
Boltons Lane	35	56	31 ± 3
Cheviot Close	35	61	34 ± 3
Neptune Road	37	97	54 ± 5
LHR2	37	98	55 ± 6
Hillingdon AURN	30	63	35 ± 3

† predicted background levels from the defra Air Quality Archive for 2006.

The LHR2, Neptune Road and Shepiston Lane sites border major roads. The bias adjusted 2006 annual mean NO_2 concentrations, measured at these sites, (adjusted to LHR2) are 54 to 56 $\mu g.m^{-3}$. This is higher than the levels at the other sites, which are set back further from the major carriageways. The LHR2-adjusted NO_2 levels at the other sites range from 31 $\mu g.m^{-3}$ to 38 $\mu g.m^{-3}$.

The predicted background levels from the defra Air Quality Archive web site are calculated from measured ambient data and knowledge of major sources. These concentrations were produced to indicate the level of background NO_2 in the survey area, in 2006, at sites with no other local influence. It was interesting to note that there was actually a good comparison between some of the sites corrected for the LHR2 bias and the predicted background, apart from the three sites with the highest levels (and closest to the major thoroughfares).

Figure 3: Bias-adjusted annual mean NO_2 concentrations for 2006.



There remains no clear evidence of any defined concentration gradient along the rough transect line of sites. However, the sites set back from the major roads have lower levels than the three sites close by main roads.

3.4 Review of the Heathrow bias-adjusted data, from the previous four contract periods

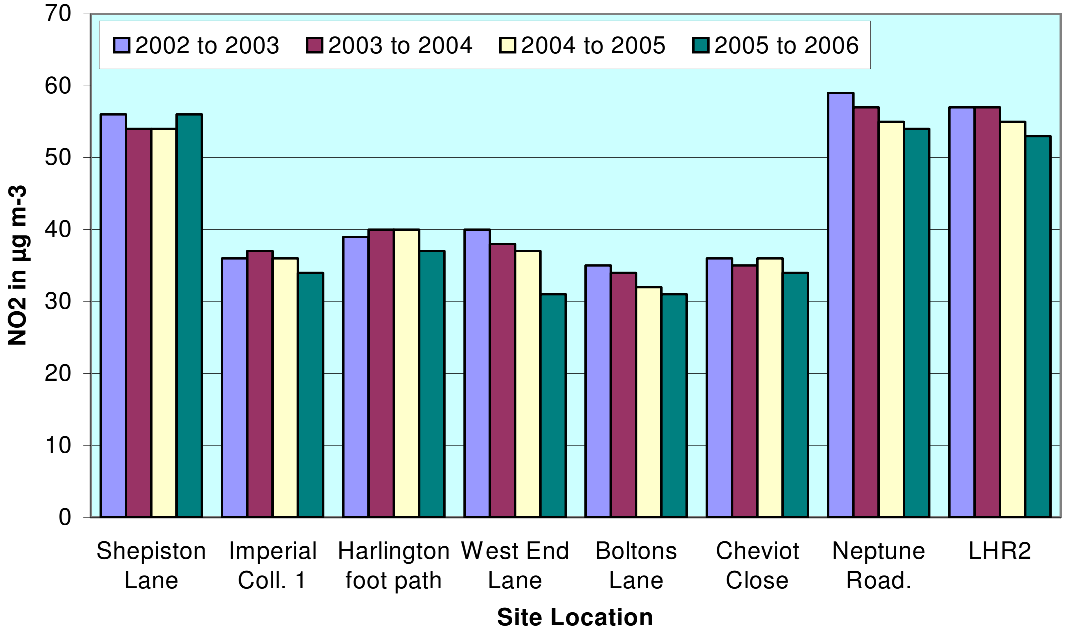
Nitrogen dioxide diffusion tube sampling has been undertaken at the current eight Heathrow locations for some years. This enables the review of the bias adjusted results (via the historic LHR2 co-location data) from the last four contract periods.

Table 6 and Figure 4 show the data from the historical contract-periods, starting in October 2002.

Table 6: LHR2 bias adjustment, 12-month mean NO_2 concentrations

Site	Bias adjusted 12-month mean from the 2002 to 2003 survey ($\mu g.m^{-3}$)	Bias adjusted 12-month mean from the 2003 to 2004 survey ($\mu g.m^{-3}$)	Bias adjusted 12-month mean from the 2004 to 2005 survey ($\mu g.m^{-3}$)	Bias adjusted 12-month mean from the 2005 to 2006 survey ($\mu g.m^{-3}$)
Shepiston Lane	56	54	54	56
Imperial College 1	36	37	36	34
Harlington Footpath	39	40	40	37
West End Lane	40	38	37	31
Boltons Lane	35	34	32	31
Cheviot Close	36	35	36	34
Neptune Road	59	57	55	54
LHR2	57	57	55	53

Figure 4: Bias adjusted NO_2 concentrations for 12-month contract periods from October 2002.



Although the results from diffusion tube surveys must be viewed as indicative only, over half the sampling locations appear to exhibit a small but consistent reduction in NO_2 concentration over the four 12-month periods displayed in Figure 4.

3.5 Comparison of 2006 annual mean NO_2 levels from Heathrow and other National sites

The bias-adjusted, 2006 Heathrow annual-mean NO_2 concentrations, quoted in this report, can be compared against annual mean NO_2 concentrations from other continuous analysers. However, the possibility of the Heathrow diffusion tube data being over corrected, by the use of the LHR2-derived bias-adjustment factor, should be born in mind.

The London Hillingdon continuous monitoring site was located in a suburban area, which borders the M4 Motorway, to the north of the airport. It shows a 2006 chemiluminescence annual mean NO_2 concentration of 51 $\mu g.m^{-3}$, which is towards the upper end of the range of tube-exposure locations, used in this Heathrow study. These displayed values between the low 30's to mid 50's $\mu g.m^{-3}$, respectively.

The London, Marylebone Road continuous monitoring station, located on the kerbside of the busy 6-lane urban highway opposite Madame Tussauds, recorded a 2006 annual mean NO_2 concentration of 111 $\mu g.m^{-3}$, twice that of the highest mean levels from Heathrow.

The London, North Kensington continuous monitoring station was classified as an urban background site. The 2006 annual mean NO_2 concentration, from the site NO_2 monitor, was 38 $\mu g.m^{-3}$. This was significantly lower than the equivalent Hillingdon annual mean of 49 $\mu g.m^{-3}$ and very similar to the London Harlington annual mean of 37 $\mu g.m^{-3}$.

Table 8 shows the 2006 annual mean chemiluminescence NO_2 concentrations from the automatic Heathrow sites and a selection of AURN air quality monitoring stations.

Table 8: 2006 annual mean NO_2 concentrations at selected AURN sites

Monitoring site	Location	2006 annual mean NO_2 concentration ($\mu g.m^{-3}$)
Heathrow LHR2	10m airside of the Northern Perimeter Road at Heathrow Airport	52 (85% data capture)
Harlington AURN affiliated	Just south of the Imperial College sports training ground	37 (98% data capture)
London Hillingdon AURN	A suburban site approximately 30m from the M4 in Hillingdon	49 (94% data capture)
London N. Kensington	An urban background location	38 (99% data capture)
London Marylebone Rd	Kerbside of Marylebone Road – a 6-lane urban highway	111 (97% data capture)

The NO_2 concentration for each site in Table 8 was calculated from Chemiluminescent NO_2 data, for the period 3rd January 2006 to 2 January 2007 (equivalent to the Heathrow diffusion tube exposure period, covering 2006).

