King's College London

Air quality in London

London Air Quality Network
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Introduction

The measurements detailed in this report result from a team effort, undertaken by staff who are dedicated and committed to their work.

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Contents

Foreword

Professor Frank Kelly, Director of the Environmental Research Group (ERG)

Welcome to the fourteenth annual report of the London Air Quality Network (LAQN). This publication provides a strategic overview of air pollution across London during 2006 and 2007 and as such, can act as a stand-alone document for comparison with other cities, as well as part of the ongoing annual air pollution record for London. The report provides a vital resource for anyone interested in air quality, especially those who are working at local and national levels, and for individuals developing policies to help reduce the level of air pollution in the UK.

The information in this report originates not only from the LAQN, managed by the Air Quality Monitoring group and led by Gary Fuller at King's College London, but is enhanced by input from the ERG's Air Quality Management Group. The combined and complementary expertise of individuals in these groups is also highlighted in the LAQN website www.londonair.org.uk. The latter contains summaries of air pollution across the LAQN, and a number of tools to allow the user to analyse and plot data. The site represents an excellent resource for all those interested in air pollution.

In 2006-7 London, in parallel with many other large cities around the world, continued to have difficulties in controlling air quality and as a consequence, experienced high levels of pollution. Traffic-related air pollution remains one of the most pressing problems in urban areas, contributing most to NO_x and PM emissions. Moreover, evidence of adverse health effects resulting from these pollutants continues to emerge at an alarming rate. Human exposure to air pollutants in densely populated urban areas is thus high, and improvement in air quality is therefore imperative. In this respect, the recently published Royal Society report on 'Ground-level Ozone in the 21st Century' is a stark reminder that climate change controls will need to be carefully formulated to attain the maximum benefit from both a climate change and air quality perspective. The health consequences of increasing background O_3 concentrations in the UK and across Europe being possibly worse than existing PM impacts.

The past 12 months also saw the publication of the long awaited updated EU air quality directive. Unfortunately, this has only caused dismay amongst health researchers as it is, in essence, a relaxation in relation to previous PM_{10} Limit Values. The new $PM_{2.5}$ Limit Value has been set at the upper end of exposure response curves from the major epidemiological studies, and hence not sufficiently protective of human health. Given that London is still having trouble meeting these insufficiently stringent PM targets, there is clearly no room for complacency and much to be achieved.

During the last 12 months ERG staff, together with colleagues from St George's, and the London School of Hygiene & Tropical Medicine, completed work on assessing the impact of the Congestion Charging Scheme (CCS) in London. The work undertaken by this interdisciplinary group of epidemiologists, toxicologists and air pollution scientists into air quality and health impacts of Europe's largest experiment in urban traffic management continues to attract international attention. The final report, to be published shortly, will confirm the difficulty in influencing urban air quality in the absence of city–wide regulatory schemes.

The same team of investigators also continued to examine the impact of the London-wide Low Emission Zone (LEZ) that was introduced in February 2008. Given the worldwide worries about diesel emissions and public health, and especially that of children's, the LEZ certainly has the potential to provide benefit to Londoners and those who work in and visit the capital.

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Summary

Air pollution concentrations in London continued to exceed UK Air Quality Strategy Objective (AQS) and EU Limit Values during 2006 and 2007. Progress towards the attainment of these legislated values varies according to pollutant; successes in the control of CO and SO_2 concentrations contrast with the less successful control of NO_2, PM_{10} and O_3.

Annual mean concentrations of CO in London have been successfully decreased by 56% from the end of 1996 to 2007. The EU Limit Value has been attained in London since 2000. Carbon monoxide emissions nevertheless remain important in regional O_3 formation. Similar decreases have also been measured in annual mean SO_2 concentrations and AQS objectives for SO_2 have not been exceeded in London since 1998. However, SO_2 pollution incidents do still occur in London; a notable incident affected west London during the July 2006 'heat wave'. The relative importance of SO_2 may increase in the future if new World Health Organisation (WHO) Guidelines are adopted within the UK and Europe.

Background NO_2 concentrations declined until 2002 but have been relatively stable since. Importantly, the annual mean AQS Objective and EU Limit Value of 40 $\mu g\ m^{-3}$ has been attained at background sites in outer London only and this concentration has been consistently exceeded at background sites in inner London and at roadside sites throughout London. During 2006 and 2007, the annual mean objective was exceeded at almost all roadside sites and it was also exceeded at background sites across inner and parts of east and west London. The mean concentration of NO_2 at roadside sites in inner London exceeded the annual mean AQS Objective and EU Limit Value by a factor of more than two during 2006 and 2007. This has important implications for the UK government's intention to seek a five year extension to the 2010 date for attainment of the EU Limit Value.

NO_2 concentrations at roadside sites do not show a clear overall change since 1997, despite the reduction in NO_X concentrations at these sites. Further examination of roadside NO_2 concentrations on a site by site basis shows a range of changes from little overall change to increases of

over 30% at some sites, including Marylebone Road. This increase in roadside NO_2 concentrations was caused by a change in the proportion of NO_2 directly emitted in vehicle exhausts. There is clearly a need for additional measures to control concentrations of this pollutant.

During December 2007 London experienced its most severe NO_2 episode in ten years. This appears to have been due to both meteorological conditions and changes in NO_2 primary emissions.

Mean PM_{10} concentrations in London decreased during the late 1990's but show a steady slow increase since this time at a mean rate of around 0.4% per year. Although the EU Limit Value has been attained at background sites since the late 1990's the EU Limit Value is regularly breached alongside the busiest parts of London's trunk road network and close to waste management sites. Use of the new volatile correction model (VCM), instead of the current 1.3 factor, to 'correct' TEOM measurements to gravimetric equivalent will decrease the number of locations exceeding the EU Limit Value during 2006 and 2007 but breaches of the Limit Value remain around waste sites and the busiest sections of the trunk road network. Use of the VCM would likely have lead to an increase in the breaches of the Limit Value during 2003.

Throughout north western Europe the PM_{10} decreases experienced during the 1990s have not continued this century, although considerable efforts have been made to abate emissions of PM_{10} and PM_{10} precursor pollutants in London, the UK and throughout Europe. It is unclear why such abatement measures are not yielding a reduction in measured PM_{10} concentrations. Worryingly there is evidence to suggest that PM_{10} concentrations arising from London's emissions have increased.

Measurements of the oxidising potential of airborne particles have been used to determine the toxicity of PM in London. This work has shown toxicity in both the PM_{10} and $PM_{2.5}$ fractions and importantly measurements have demonstrated additional toxicity in roadside PM_{10} when compared with that in background locations. Recent Defra funded research in London has looked at short-term health outcomes and changes in daily mean concentrations of different measurements of particle mass concentration and composition. Measurements of particle mass concentrations eg PM_{10} and $PM_{2.5}$ were found to be associated with short-term increases in respiratory health effects while changes in particle number concentrations were associated with cardiovascular effects. Given the localised nature of particle number concentrations and the additional toxicity of roadside PM_{10}, London-wide measures to abate PM_{10} may be effective in reducing both mass concentration and health effects of PM_{10} in London.

The Greater London Authority and Transport for London funded emissions inventory form a core upon which such abatement scenarios can be assessed. The transport part of this inventory has been recently updated for the 2006 base year.