The data was fully ratified up to 1 October 2006 for all except LHR2, which was ratified up to end of 31 December 2006.

3.6 Likelihood of Air Quality Objective and Limit Value Exceedences

Appendix 3 shows a summary of the Air Quality Objectives and Limit Values associated with NO_2 monitoring. The relevant Objective is the 40 µg.m^{-3} level for nitrogen dioxide, equivalent to 21 ppb and measured as an annual mean (calendar year) concentration. This objective was to be achieved by 31 December 2005. Further, the Air Quality Limit Value Regulations 2003 set a limit value for NO_2 of 40 µg.m^{-3} to be achieved by 1st January 2010. From 2005, the limit value contains a 10 µg.m^{-3} margin of tolerance. There is a subtle difference between the Objective and the Limit Value, which may be significant for installations under IPPC.

From the diffusion tube monitoring undertaken over the last few years, the likelihood of the bias adjusted NO_2 concentrations, at the majority of sampled locations, exceeding the 40µg m^{-3} Objective level, appeared low. Using the 2006 annual mean LHR2 bias-adjustment factor, the only two tube-only locations, which appeared to consistently indicate likely exceedences, were and remain, Neptune Road and Shepiston Lane. The tube results from the LHR2 continuous monitoring site, also indicates an annual mean NO_2 concentration above the Objective level. The likelihood of the Harlington footpath location exceeding the Objective level, is borderline, at 38 µg.m^{-3} ± 4 µg.m^{-3}. However, with the possibility that the LHR2 bias adjustment may be over-correcting the tube results, these findings may require revision.

The bias adjusted concentrations resulting from both the Hillingdon co-location site and the data reviewed from the 'Harlington AURN / imperial College 1' pairing, were higher than those from the historical LHR2 site. However, as exhibited in 2005, there is generally good agreement between these LHR2-derived concentrations and the defra Air Quality website predicted 2006 NO_2 background concentrations, for the Heathrow tube-monitoring locations.

Hence, without further evidence to support the use of one or other co-location factor, or an explanation as to the substantial difference, it was also difficult to substantiate the use of a mean factor, derived from the combination of data from the two co-location sites.

The diffusion tube method was indicative and may be used to provide an indication of relative levels over a wider area and as such, the larger overall uncertainty over the measurement should be taken into consideration. The assessment of the precision of the triplicate tubes at the co-location sites showed an uncertainty of ±6% assuming that the reference analyser was ideal. Since there will be an uncertainty with the measurement by the reference analyser, the overall measurement uncertainty will be between ± 15% (given for the reference system) and the ±25% target uncertainty for the manual method.

3.7 Meteorological Analysis of 2005-06 Data

Wind and pollution rose analysis plots are traditionally used in order to make an assessment of likely pollution sources. However, due to the extended exposure-periods of approximately one month, detailed meteorological examination was not possible and mean wind direction analysis therefore gives an overview of the situation, over a 12-month period. The meteorological and NO_2 data used in this section has been obtained from the LHR2 continuous monitoring trailer. However, it should be noted that due to a modem communications fault, late in 2006, it was not possible to include met data from December, in the plots shown in figures 6 and 7. Data capture was also affected by a coincident fault with the NO_X monitor.

The following figures are aligned such that the top of each 'rose' is north. Each is divided into segments of 22.5 degrees each.

The inner and outer rings, on the NO_2 plots, indicate concentrations of 40 and 80 µg.m^{-3}, respectively. On the wind speed plots, the same rings indicate 3 m/s and 6 m/s, respectively.

Figure 6 shows the wind rose analysis plot of mean NO_2 concentration against mean wind direction. It confirms that over the 2006 monitoring period, the highest mean NO_2 concentrations occurred when the wind direction was from the North East and to a lesser extent the South West. This was also the case in 2005.

Figure 7 shows the wind rose analysis plot of mean wind speed against mean wind direction, for the 2006 sampling period. This confirms that the highest wind speeds occur from the South West.
There continues to be a fairly even spread of mean concentrations from directions other than from those described above.

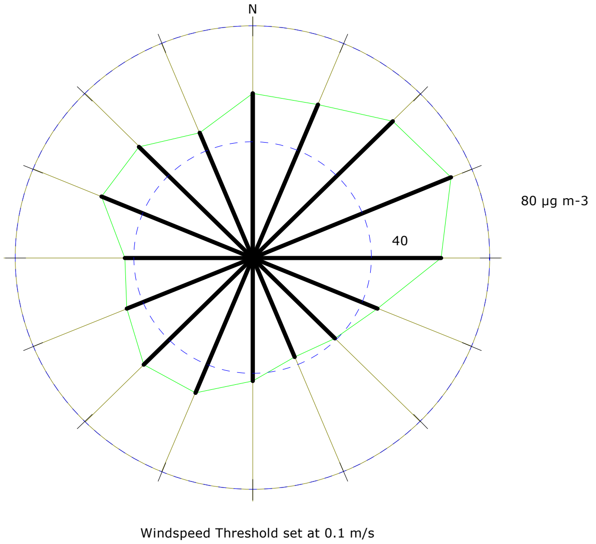


Figure 6: LHR2 NO_2 vs Wind Direction Analysis for the Period 03/01/06 To 02/01/07 (Produced from data standardised to 20^o C and 1013 mb)

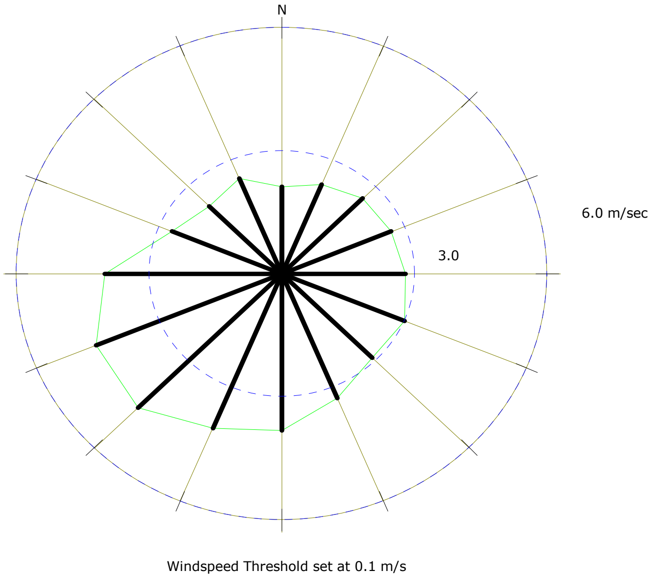


Figure 7: LHR2 Wind Speed vs Wind Direction Analysis for the Period 03/01/06 To 02/01/07 (Produced from data standardised to 20^o C and 1013 mb)

4 Conclusions

The main body of text within this report has been compiled using data from the historical LHR2 co-location site. The bias adjusted, mean NO_2 concentrations from the 2006 annual mean period indicate the following:

- Concentrations, at each Heathrow location, remain consistent with those from the previous sampling periods. The concentration-profile across the eight sites continues to remain virtually unchanged.
- Comparing the results from these locations, from the last four 'November to October' sampling periods (spanning 2002 to 2006), a slight 'year on year' reduction in bias-adjusted NO_2 concentration may be evident at the five sites closest to the airport (including LHR2). However, the uncertainties associated with the indicative measurement technique should be born in mind. The remaining three sampling locations, at Harlington footpath, Imperial College and Shepiston Lane, display more consistent NO_2 levels across the four 12-month periods.
- The LHR2-derived 2006 bias-adjusted NO_2 concentrations appear relatively well aligned with defra Air Quality wesite predicted 2006 background concentrations. This remains more evident at the tube locations away from the busier main roads.
- Using the LHR2 bias adjustment factors, the only off-airport locations that are likely to significantly exceed the 40 $\mu g.m^{-3}$ NO_2 Objective are the Neptune Road and Shepiston Road sites (56 and 54 $\mu g.m^{-3}$, respectively). The Harlington Footpath location, remains a borderline exceedence location, at 38 $\mu g.m^{-3}$.
- Due to access and operator safety implications, the sitting of the Hillingdon tubes was not ideal, being close to the wall of the northern side of the hut.
- Applying the 2006 Hillingdon bias-adjustment factor, result in a less severe correction which produced higher mean concentrations and the likelihood that all the tube-monitoring locations would exceed the 40 $\mu g.m^{-3}$ Objective / Limit Value level.
- Until possible reasons for the differing bias adjustment factors have been further investigated, it was inappropriate to simply recalculate the annual mean concentrations by applying a single factor produced from the average of those derived from either the two included co-location sites or the third comparison pairing. Both The Hillingdon and Harlington 2006 results are therefore presented separately, in Appendix 2 and 3.
- In order to further investigate the possibility that the higher diffusion tube concentrations at LHR2 are the result of wind-effect, it was recommended, in the 2005 annual report, that additional NO_2 diffusion tubes are exposed at this site. These would be fitted with an 'open-weave' gauze, in-order to reduce the effect of higher wind speeds on the, normally, open end of the tube. AEA E&E proceeded to expose some additional tubes at LHR2 during 2006, as part of a much wider study into possible factors, which may affect the use and accuracy of NO_2 diffusion tubes. This is still proceeding and the results have yet to be assessed.

Appendices

Appendix 1: NO_2 Diffusion Tubes – Individual Results, in µg m^{-3}

Appendix 2: Hillingdon AURN co-location results

Appendix 3: Summary of Objectives of the National Air Quality Strategy

Appendix 4: UK diffusion tube exchange schedule for 2006

Appendix 5: Diffusion Tube Method

Appendix 1

NO2 Diffusion Tubes – Individual Results, in µg m^{-3}

Table A1: Heathrow Transect Air Quality Monitoring,1st Nov 2005 – 29th Nov 2005 (Period 37)

Location	NO_2 Tube 1 ($\mu g\ m^{-3}$)	NO_2 Tube 2 ($\mu g\ m^{-3}$)	NO_2 Tube 3 ($\mu g\ m^{-3}$)	Triplicate mean (duplicate mean)	Standard Deviation of triplicate	Coefficient of Variation (%) of triplicate	Tubes precision-Check (triplicate)
Shepiston Lane	95	103	92	97	5.5	5.7	GOOD
Imp Coll.1	79	77	75	77	2.1	2.8	GOOD
Harlington f/p	70	98	80	83(75)	18.8	24.9†	POOR
West End Lane	71	70	66	69	2.7	4.0	GOOD
Boltons Lane	62	66	4	64	2.3	3.5	GOOD
Cheviot Close	74	78	74	75	2.1	2.7	GOOD
Neptune Rd	108	120	105	111	8.0	7.3	GOOD
LHR2	111	111	115	113	2.4	2.0	GOOD
Hillingdon AURN	61	52	62	58	5.9	10.0	GOOD

† = Data has been omitted the bias-adjustment calculation, where the C.o.V. was above 20%.

Table A2: Heathrow Transect Air Quality Monitoring, 29th Nov 2005 – 3rd Jan 2006 (Period 38)

Location	NO_2 Tube 1 ($\mu g\ m^{-3}$)	NO_2 Tube 2 ($\mu g\ m^{-3}$)	NO_2 Tube 3 ($\mu g\ m^{-3}$)	Triplicate mean (Duplicate mean)	Standard Deviation of triplicate	Coefficient of Variation (%) of triplicate	Tubes precision-Check (triplicate)
Shepiston Lane	66	99	93	86(96)	17.6	20.5†	POOR
Imperial College 1	77	59	74	70	9.7	14.0	GOOD
Harlington f/p	59	96	71	75	18.8	24.9†	POOR
West End Lane	64	69	46	59(67)	12.3	20.7†	POOR
Boltons Lane	62	64	60	62	1.9	3.1	GOOD
Cheviot Close	65	66	68	66	1.8	2.6	GOOD
Neptune Rd.	104	105	97	102	4.3	4.2	GOOD
LHR2	85	102	92	93	9.0	10.0	GOOD
Hillingdon AURN	64	63	61	63	1.3	2.0	GOOD

† = Data has been omitted from the bias-adjustment calculation, where the C.o.V. was above 20%.

Exposed tube concentrations and ‘triplicate mean’ are shown rounded to nearest integer. S.D. and C.O.V. are shown rounded to one decimal place.

Table A3: Heathrow Transect Air Quality Monitoring, 3rd Jan 2006 – 31st Jan 2006 (Period 39)

Location	NO_2 Tube 1 (µg m^{-3})	NO_2 Tube 2 (µg m^{-3})	NO_2 Tube 3 (µg m^{-3})	Triplicate mean (Duplicate mean)	Standard Deviation of triplicate	Coefficient of Variation (%) of triplicate	Tubes precision Check (triplicate)
Shepiston Lane	51	86	84	74(85)	19.6	26.6[†]	POOR
Imperial College 1	53	74	50	59(52)	13.2	22.4[†]	POOR
Harlington f/p	71	72	67	70	2.6	3.7	GOOD
West End Lane	58	63	29	75(61)	18.5	37.3[†]	POOR
Boltons Lane	37	52	55	48	9.5	19.8	GOOD
Cheviot Close	54	57	44	52	6.5	12.5	GOOD
Neptune Rd.	86	73	84	81	6.9	8.6	GOOD
LHR2	88	59	99	82	21	25[†]	POOR
Hillingdon AURN	61	56	59	59	2.7	4.5	GOOD

[†] = Data has been omitted from the bias-adjustment calculation, where the C.o.V. was above 20%.

Table A4: Heathrow Transect Air Quality Monitoring, 31st Jan 2006 – 28th Feb 2006 (Period 40)

Location	NO_2 Tube 1 (µg m^{-3})	NO_2 Tube 2 (µg m^{-3})	NO_2 Tube 3 (µg m^{-3})	Triplicate mean	Standard Deviation	Coefficient of Variation (%)	Tubes precision check
Shepiston Lane	80	84	89	84	4.9	5.8	GOOD
Imperial College 1	67	47	68	60	11.8	19.6	GOOD
Harlington f/p	80	64	58	67	11.6	17.2	GOOD
West End Lane	57	60	69	62	6.0	9.7	GOOD
Boltons Lane	52	59	61	57	4.9	8.6	GOOD
Cheviot Close	58	57	58	58	0.7	1.2	GOOD
Neptune Rd.	90	104	101	99	7.5	7.6	GOOD
LHR2	93	82	99	91	9.0	10.0	GOOD
Hillingdon AURN	52	54	53	53	1.2	2.3	GOOD

Exposed tube concentrations and 'triplicate mean' are shown rounded to nearest integer. S.D. and C.o.V. are shown rounded to one decimal place.