Annual mean concentration of O_3 increased by 37% between the end of 1996 and 2007. This increase is thought to be due to changes in global concentrations and also London-wide abatement of NO_X. O_3 concentrations during the 2006 'heat wave' were the greatest since 2003. The peak concentrations during these episodes have decreased due to European-wide emissions control; peak concentrations during 2003 and 2006 were less than those experienced in London during the 1980s and 1990s and were less than around half of the concentration measured during the 1976 'heat wave'.

Introduction

This report details the results of air pollution measurements made during 2006 and 2007. Measurements have been presented with specific reference to the UK Air Quality Strategy (AQS) Objectives and European Union (EU) Limit Values. The report also describes changes in London's air pollution from 1996 to 2007. Appendices to the report provide detailed results from individual sites and information about each monitoring site in the LAQN.

The London Air Quality Network (LAQN) is a unique resource, providing robust air pollution measurements that are essential to underpin air quality management and health studies. The public face of the network, the London Air website (www.londonair.org.uk), is visited by thousands of Londoners seeking hourly updated air pollution information.

The LAQN was formed in 1993 to coordinate and improve air pollution monitoring in London. Currently, 31 of London's 33 boroughs supply measurements to the network. In addition, these data are increasingly being supplemented by measurements from local authorities surrounding London, thereby providing an overall perspective of air pollution in London and the Home Counties.

The LAQN is operated and managed by the Environmental Research Group (ERG) at King's College London. Each borough funds air quality monitoring in its own area. The Department of Environment, Food and Rural Affairs (Defra) funds King's to operate the Marylebone Road site and to maintain several of the LAQN sites as affiliate sites to the UK Automatic Urban and Rural Network (AURN). This Defra support assists the operation of the overall LAQN. Analysis of LAQN measurements has been augmented by measurements from the directly-funded Defra sites in London. Measurements from Defra sites were provided by AEA from the National Air Quality Archive and were included within the LAQN database. Transport for London (TfL) has also funded monitoring to help assess the air pollution impacts of the Low Emission Zone.

Measurement of air pollution is only part of the air quality management process in London. Other essential resources include the GLA and TfL funded London Atmospheric Emission Inventory (LAEI) and the extensive air pollution modelling toolkit developed at King's. New developments in air pollution modelling are detailed in this report.

Research at King's also focuses on measurement methods, specifically those for airborne particulate. This programme has led to the development of the Volatile Correction Model which uses measurements of volatile PM_{10} from FDMS equipment to allow TEOM PM_{10} measurements to be reported as equivalent to the EU reference method.

The founding of the LAQN was driven by concerns about the health effects of air pollution and research in this area forms an important part of the LAQN activities today. This includes not only the provision of measurements for health studies but also the direct measurement of the toxicity of airborne particles.

The Volatile Correction Model and measurements of PM toxicity are summarised in this report.

1. Recent trends in London's air pollution

Air quality strategy objectives and EU Limit Values

There is ample evidence of the adverse health effects caused by air pollution (WHO, 2006). In response to these health impacts, the Air Quality Strategy (AQS) for England, Scotland, Wales and Northern Ireland (Defra, 2008) sets out the UK's way forward on air quality issues, details objectives to be achieved, and proposes measures to help reach them. These UK objectives largely reflect EU Limit Values (EU, 2008). The GLA and the London boroughs and district councils outside the capital have responsibilities for the management of air quality and must work towards the attainment of AQS objectives. The AQS Objectives and EU Limit Values are detailed in Table 1. Monitoring progress towards the attainment of these Objectives and Limit Values forms a core activity for the LAQN. The following section details the spatial distribution and trends in the concentration of these pollutants in London and the surrounding region.

Table 1 AQS Objectives and EU Limit Values

Pollutant	Measured as	AQS objective	AQS attainment date	EU limit or target value	EU attainment date
Carbon monoxide (CO)	Max daily 8h mean	10 mg m^{-3}	31 December 2003	10 mg m^{-3}	1 January 2005
Nitrogen dioxide (NO_2)	Annual mean	40 $\mu g\ m^{-3}$	31 December 2005	40 $\mu g\ m^{-3}$	1 January 2010
	Hourly mean	200 $\mu g\ m^{-3}$ not to be exceeded more than 18 times per year	31 December 2005	200 $\mu g\ m^{-3}$ not to be exceeded more than 18 times per year	1 January 2010
Ozone (O_3)	8h mean	100 $\mu g\ m^{-3}$ not to be exceeded on more than 10 days per year	31 December 2005	120 $\mu g\ m^{-3}$ not to be exceeded more than 25 days per year averaged over 3 years	31 December 2010
PM_{10} particles	Daily mean	50 $\mu g\ m^{-3}$ not to be exceeded more than 35 times a year	31 December 2004	50 $\mu g\ m^{-3}$ not to be exceeded more than 35 times a year	31 December 2004
	Annual mean	40 $\mu g\ m^{-3}$	31 December 2004	40 $\mu g\ m^{-3}$	31 December 2004
$PM_{2.5}$ particles	Annual mean	25 $\mu g\ m^{-3}$	2020	25 $\mu g\ m^{-3}$	1 January 2010
	Annual mean at background sites averaged over 3 years	20 $\mu g\ m^{-3}$	2020	20 $\mu g\ m^{-3}$	2015
	Annual mean at background sites	15% reduction	2010-20	0-20% reduction depending on 2010 concentration	2010-20
Sulphur dioxide (SO_2)	15 minute mean	266 $\mu g\ m^{-3}$ not to be exceeded more than 35 times a year	31 December 2005		
	Hourly mean	350 $\mu g\ m^{-3}$ not to be exceeded more than 24 times a year	31 December 2004	350 $\mu g\ m^{-3}$ not to be exceeded more than 24 times a year	1 January 2005
	Daily mean	125 $\mu g\ m^{-3}$ not to be exceeded more than 3 times a year	31 December 2004	125 $\mu g\ m^{-3}$ not to be exceeded more than 3 times a year	1 January 2005
Benzene	Annual mean	5 $\mu g\ m^{-3}$	31 December 2010	5 $\mu g\ m^{-3}$	1 January 2010
1,3 Butadiene	Annual mean	2.25 $\mu g\ m^{-3}$	31 December 2003		
Lead	Annual mean	0.5 $\mu g\ m^{-3}$	31 December 2004	0.5 $\mu g\ m^{-3}$	1 January 2005

The LAQN annual mean index

Analysis of air pollution trends is important to determine the effect of air quality management interventions and progress towards the attainment of air quality objectives. Previous LAQN annual reports have focused on tracking changes using the LAQN pollution index. The LAQN index is based on annual mean concentrations and tracks changes since 1996 at a sample of long-term monitoring sites. The LAQN index was set to 100 for each pollutant during the year ending November 1996.

Figure 1 shows the LAQN index values for CO, PM_{10} and SO_2. Over the period of the index CO and SO_2 exhibited statistically significant downward trends at 95% confidence interval. No statistically significant trend was present for PM_{10}. The annual mean concentration of SO_2 has demonstrated the most dramatic change having fallen by 78% to the end of 2007. Recently, the rate of SO_2 decrease diminished, compared to that experienced during the late 1990s, with a decrease of 2% per year during 2006 and 2007. Similarly important decreases have been measured in the annual mean concentration of CO, which fell by 56% to the end of 2007, with a continued decrease of 5% per year during 2006 and 2007. Although the annual mean PM_{10} concentration fell by a total of 28% up to the end of 2007, the decrease in annual mean concentrations was achieved in the period up to late 2000 and the index shows evidence of a steady increase since this time at a mean rate of around 0.4 % per year. During 2006 the PM_{10} index increased by 3.5% and then fell by 2.5% during 2007 to give a mean increase of 0.5% per year in line with the mean rate of change from 2000.