Table A5: Heathrow Transect Air Quality Monitoring, 28th Feb 2006 – 4th Apr. 2006 (Period 41)

Location	NO_2 Tube 1 ($\mu g\ m^{-3}$)	NO_2 Tube 2 ($\mu g\ m^{-3}$)	NO_2 Tube 3 ($\mu g\ m^{-3}$)	Triplicate mean Duplicate mean	Standard Deviation of tripliate	Coefficient of Variation (%) of triplicate	Tubes precision check
Shepiston Lane	93	97	90	93	3.6	3.9	GOOD
Imperial College 1	70	58	48	59	11	18.7	GOOD
Harlington f/p	71	62	74	69	6.3	9.0	GOOD
West End Lane	54	45	66	55	10.7	19.5	GOOD
Boltons Lane	57	62	41	53(60)	10.7	20.1†	POOR
Cheviot Close	62	54	57	58	4.1	7.2	GOOD
Neptune Rd.	87	97	64	83	17.2	20.8†	POOR
LHR2	87	98	108	98	10.5	11.0	GOOD
Hillingdon AURN	61	54	59	58	3.7	6.4	GOOD

† = Data has been omitted from the bias-adjustment calculation, where the C.o.V. was above 20%.

Table A6: Heathrow Transect Air Quality Monitoring, 4th Apr 2005 – 2nd May 2006 (Period 42)

Location	NO_2 Tube 1 ($\mu g\ m^{-3}$)	NO_2 Tube 2 ($\mu g\ m^{-3}$)	NO_2 Tube 3 ($\mu g\ m^{-3}$)	Triplicate mean	Standard Deviation	Coefficient of Variation (%)	Tubes precision check
Shepiston Lane	94	107	92	98	8.0	8.2	GOOD
Imperial College 1	57	58	56	57	0.9	1.5	GOOD
Harlington f/p	58	67	65	63	5.0	8.0	GOOD
West End Lane	49	52	50	51	1.2	2.4	GOOD
Boltons Lane	52	46	52	50	3.3	6.5	GOOD
Cheviot Close	59	62	59	60	1.9	3.2	GOOD
Neptune Rd.	90	94	92	92	2.2	2.3	GOOD
LHR2	78	86	113	92	18.1	20	GOOD
Hillingdon AURN	55	54	57	55	1.5	2.8	GOOD

Exposed tube concentrations and 'triplicate mean' are shown rounded to nearest integer. S.D. and C.o.V. are shown rounded to one decimal place.

Table A7: Heathrow Transect Air Quality Monitoring, 2nd May 2006 – 31st May 2006 (Period 43)

Location	NO_2 Tube 1 (µg m^{-3})	NO_2 Tube 2 (µg m^{-3})	NO_2 Tube 3 (µg m^{-3})	Triplicate mean	Standard Deviation	Coefficient of Variation (%)	Tubes precision check
Shepiston Lane	105	94	101	100	5.5	5.5	GOOD
Imperial College 1	61	61	56	59	3.2	5.3	GOOD
Harlington f/p	63	69	55	62	7.2	11.6	GOOD
West End Lane	49	52	50	51	1.2	2.4	GOOD
Boltons Lane	56	59	56	57	1.8	3.2	GOOD
Cheviot Close	65	63	52	60	7.1	11.8	GOOD
Neptune Rd.	96	-	98	97	0.9	1.0	GOOD
LHR2	89	103	115	102	12.8	12.0	GOOD
Hillingdon AURN	66	64	62	64	2.1	3.3	GOOD

Neptune Road second tube result was lost in analysis.

Table A8: Heathrow Transect Air Quality Monitoring, 31st May 2006 – 27th June 2006 (Period 44)

Location	NO_2 Tube 1 (µg m^{-3})	NO_2 Tube 2 (µg m^{-3})	NO_2 Tube 3 (µg m^{-3})	Triplicate mean	Standard Deviation	Coefficient of Variation (%)	Tubes precision check
Shepiston Lane	97	90	100	96	5.3	5.6	GOOD
Imperial College 1	49	52	52	51	1.3	2.6	GOOD
Harlington f/p	46	49	45	47	2.0	4.3	GOOD
West End Lane	43	39	43	42	2.6	6.3	GOOD
Boltons Lane	46	47	44	45	1.5	3.2	GOOD
Cheviot Close	54	56	54	55	1.3	2.3	GOOD
Neptune Rd.	83	85	86	85	1.4	1.7	GOOD
LHR2	82	79	87	82	4.1	5.0	GOOD
Hillingdon AURN	69	57	58	61	6.9	11.2	GOOD

Exposed tube concentrations and ‘triplicate mean’ are shown rounded to nearest integer. S.D. and C.o.V. are shown rounded to one decimal place

Table A9: Heathrow Transect Air Quality Monitoring, 27th June 2006 – 24th Jul 2006 (Period 45)

Location	NO_2 Tube 1 (µg m^{-3})	NO_2 Tube 2 (µg m^{-3})	NO_2 Tube 3 (µg m^{-3})	Triplicate mean	Standard Deviation	Coefficient of Variation (%)	Tubes precision check
Shepiston Lane	124	127	128	126	1.9	1.5	GOOD
Imperial College 1	55	62	59	59	3.3	5.6	GOOD
Harlington f/p	58	53	60	61	2.4	3.9	GOOD
West End Lane	46	50	50	49	2.2	4.4	GOOD
Boltons Lane	51	53	57	54	3.4	6.4	GOOD
Cheviot Close	63	66	61	63	2.5	4.0	GOOD
Neptune Rd.	98	102	98	99	2.3	2.4	GOOD
LHR2	84	95	115	98	15.8	16.0	GOOD
Hillingdon AURN	76	78	78	77	1.6	2.1	GOOD

Table A10: Heathrow Transect Air Quality Monitoring, 24th Jul 2006 – 29th Aug 2006 (Period 46)

Location	NO_2 Tube 1 (µg m^{-3})	NO_2 Tube 2 (µg m^{-3})	NO_2 Tube 3 (µg m^{-3})	Triplicate mean	Standard Deviation	Coefficient of Variation (%)	Tubes precision check
Shepiston Lane	78	86	83	82	4.0	4.8	GOOD
Imperial College 1	49	50	36	45	7.6	16.8	GOOD
Harlington f/p	54	63	52	56	5.8	10.4	GOOD
West End Lane	43	47	47	46	2.2	4.7	GOOD
Boltons Lane	45	38	42	42	3.7	8.8	GOOD
Cheviot Close	49	52	45	48	3.7	7.5	GOOD
Neptune Rd.	78	86	81	82	3.9	4.8	GOOD
LHR2	80	75	78	77	2.6	3.0	GOOD
Hillingdon AURN	52	49	52	51	1.9	3.7	GOOD

Exposed tube concentrations and ‘triplicate mean’ are shown rounded to nearest integer. S.D. and C.o.V. are shown rounded to one decimal place.

Table A11: Heathrow Transect Air Quality Monitoring, 29th Aug 2006 – 3rd Oct 2006 (Period 47)

Location	NO$_2$ Tube 1 (µg m^{-3})	NO$_2$ Tube 2 (µg m^{-3})	NO$_2$ Tube 3 (µg m^{-3})	Triplicate mean	Standard Deviation	Coefficient of Variation (%)	Tubes precision check
Shepiston Lane	108	108	101	106	4.1	3.9	GOOD
Imperial College 1	60	62	56	59	2.6	4.5	GOOD
Harlington f/p	68	74	66	70	4.3	6.2	GOOD
West End Lane	59	60	61	60	1.0	1.6	GOOD
Boltons Lane	52	62	59	57	4.9	8.6	GOOD
Cheviot Close	59	60	60	60	0.6	1.0	GOOD
Neptune Rd.	87	100	91	93	6.7	7.2	GOOD
LHR2	76	90	74	80	8.3	10.0	GOOD
Hillingdon AURN	67	69	69	68	1.0	1.5	GOOD

Table A12: Heathrow Transect Air Quality Monitoring, 3rd Oct 2006 – 31st Oct 2006 (Period 48)

Location	NO$_2$ Tube 1 (µg m^{-3})	NO$_2$ Tube 2 (µg m^{-3})	NO$_2$ Tube 3 (µg m^{-3})	Triplicate mean	Standard Deviation	Coefficient of Variation (%)	Tubes precision check
Shepiston Lane	1010	110	93	104	9.5	9.1	GOOD
Imperial College 1	65	69	65	66	2.2	3.3	GOOD
Harlington f/p	74	71	72	72	1.5	2.1	GOOD
West End Lane	54	62	66	61	6.0	9.8	GOOD
Boltons Lane[2]	62	66	57	62	4.2	6.7	GOOD
Cheviot Close	60	58	63	60	2.1	3.4	GOOD
Neptune Rd.	98	93	90	94	4.0	4.2	GOOD
LHR2	95	86	95	92	4.9	5.0	GOOD
Hillingdon AURN	68	73	73	71	3.2	4.5	GOOD

Exposed tube concentrations and ‘triplicate mean’ are shown rounded to nearest integer. S.D. and C.o.V. are shown rounded to one decimal place.

Table A13: Heathrow Transect Air Quality Monitoring, 31st Oct 2006 – 28th Nov 2006 (Period 49)

Location	NO_2 Tube 1 (µg m^{-3})	NO_2 Tube 2 (µg m^{-3})	NO_2 Tube 3 (µg m^{-3})	Triplicate mean	Standard Deviation	Coefficient of Variation (%)	Tubes precision check
Shepiston Lane	116	116	107	113	5.4	4.8	GOOD
Imperial College 1	90	85	76	84	6.7	8.0	GOOD
Harlington f/p	87	102	83	91	10	11	GOOD
West End Lane	71	71	81	74	5.9	7.9	GOOD
Boltons Lane	72	74	71	73	1.7	2.3	GOOD
Cheviot Close	75	81	76	77	3.5	4.6	GOOD
Neptune Rd.	113	137	117	122	12.8	10.5	GOOD
LHR2	121	133	131	128	6.8	5.0	GOOD
Hillingdon AURN	70	67	76	71	4.6	6.5	GOOD

Table A14: Heathrow Transect Air Quality Monitoring, 28th Nov 2006 – 2nd Jan 2007 (Period 50)

Location	NO_2 Tube 1 (µg m^{-3})	NO_2 Tube 2 (µg m^{-3})	NO_2 Tube 3 (µg m^{-3})	Triplicate mean	Standard Deviation	Coefficient of Variation (%)	Tubes precision check
Shepiston Lane	101	120	92	104	15	14	GOOD
Imperial College 1	79	89	97	88	8.7	9.9	GOOD
Harlington f/p	82	60	86	76	14.1	18.6	GOOD
West End Lane	69	65	84	73	10.4	14.3	GOOD
Boltons Lane	72	74	70	72	2.2	3.0	GOOD
Cheviot Close	80	92	79	84	7.2	8.7	GOOD
Neptune Rd.	115	137	109	120	14.5	12.1	GOOD
LHR2	137	136	131	134	2.8	2.0	GOOD
Hillingdon AURN	64	64	68	65	2.2	3.4	GOOD

Exposed tube concentrations and ‘triplicate mean’ are shown rounded to nearest integer. S.D. and C.O.V. are shown rounded to one decimal place.

Table A15: Period-Mean Chemiluminescence NO2 Concentrations from Heathrow-Area and Selected AURN Sites - 01/11/2005 – 02/01/2007 (µg m^{-3})

Location	Period 37	Period 38	Period 39	Period 40	Period 41	Period 42	Period 43	Period 44	Period 45	Period 46	Period 47	Period 48	12-month mean	Period 49	Period 50	2006 annual mean
LHR2	62	58	57	61	55	52	50	52	55	44	45	45	53	-†	-†	52††
Hillingdon	53	50	46	45	52	45	51	47	54	30	52	51	48	60	55	49
Harlington	47	44	42	42	37	36	33	34	38	29	33	36	37	47	39	37
N. Kensington	58	48	44	50	37	36	31	31	36	30	35	37	39	46	41	38
Marylebone Rd	125	118	93	95	112	108	115	108	117	84	115	112	109	142	125	111

† - Values not quoted due to a NO$_X$ monitor fault for half of P49 and all of P50.

††.- LHR2 2006 annual mean NO$_2$ concentration is derived from a data-capture of only 85%.

The P48, 49 and 50 values for all sites, except LHR2, are from, as yet, unratified data sets. All other data was fully ratified.
All Chemiluminescence NO$_2$ concentrations are in µg m^{-3} at Standard Temperature/pressure of 1013 mb & 20 degrees Centigrade.

Appendix 2

Review of 2006 data from Hillingdon co-location site

Hillingdon AURN (Source: Defra Site Information Archive **http://www.stanger.co.uk/siteinfo/**)

Figure: Photograph of the area surrounding the Hillingdon AURN air quality monitoring station. Passing the hut is a 'no-through' road.

At the time of production of the report the fully ratified dataset for the Hillingdon AURN site was not available. The ratification of the final quarter of 2006 will be completed in early April 2007. The data capture rates from the chemiluminescence NO_X monitor, for the 2006 annual mean period, was 94.3%.

Table : 2006 NO_2 data from the Hillingdon co-location site.

Overall Period	Tube 1 (µg.m^{-3})	Tube 2 (µg.m^{-3})	Tube 3 (µg.m^{-3})	Mean (S.D.) (µg.m^{-3})	CoV (%)	Tube Precision Check	Analyser mean (µg.m^{-3})	Data Capture (%)	Data Ratification Status
37	61	52	62	58 (5.9)	10.0	Good	53	92	R
38	64	63	61	63 (1.3)	2.0	Good	50	99	R
39	61	56	59	59 (2.7)	4.5	Good	46	92	R
40	52	54	53	53 (1.2)	2.3	Good	45	90	R
41	61	54	59	58 (3.7)	6.4	Good	52	97	R
42	55	54	57	55 (1.5)	2.8	Good	45	93	R
43	66	64	62	64 (2.1)	3.3	Good	51	99	R
44	69	57	58	61 (6.9)	11.2	Good	47	99	R
45	76	78	78	77 (1.6)	2.1	Good	54	98	R
46	52	49	52	51 (1.9)	3.7	Good	30[†]	71	R
47	67	69	69	68 (1.0)	1.5	Good	52	99	R
48	68	73	73	71 (3.2)	4.5	Good	51	98	P
49	70	67	76	71 (4.6)	6.5	Good	60	99	P
50	64	64	68	65 (2.2)	3.4	Good	55	99	P

S – Standard Deviation. R – Fully ratified automatic data. P – Provisional data subject to change on full ratification. † - analyser period-mean not included in calculations of bias adjustment.
The bias adjustment factor obtained from the Hillingdon AURN co-location study, for the monitoring period of 3/01/2006 to 2/01/2007, was 0.79.