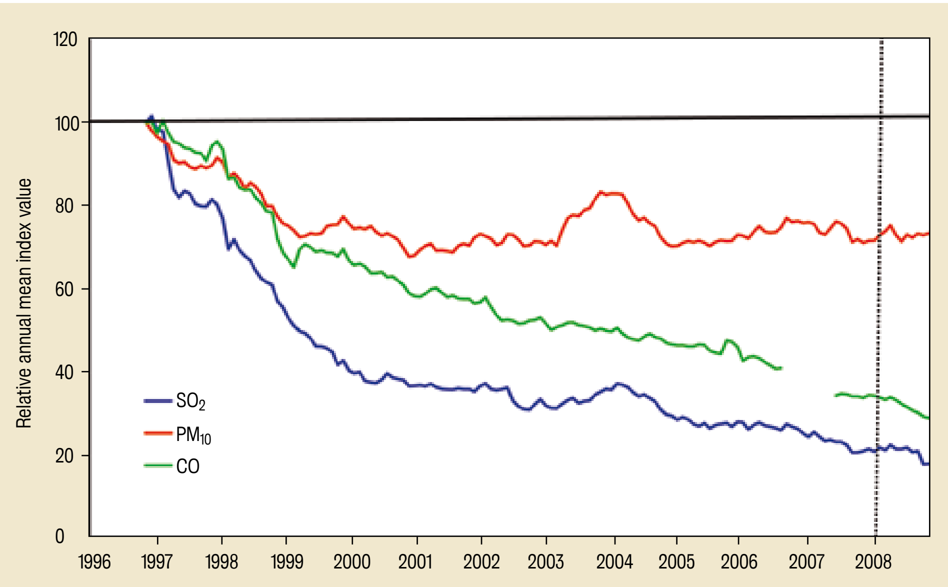


Figure 1 LAQN annual mean index values for CO, PM_{10} and SO_2. Measurements following the dashed line were provisional.

LAQN Annual Mean Index

Measurements from a range of site types were used to derive the LAQN annual mean index. However, due to measurement availability, different sites were used for each pollutant. The sites used in the index were revised in 2004 and again in 2005 to reflect the changing availability of pollution measurements. This was to ensure that the index for each pollutant was based on measurement sites with the longest datasets and to represent the range of pollution concentrations experienced in the network. Six long-term sites were used for the PM_{10} calculation, seven for CO, O_3 and SO_2, and 16 for NO_X and NO_2. It should be noted that measurements during 2008 were provisional and subject to ratification.

Figure 2 shows the LAQN index values for NO_X, O_3 and NO_2. Over the period of the index, statistically significant downward trends have been exhibited by NO_X and NO_2. O_3 shows a statistically significant upwards trend. The annual mean concentration of NO_X has shown the greatest overall decrease of these three pollutants with a fall of 37% to the end of 2007. However, during 2006 and 2007 the annual mean concentration of NO_X had a mean decrease of just 1% per year and if we also consider provisional measurements from 2008 there is evidence to suggest that annual mean concentrations of NO_X have stabilised despite the continued turn-over in the vehicle fleet with older vehicles being replaced by newer ones that emit less pollution. This relative stability in NO_X concentrations contrasts with the continued decrease in CO, which also arises substantially from road transport sources. Abatement of NO_X emissions are needed to control NO_2 concentrations. Within this context, medium term stability in NO_X concentrations, and therefore NO_X emissions give rise to concern regarding future NO_2 concentrations. However, the mean concentration of NO_2 did decrease by 14% by the end of 2007, around 1/3 of the decrease in concentrations of NO_X. The slow response of the annual mean concentration of NO_2 to decreases in the concentration of NO_X is due to the role that atmospheric chemistry plays in the formation of NO_2 and also due to changes in the fraction of NO_X that is emitted directly as NO_2. The annual mean concentration of O_3 is the only pollutant to have increased during the period of the index. Up to the end of 2007 the annual mean concentration of O_3 increased by 37%.

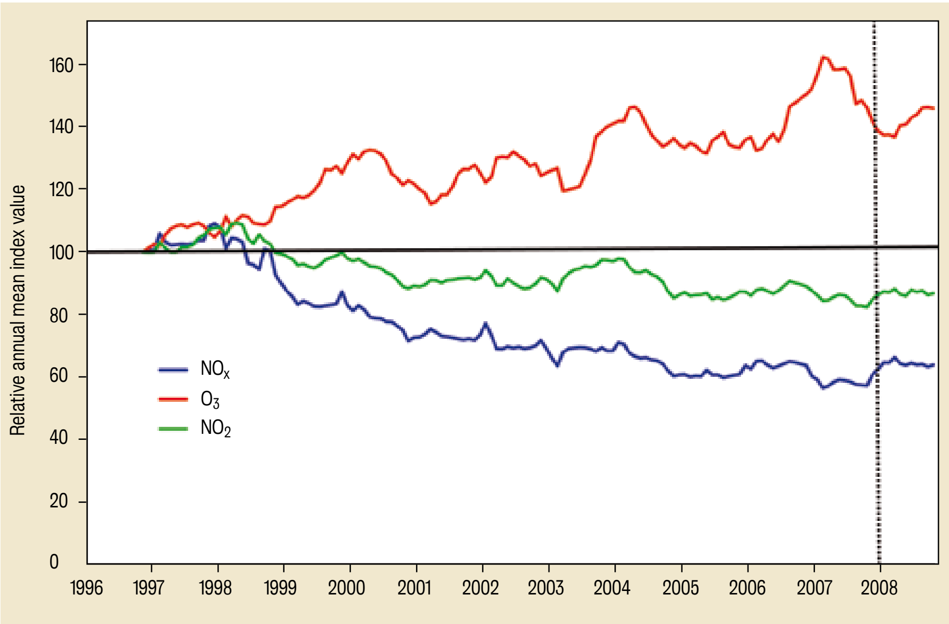


Figure 2 LAQN annual mean index values for NO_X, O_3 and NO_2. Measurements following the dashed line were provisional.

Although the LAQN index is a very useful indicator of the change in annual mean concentration of air pollution in London the index does not show the differences in concentrations between site types eg roadside and background and between different areas of London. A more detailed approach has therefore been taken in this report that looks at concentrations measured at different locations and different site types in London. The analysis below shows monthly mean concentrations and smoothed trend lines (to minimise the variations caused by seasonal effects). Measurements were grouped into four classes – Background (BG) Outer London, Background (BG) Inner London, Roadside (RS) Outer London and Roadside (RS) Inner London. 'Inner London' was defined here as within approximately 7 km of the centre of London. Additionally, measurements from the Marylebone Road (MY1) kerbside site are shown to represent concentrations occurring alongside the busiest roads in central London. This more detailed analysis requires more monitoring sites than that used in the LAQN index, for this reason, the more detailed analysis below applies to the period from the end of 1997.