Table C2: 2006 mean NO_2 concentrations

Site	Defra archive† Predicted 2006 NO_2 Background ($\mu g.m^{-3}$)	Non-adjusted Mean NO_2 ($\mu g.m^{-3}$)	Via LHR2 bias-adjustment, mean NO_2 ($\mu g.m^{-3}$)	Via Hillingdon bias-adjust, mean NO_2 ($\mu g.m^{-3}$)
Shepiston Lane	31	101	56 ± 5	79 ± 5
Imperial College 1	35	62	35 ± 4	49 ± 3
Harlington Footpath	35	67	38 ± 4	51 ± 3
West End Lane	35	57	32 ± 3	45 ± 3
Boltons Lane	35	56	31 ± 3	44 ± 3
Cheviot Close	35	61	34 ± 3	48 ± 3
Neptune Road	37	97	54 ± 5	76 ± 5
LHR2	37	98	55 ± 6	77 ± 5
Hillingdon AURN	30	63	35 ± 3	50 ± 3
Bias factor applied	-	-	0.56	0.79

† predicted background levels from the defra Air Quality Archive web site for 2006.

Figure C2: Bias-adjusted mean NO_2 concentrations using both co-location sites, 2006.

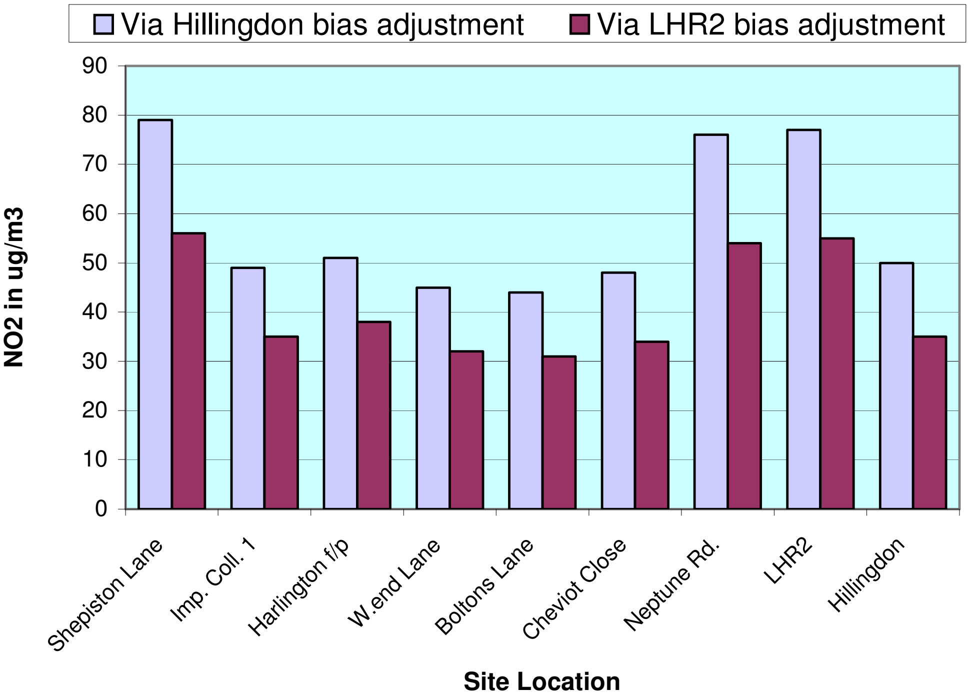


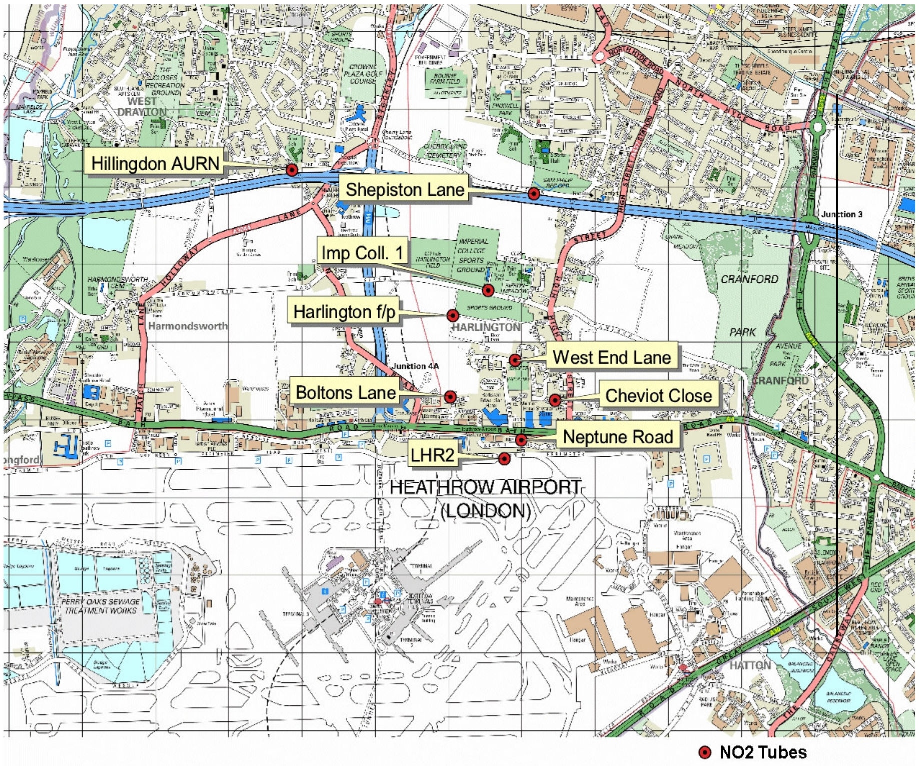
Table : Triplicate tube mean concentrations excluded from final 2006 calculations.

Site	Excluded Monthly-Means -	Site	Excluded Monthly-Means -
Shepiston Lane	1	Cheviot Close	0
Imperial College 1	1	Neptune Road	1
Harlington Footpath	0	LHR2	1
West End Lane	0	Hillingdon AURN	0
Boltons Lane	1	-	-

It was evident from the data that the mean levels of NO_2 resulting from the application of the Hillingdon bias adjustment factor are substantially higher than those derived from applying the LHR2 factor. This difference was due to the disparity in the levels of NO_2 measured by the diffusion tubes at each site, compared to the NO_X monitors. The difference, between the factors from the two co-location sites, appears to indicate a difference in the sampling environment. At present, the underlining reason was unconfirmed. However, it may be wind-related, as the LHR2 site was considerably more exposed than the Hillingdon site. Ratified data analysed from 2005, shows that mean wind speeds may be over 1 $m.s^{-1}$ higher at LHR2. It may also relate to more spikes of pollution, evident at the LHR2 site, due to the proximity of both the northern perimeter road and runway. Further monitoring is recommended at LHR2, using diffusion tubes protected from the direct effects of higher wind speeds at exposed locations.

Appendix 3

Review of 2006 data, from the Harlington air quality site and Imperial College diffusion tube site, located close by.



Map extract to highlight the location of the Harlington air-monitoring site. This is within a few meters of the "Imperial College 1" diffusion tube exposure location, shown above.