Figure 3 (right) Monthly mean and smoothed CO concentrations in London.

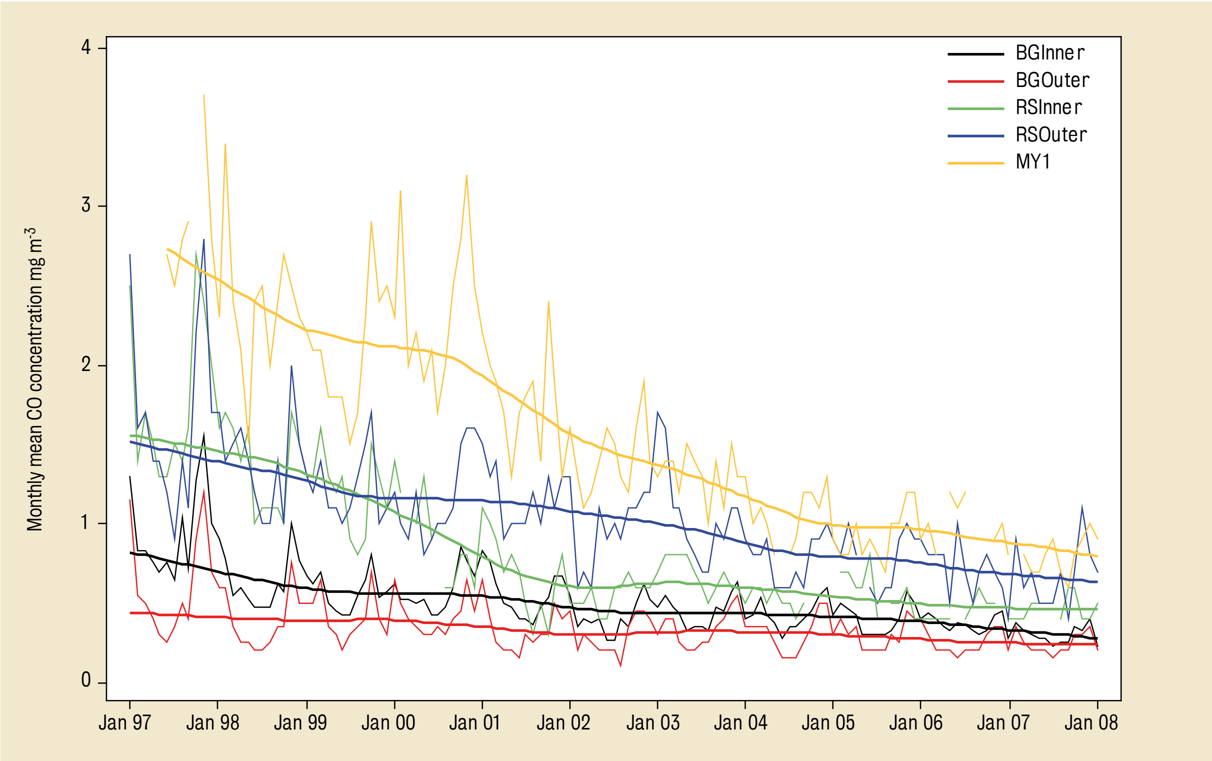
Note: there is little long-term monitoring of CO at roadside sites in London. The apparent excess in CO concentrations at roadside sites in outer London when compared to inner London is an artefact of the specific monitoring sites used in the analysis (Tower Hamlets 2 – Mile End Road and Ealing 2 – Acton) and is unlikely to represent concentration differentials between most inner and outer London roads.

CO

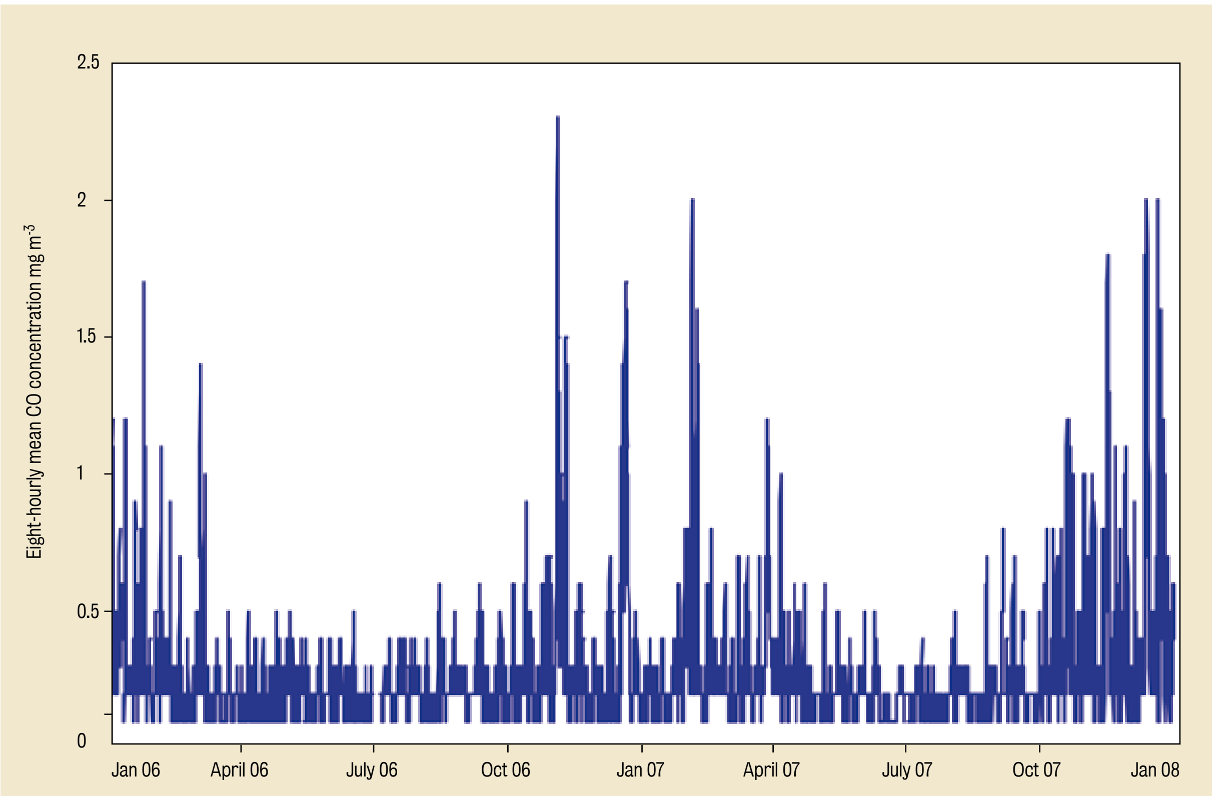
Monthly mean CO concentrations in London are shown in **Figure 3**. CO is a primary pollutant and concentrations are greatest at roadside sites in London reflecting the fact the road traffic is the dominant source of CO emissions in London. As shown in **Figure 3**, CO concentrations in London exhibit a clear seasonality with higher concentrations measured in winter due to reduced pollution dispersion at this time. CO concentrations show clear reductions across all site types due to the effective abatement of vehicle sources. As a consequence, the AQS Objective and EU Limit Value for CO was attained at all sites during 2006 and 2007 and has not been breached in London since 2000. Measurements of CO concentrations at the Bexley 1 suburban site are shown in **Figure 4**. This clearly shows greater concentrations during wintertime and also shows several wintertime episodes. Elevated concentrations during the late part of 2007 are also apparent. These episodes are discussed in more detail with respect to NO_2 and PM_{10}, below. However, even during CO episodes, concentrations were not more than 33% of the AQS Objective and EU Limit Value of 10 mg m^{-3}.

Figure 4 (right) Eight hour mean concentrations of CO at the Bexley 1 suburban site during 2006 and 2007.

Although concentrations of CO in London are below the AQS Objective and EU Limit Value, there is some recent evidence of health effects from CO in European cities at the concentrations of CO currently experienced in London (Samoli et al, 2007). With an atmospheric lifetime of several months, CO emissions are also important precursor to the formation of the global background concentration of O_3 (AQEG, 2008). For these reasons further reductions in CO emissions are desirable.



Monthly mean CO concentration mg m-3
0
1
2
3
4
BGInner
BGOuter
RSInner
RSOuter
MY1
Jan 97
Jan 98
Jan 99
Jan 00
Jan 01
Jan 02
Jan 03
Jan 04
Jan 05
Jan 06
Jan 07
Jan 08



Eight-hourly mean CO concentration mg m-3
0
0.5
1
1.5
2
2.5
Jan 06
April 06
July 06
Oct 06
Jan 07
April 07
July 07
Oct 07
Jan 08

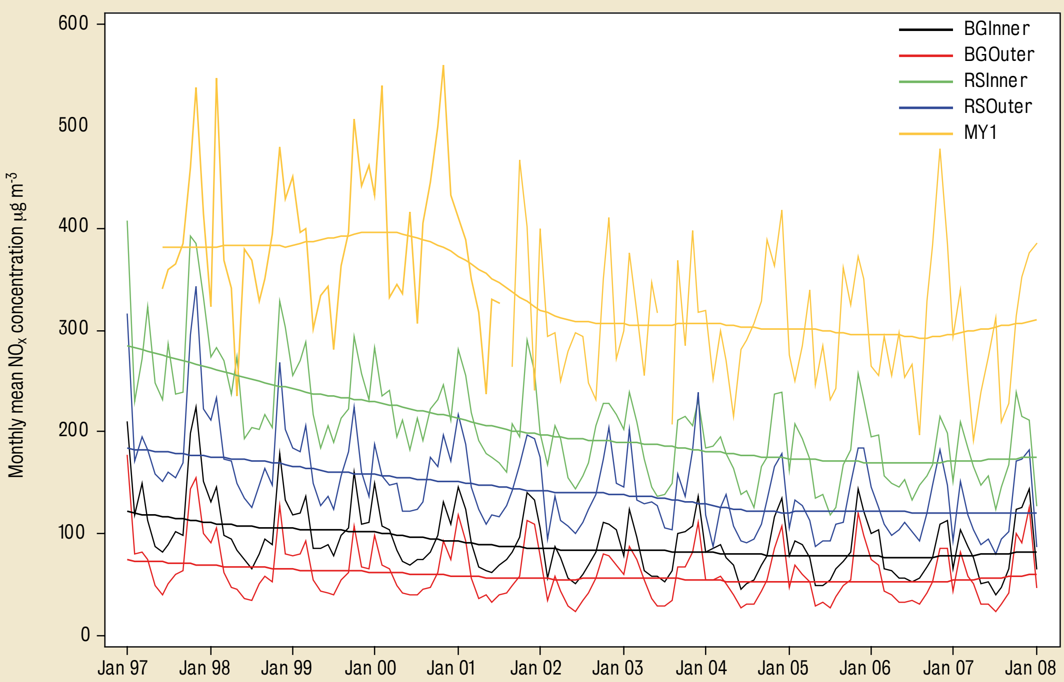
NO_X and NO_2

NO_2 is largely a secondary pollutant with concentrations being determined by a combination of emissions of both NO and NO_2 and the capacity of the atmosphere to convert NO to NO_2. For this reason concentrations of NO_2 cannot be understood without considering the total concentrations of NO and NO_2, termed NO_X. Monthly mean NO_X concentrations are shown in **Figure 5**. Due to traffic emissions, mean NO_X concentrations are greater at roadside locations when compared with background. NO_X concentrations at all site types show a clear seasonal variation with the greatest concentrations being measured in winter due to poor pollutant dispersion at this time. Overall, concentrations of NO_X have fallen across all site types with concentrations falling fastest at roadside sites, though the rate of decline decreased around 2001 and concentrations were stable during 2005 and 2006. The overall decrease in NO_X concentrations reflects the abatement of vehicle emissions; however, the recent stability gives rise to concern regarding control of NO_2 concentrations. There was a rise in NO_X concentrations at the end of the 2007 due to a series of pollution episodes discussed below. The sharp decrease in NO_X concentrations at Marylebone Road during 2001 in **Figure 5** reflected the introduction of a bus lane at this time.

In line with NO_X concentrations, concentrations of NO_2 (**Figure 6**) were also greatest at roadside sites with lower concentrations measured at background locations. Like NO_X, NO_2 concentrations are generally higher in wintertime due to poor dispersion.

Figure 5 Monthly mean and smoothed NO_X concentrations in London.

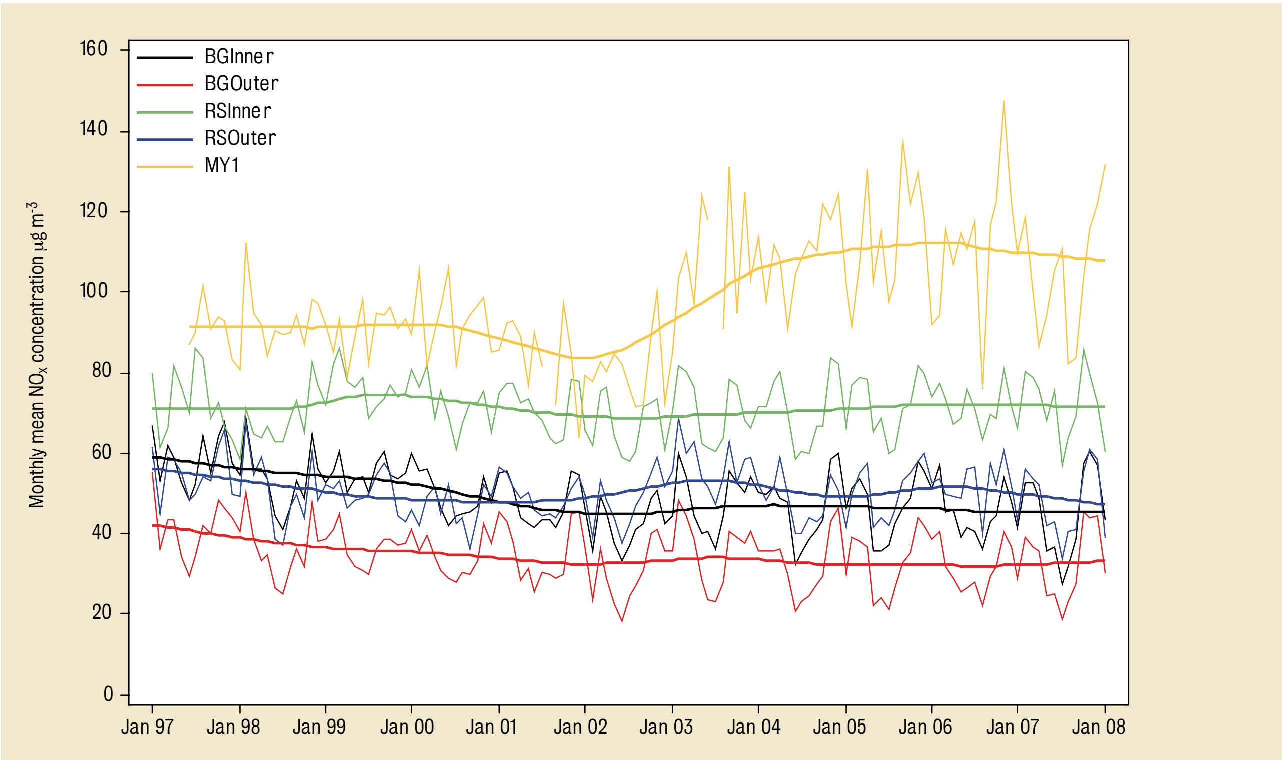
Note: The sharp reduction in NO_X concentrations at Marylebone Road during 2001 in Figure 5 reflected the introduction of a bus lane at this time.