The comparison of past results obtained from the continuous NO_X analyser and co-located NO_2 diffusion tubes, at the LHR2 trailer, has historically shown a somewhat lower bias correction factor than might be expected. The opportunity has, therefore, been taken, to assess the results from a second local AURN "continuous" air monitoring station – Harlington. This is located within a few meters of the "Imperial College "1 diffusion tubes, sited on a lamp post close to the air monitoring site, some distance to north of the Airport. The Harlington AURN site should not be confused with the Harlington f/p (foot path) diffusion tube-only location, shown on the map extract above. The final contract-period was Nov. 2005 (37) to Dec. 2006 (50).

Table : 2006 NO_2 data from the "Imperial College 1" tube location and Harlington AURN site.

Overall Period	Tube 1 (µg.m^{-3})	Tube 2 (µg.m^{-3})	Tube 3 (µg.m^{-3})	Mean (S.D.) (µg.m^{-3})	CoV (%)	Tube Precision Check	Analyser mean (µg.m^{-3})	Data Capture (%)	Data Ratification Status
37	79	77	75	77 (2.1)	2.8	Good	47	99	R
38	77	59	74	70 (9.7)	14.0	Good	44	97	R
39	53	74	50	59 (2.7)	13.2	Good	42	99	R
40	67	47	68	60 (11.8)	19.6	Good	42	99	R
41	70	58	48	59 (11.0)	18.7	Good	37	99	R
42	57	58	56	57 (0.9)	1.5	Good	36	99	R
43	61	61	56	59 (3.2)	5.3	Good	33	98	R
44	49	52	52	51 (1.3)	2.6	Good	34	99	R
45	55	62	59	59 (3.3)	5.6	Good	38	99	R
46	49	50	36	45 (7.6)	16.8	Good	29	99	R
47	60	62	56	59 (2.6)	4.5	Good	33	99	R
48	65	69	65	66 (2.2)	3.3	Good	36	93	P
49	90	85	76	84 (6.7)	8.0	Good	47	99	P
50	79	89	97	88 (8.7)	9.9	Good	39	92	P

S – Standard Deviation. R – Fully ratified automatic data. P – Provisional data subject to change on full ratification. † - analyser period-mean not included in calculations of bias adjustment.

The bias adjustment factor calculated from the additional Harlington AURN semi-co-location study, for the monitoring period of 3/01/2006 to 2/01/2007, was 0.59. (using 11 “GOOD” periods of tube results)

Table : 2006 annual-mean NO$_2$ concentrations

Site	Defra archive† predicted 2006 NO$_2$ background (µg.m^{-3})	Non-adjusted mean NO$_2$ Conc. (µg.m^{-3})	NO$_2$ conc. via LHR2 bias-adjustment, (µg.m^{-3})	No$_2$ conc. via Hillingdon bias-adjust^{t}. (µg.m^{-3})	No$_2$ conc. via Harlington bias-adjust^{t}. (µg.m^{-3})
Shepiston Lane	31	101	56 ± 5	79 ± 5	60
Imperial College 1	35	62	35 ± 4	49 ± 3	37
Harlington Footpath	35	67	38 ± 4	51 ± 3	40
West End Lane	35	57	32 ± 3	45 ± 3	34
Boltons Lane	35	56	31 ± 3	44 ± 3	33
Cheviot Close	35	61	34 ± 3	48 ± 3	36
Neptune Road	37	97	54 ± 5	76 ± 5	57
LHR2	37	98	55 ± 6	77 ± 5	58
Hillingdon AURN	30	63	35 ± 3	50 ± 3	37
2006 bias factor used	-	-	0.56	0.79	0.59

† predicted background levels from the defra Air Quality Archive web site for 2006.

The table above shows that the 2006 bias adjusted NO$_2$ concentrations, calculated from the Harlington semi-co-location exercise, exhibit good agreement with those calculated from the LHR2-derived factor.

Appendix 4

Summary of current Objectives of the National Air Quality Strategy

The legislation and air quality objectives/limits relevant to this study are contained and discussed in the following publications:

- Part IV of the Environment Act 1995 (Local Air Quality Management);
- Directive 1996/62/EC of the European Parliament and of the Council of 27 September 1996 on ambient air quality assessment and management and amendment Regulation 1882/2003 – The Framework Directive; and
- Council Directive 1999/30/EC of 22 April 1999 relating to limit values for sulphur dioxide, nitrogen dioxides and oxides of nitrogen, particulate matter and lead in air – The 1st Daughter Directive.

The Government has published a number of Statutory Instruments relevant to England for the direct assessment of air quality and air pollution levels. These are:

- SI 2000/928 - The Air Quality (England) Regulations 2000;
- SI 2002/3043 - The Air Quality (England) (Amendment) Regulations 2002;
- SI 2003/2121 - The Air Quality Limit Values Regulations 2003 (this is the main enabling SI for the first, second and third Daughter Directives); and
- SI 2004/2888 - The Air Quality Limit Values (Amendment) (England) Regulations 2004.

The objectives and limit values from these Statutory Instruments are summarised as follows. The Limits in the Air Quality Limit Values Regulations 2003 are essentially identical with the First Daughter Directive.

Table E1: UK Air Quality Strategy Objectives

Pollutant	**Objective**	**Measured as**	**To be achieved by**
Nitrogen dioxide	200 µg m^{-3} (105 ppb) Not to be exceeded more than 18 times per year	1 Hour Mean	31 December 2005
	40 µg m^{-3} (21 ppb)	Annual Mean	31 December 2005
Nitrogen oxides*	(V) 30 µg m^{-3} (16 ppb)	Annual Mean	31 December 2000
Notes: µg m^{-3} - micrograms per cubic metre. * (V) = Applies only to 'rural' areas, for protection of vegetation.			

Table E2: The Air Quality Limit Values Regulations 2003: Limit Values

Pollutant	Limit Value	Measured as	To be achieved by
Nitrogen dioxide annual limit value for the protection of human heath	200 µg m^{-3} (105 ppb) Not to be exceeded more than 18 times per calendar year. A margin of tolerance is granted of 70 µg.m^{-3} for 2003, which reduces by 10 µg.m^{-3} each year until 2010. Hence, the effective limit value for 2005 is 250 µg.m^{-3}	1 Hour Mean	1 January 2010
	40 µg m^{-3} (21 ppb). A margin of tolerance is granted of 14 µg.m^{-3} for 2003, which reduces by 2 µg.m^{-3} each year until 2010. Hence, the effective limit value for 2005 is 50 µg.m^{-3}	Calendar Mean	1 January 2010
Nitrogen Oxides annual limit value for the protection of vegetation	(V) 30 µg m^{-3} (16 ppb)	Calendar Mean	19 July 2001
Notes: µg m^{-3} - micrograms per cubic metre. ppb – parts per billion			

Table E3: The Air Quality Limit Values Regulations 2003: Assessment Threshold

Threshold	Hourly limit value for the protection of human health (NO_2)	Annual limit value for the protection of human health (NO_2)	Annual limit value for the protection of vegetation (NO_X)
Upper assessment threshold (UAT)	70% of limit value (140 µg.m^{-3}), not be exceeded more than 18 times in any calendar year	80% of limit value (32 µg.m^{-3})	80% of limit value (24 µg.m^{-3})
Lower assessment threshold (LAT)	50% of limit value (100 µg.m^{-3}), not be exceeded more than 18 times in any calendar year	65% of limit value (26 µg.m^{-3})	65% of limit value (19.5 µg.m^{-3})

Appendix 5

UK Diffusion Tube "Monthly" Exchange

Schedule for 2006

	Month	Start Date	Duration (weeks)
2006	January	3 January 2006	4
	February	31 January	4
	March	28 February	5
	April	4 April	4
	May	2 May	4
	June	30 May	4
	July	27 June	5
	August	1 August	4
	September	29 August	5
	October	3 October	4
	November	31 October	4
	December	28 November	5
2007	January	2 January 2007	4

Notes

For 2006, the pollution months will always start on a Tuesday, to avoid the problem of bank holidays, and consist of 4 or 5 whole weeks, i.e. 28 or 35 days.