Background NO_2 concentrations declined until 2002 but have been relatively stable since. Importantly, the annual mean AQS Objective and EU Limit Value of 40 µg m^{-3} has been attained at background sites in outer London only and this concentration has been consistently breached at background sites in inner London and at roadside sites throughout London. During 2006 and 2007, the annual mean objective was breached at all except a few roadside sites and it was also breached at background sites across inner and parts of east and west London. The mean concentration of NO_2 at roadside sites in inner London breached the annual mean AQS Objective and EU Limit Value by a factor of almost two during 2006 and 2007 and five sites measured concentrations of over 100 µg m^{-3}. This has important implications for the UK government's intention to seek a five year extension to the 2010 date for attainment of the EU Limit Value; an extension may only be applied for if annual mean concentrations do not exceed the maximum 'margin of tolerance', which equates to a maximum annual mean concentration of 60 µg m^{-3} (EC, 2008).

NO_2 concentrations at roadside sites do not show a clear overall change since 1997, despite the reduction in NO_X concentrations at these sites. Further examination of roadside NO_2 concentrations on a site by site basis shows a range of changes from little overall change to increases of over 20% at some sites, including Marylebone Road as shown in **Figure 6**.

Figure 6 Monthly mean and smoothed NO_2 concentrations in London.



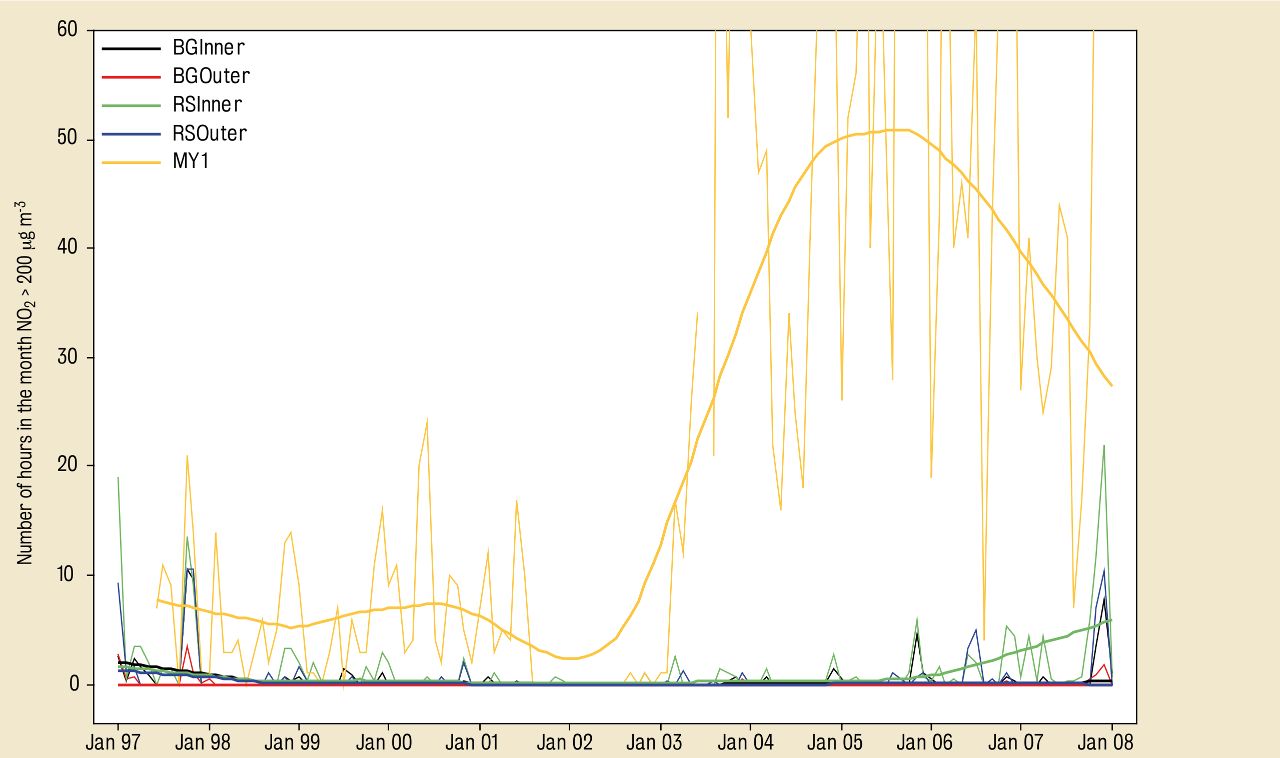


Figure 7 Monthly frequency of hourly mean concentrations of NO_2 above 200 µg m^{-3}. The scale has been truncated at 60 hours per month.

The increase in NO_2 at roadside sites has been due to an increase in primary NO_2 emissions from vehicle exhausts or more specifically an increase in the proportion of NO_X emitted as NO_2. These emission changes began around 1998-2001 and are thought to be due to changes in diesel vehicle technologies, including particle traps and oxidation catalysts, and an increase in the proportion of diesel vehicles on London's roads. Similar changes have been observed at other sites across the UK; although evidence of an increase in the proportion of NO_2 emitted as NO_X is less clear outside London. Looking to the future, it is thought that improvement in vehicle NO_X abatement will lead to an overall reduction in NO_2 concentrations by 2010, when compared to 2004, but this is subject to considerable uncertainty. (AQEG 2007, Carslaw 2005, Carslaw and Beevers 2004. Carslaw et al, 2007). Projections of future decreases in primary NO_2 do not include the possibility of an increase in NO_X emissions due to increased sales of new diesel vehicles, to attain future CO_2 reduction targets, (DfT, 2007) and this remains a concern.
The monthly frequency of NO_2 pollution episodes (breaches of the hourly mean AQS Objective and EU Limit Value concentration of 200 µg m^{-3}) are shown in **Figure 7**. It can be seen that the frequency of these episodes reached a minimum around 2001-2 (when no such episodes were measured for several months) and that the frequency of these episodes has increased since this time, with the December 2007 NO_2 episode being the most severe in London for ten years, as discussed below. Although not shown in **Figure 7**, the Lambeth 4 kerbside site has measured NO_2 concentrations above 200 µg m^{-3} on most days since the site was installed in 2004. During 2006 and 2007, 25 of 123 sites breached the hourly mean objective (18 hours per year above 200 µg m^{-3}) including two urban background sites.