Tubes should be changed on the specified date. If not tubes may be changed within ±2 days of the due date.

Please keep a record of site-irregularities that may occur in monitoring, for example, building work, changes in traffic flow, etc. This information may be helpful in explaining any unusual results.

Appendix 6

NO_2 Diffusion Tube Method

A.1 The NO_2 Diffusion Tube

Passive sampling involves the collection of air pollutants using an absorbing material without the use of pumps; hence, no power supply is required. This makes these samplers very easy to deploy and flexible in terms of sitting.

A passive sampler for gaseous species is defined as a device which is capable of sampling gas or vapour pollutants from the atmosphere, at a rate controlled by a physical process such as diffusion through a static layer or permeation through a membrane, but which does not involve the active movement of air through the sampler.

Samplers are available for a wide range of pollutant species. The NO_2, SO_2, NH_3 and O_3 diffusion tubes supplied by AEA Technology are based on the work of Palmes, and consist of a cylindrical plastic tube, approximately 71 mm long and 11 mm in diameter. During sampling, one end is open and the other end holds an absorbent for the gaseous species to be monitored.

The basic principle on which diffusion tube samplers operate is that of molecular diffusion, with molecules of a gas diffusing from a region of high concentration (open end of the sampler) to a region of low concentration (absorber end of the sampler). The movement of molecules of gas (1) through gas (2) is governed by Fick's law, which states that the flux is proportional to the concentration gradient:

$$J = -D_{12}\frac{dc}{dz} \qquad (1)$$

Where:

J = the flux of gas (1) through gas (2) across unit area in the Z direction ($\mu g/m^2/s$);
c = the concentration of gas (1) in gas (2) ($\mu g\ m^{-3}$);
z = the length of the diffusion path (m); and
D_{12} = the molecular diffusion coefficient of gas (1) in gas (2) (m^2/s).

For a cylinder of cross-sectional area **a** (m^2) and length **l** (m), then **Q** (µg) the quantity of gas transferred along the tube in **t** seconds (taken as the quantity of gas absorbed during **t**) is given by:

$$Q = \frac{D_{12}(C_1 - C_o)at}{l} \qquad (2)$$

Where: C_o and C_1 are the gas concentrations at either end of the tube.

In a diffusion tube, the concentration of gas (1) is maintained at zero by an efficient absorber at one end of the tube (i.e. C_o = zero) and the concentration C_1 is the average concentration of the gas (1) at the open end of the tube over the period of exposure. Hence:

$$C = \frac{Ql}{D_{12}at} \qquad (3)$$

The diffusion coefficient for the gas to be monitored must be determined, or obtained from the literature. A best estimate of the area and length of a typical tube must be determined by measurement using Vernier callipers. Nominal tube dimensions are set at 11mm (diameter) and 71mm (length). The gas concentration C, can be readily derived from the quantity of gas absorbed Q, (assessed by desorption & chemical analysis of the tube), and the exposure time t.

A.2 Analysis of the NO_2 Diffusion Tube

The current NO_2 diffusion tube was of the Palmes design, with a cap containing woven wire cloth grids coated in a 50:50 absorbing solution of triethanolamine[1] and acetone. During transportation, the other end of the tube had a protective end cap in place. The site operator removed this protective cap during the tube exposure on site.

After exposure, the analyst extracted NO_2 from the tubes using a known volume of deionised water. The extract was analysed using an automated colorimetric method (Bran and Luebbe Segmented flow Auto-analyser III with ultraviolet detection). The analyst used the concentration found in the extract, the exposure period and the diffusion coefficient to calculate the concentration of NO_2. There has been no correction made for the sample travel blanks in the results. The levels found in the travel blanks inform the user on the level of uncertainty in the result. The calculation used to determine the concentration of NO_2 was as follows:

$$\mu g.m^{-3} = \left(\frac{QL}{D_{NO2}At} \right)$$

(Referenced in AERE Report: AERE R 12133)

Where:

Q = Mass of nitrogen dioxide in sample (µg);

L = Length of diffusion path (m);

D = Diffusion coefficient for nitrogen dioxide (m^2 s^{-1});
A = Tube area (m^2); and
t = Exposure time of tube (s).

Rearranging and simplifying this equation, gives:

$$\mu g.m^{-3} = 14088\left(\frac{Q}{T} \right)$$

Where:

T = Exposure time of diffusion tube in hours.

It may also be useful to show the concentration in parts per billion (ppb) especially when comparing against older data. The conversion used was as follows:

ppb = $\mu g.m^{-3}$ x 0.52 (assuming 1 atm and 20°C).

The analysis of nitrogen dioxide in the samples was within the scope of the Laboratory's UKAS accreditation. However, Harwell Scientifics UKAS accreditation does not cover the calculations and assessments of the exposure period, as these are factors are outside the control of the analyst.

The current limit of detection for NO_2 by the diffusion tube method was 0.03µg in the extracted solution. The method detection limit will depend on the length of exposure. Figure A1 shows the relationship between the method detection limit and exposure time.

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[1] 2,2',2-Nitrilotriethanol trihydroxytriethylamine

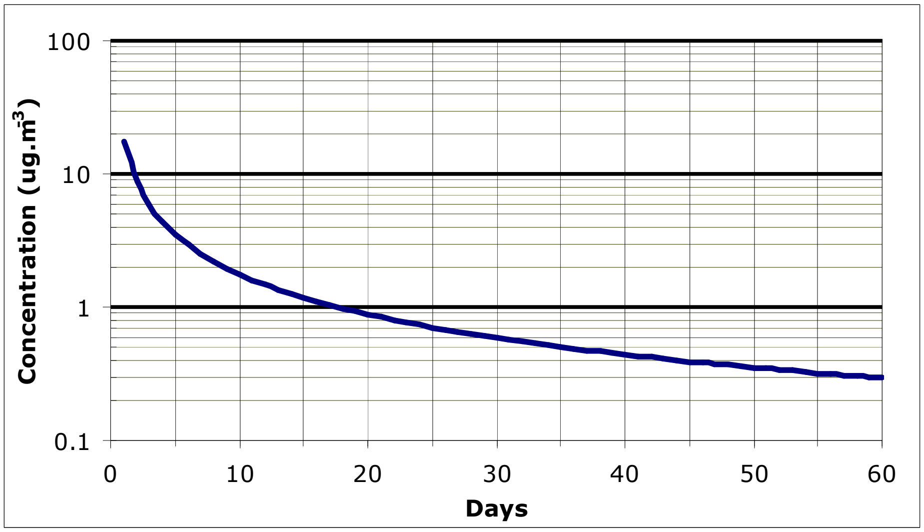

Figure A1: NO_2 Diffusion Tube Method Detection Limit