Hourly mean concentrations of NO_2 at the inner London background site Kensington & Chelsea 1 are shown in **Figure 9** for 2006 and 2007. The wintertime NO_2 episodes

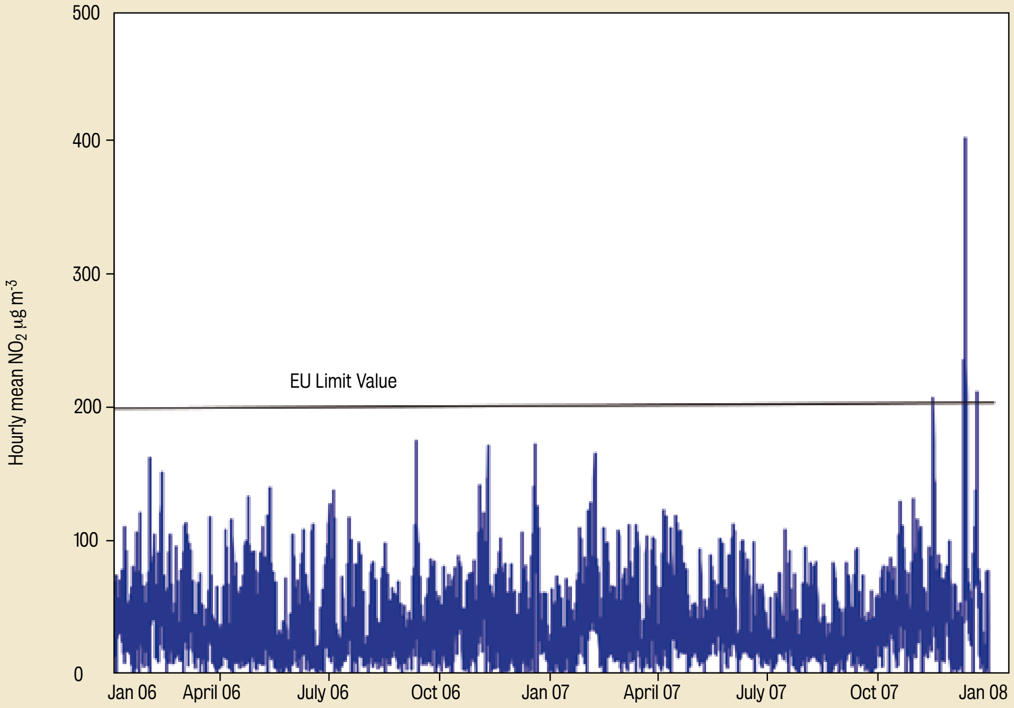


Figure 8 Hourly mean concentrations of NO_2 at the background site Kensington & Chelsea 1 site during 2006 and 2007. The hourly mean EU Limit Value concentration is shown.

during late 2007 can be seen with elevated concentrations being measured around 15 November and around the 11, 12 and 22 December. The episode of 11 and 12 December was notable not only for maximum concentrations, but also for the spatial extent of the episode; 74 monitoring sites in London and towns in south east England measured NO_2 concentrations above the EU Limit Value of 200 µg m^{-3}.

Given the spatial extent of breaches of the annual and hourly mean EU Limits and the new challenges posed by increases in primary emissions of NO_2 it is difficult to see how EU Limit Values for this pollutant will be met in London by 2010 without substantial new abatement measures.

The December 2007 NO_2 episode

The December 2007 NO_2 episode was the most severe to affect London since 1997. Given that these episodes were separated by ten years of NO_2 control measures it is important to consider the reasons why NO_2 concentrations were so high during the 2007 episode.

Pollution episodes are determined by the combination of emissions, pollutant dispersion and atmospheric chemistry. The effects of pollutant dispersion can be determined by considering concentrations of NO_X, a simple primary pollutant, rather than NO_2. It is clear that during the 2007 episode the peak hourly mean NO_X concentration at the Kensington & Chelsea 1 background site (1668 $\mu g\ m^{-3}$) was the highest measured at the site since 1997 (1925 $\mu g\ m^{-3}$). However, during this ten year period, annual mean NO_X concentrations at the site decreased by 41%, due to successful emissions control measures, and a direct comparison is therefore misleading. It is instead better to consider the ratio of the peak hourly mean NO_X concentration to the annual mean NO_X as an indicator of the dispersion conditions. Using this measure the 2007 episode has a ratio of 26 at Kensington & Chelsea 1 compared with 17 for the 1997 episode indicating that dispersion conditions during the 2007 episode were worse than 1997, relative to the average dispersion for each year. In fact, the 2007 episode has the greatest peak to mean NO_X ratio during the period 1997 to 2007. By way of comparison, the December 1991 episode, when background NO_2 concentrations reached a record 808 $\mu g\ m^{-3}$, had a peak hourly to annual mean NO_X ratio of 16 at the now closed Bridge Place monitoring site near Victoria. However, this simple ratio does not include the length of time that the episode persisted and minimum temperatures which were identified as important factors in the maximum NO_2 concentration in the 1991 episode (Bower et al, 1994).

Considerable insight into the complicated relationship between NO_2 and NO_X concentrations can be achieved by plotting mean NO_2 concentrations against NO_X as shown in **Figure 8**. The relationship between NO_2 and NO_X concentrations can be divided into two parts. For NO_X concentrations less than around 50 $\mu g\ m^{-3}$, there is sufficient O_3 present in the atmosphere to oxidise NO to form NO_2. At higher NO_X concentrations the NO_2 concentration is determined by other mechanisms that produce atmospheric NO_2, including primary emissions. It can be seen from **Figure 8** that higher concentrations of NO_2 were measured for given concentrations of NO_X during 2007 when compared with 1997. This means that the peak NO_X concentrations during the 2007 episode would have been linked to NO_2 concentrations of around 290 $\mu g\ m^{-3}$ during 1997, rather than the 390 $\mu g\ m^{-3}$ experienced during 2007.

It would therefore appear that the 2007 episode was caused by the combination of both exceptionally poor dispersion conditions and changes in the emissions ratio of $NO_2 : NO_X$.

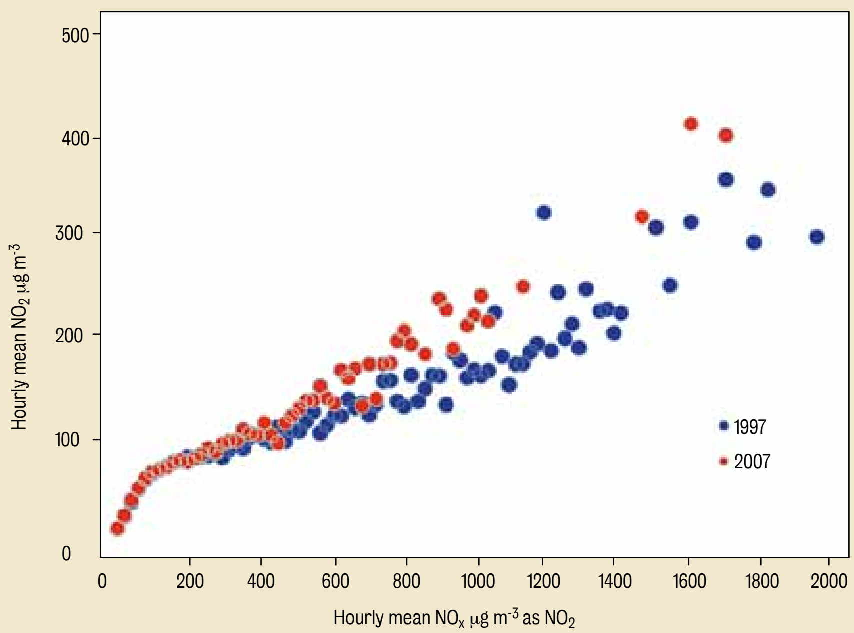


Figure 9 Hourly mean NO_2 against hourly mean NO_X concentrations at the background site Kensington & Chelsea.

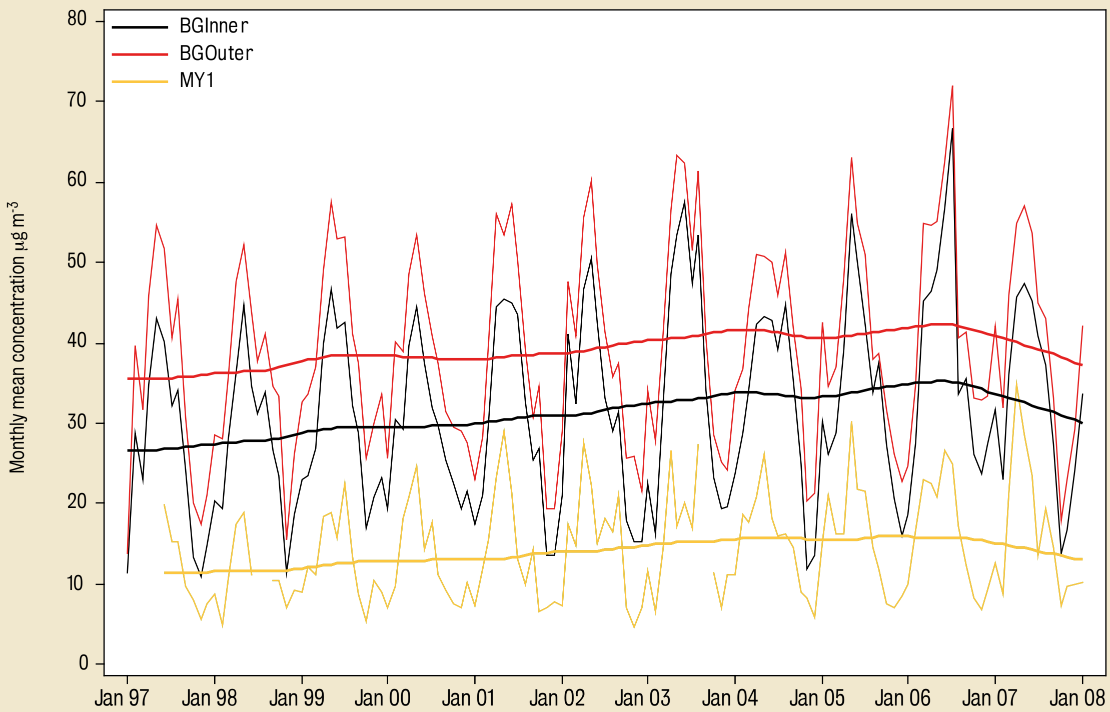
The mean NO_2 concentration is shown for each 20 $\mu g\ m^{-3}$ as NO_2 concentration bin for NO_X using the methods described in Derwent and Middleton (1996) and Carslaw et al (2001).

O_3

O_3 is important not only as a pollutant with direct human health and ecosystem consequences (in its own right) but it also plays an important role in the atmospheric production of NO_2 and PM_{10}.

Monthly mean O_3 concentrations are shown in **Figure 10**. It can be seen that O_3 concentrations exhibit a clear seasonality with the monthly mean concentrations being greatest during the spring and summer months. Mean concentrations in London exhibit a clear increase during the last ten years, although poor summer weather during 2007 lead to a decrease at this time. In contrast to concentrations of CO, NO_2 and PM_{10}, concentrations of O_3 are greatest at outer London background sites and lowest at the roadside. For this reason O_3 monitoring has not been historically undertaken at roadside sites and long-term roadside measurements in London are only available from Marylebone Road. More recently the need to assess primary NO_2 emissions has led to an increase in roadside O_3 measurement.

Figure 10 Monthly mean and smoothed O_3 concentrations in London.



O_3 is a secondary pollutant formed by atmopheric reactions between precursor pollutants in the presence of sunlight. These precursor pollutants include volatile organic gases and NO_X. Other gases with longer atmospheric lifetimes are also important in O_3 formation; including CO and methane. Trends in the mean concentration of O_3 in London are determined by three factors.

- An increase in the O_3 concentrations in the northern hemisphere has influenced the background concentrations that affect London. This change has been due to increases in the global emission of O_3 precursors. (AQEG, 2008).
- Reduction in the emissions of O_3 precursors across the UK and Europe have caused a decrease in O_3 concentrations during summertime smog episodes. These episodes lead to the peak concentrations of O_3 in London each year and occur when London is part of a shared continental air mass. The peak O_3 concentrations during these summertime smog episodes in London have decreased from those measured during the 1970s and 1980s. This was due to the abatement of precursor emissions in the UK and Europe although analysis of peak concentrations between 1997 and 2003 indicate relative stablity and an increasing trend in peak O_3 concentrations at some London sites (AQEG, 2008).
- The successful decrease in NO_X emissions within London has lead to an increase in O_3 concentrations in the city. Although London's NO_X emissions ultimately contribute to O_3 production, high concentrations of NO_X also lead to a local depletion of O_3 concentrations. The decrease in NO_X concentrations in London are thought to be the main cause of the increase in annual mean O_3 shown in Figure 10. With diminishing NO_X concentrations in the city, it is likely that future O_3 concentrations in London will more closely resemble those in surrounding rural areas (AQEG 2008).

The AQS Objective for O_3 is based on the frequency of O_3 episodes. This Objective has not been acheived at suburban background sites in London and, during adverse years such as the 2003 and 2006 'heat wave' years, background locations in inner London and at some roadside sites can also fail the Objective.

The mean hourly concentration of O_3 during 2006 and 2007 is shown in **Figure 11**. This is a mean of concentrations in suburban London and the area immediately beyond. The O_3 concentrations during 2006 and 2007 were clearly very different; 2006 was characterised by a series of summertime O_3 episodes during periods of so called 'heat wave' temperatures. By contrast, summer 2007 was cooler and wetter and 'high' ozone was not measured. The primary pollution incidents during November and December 2007 also led to lower O_3 concentrations at this time compared with 2006.

The maximum O_3 hourly mean concentrations during July 2006 were the greatest concentrations of O_3 measured since August 2003 (Fuller and Johnson, 2005) and affected all of London and south east England. During 2006 peak concentrations in south east England reached 257 $\mu g\ m^{-3}$, which was measured at Lodsworth in West Sussex. Elsewhere in the UK, peak concentrations reached 278 $\mu g\ m^{-3}$ at Wicken Fen in east Anglia. During this episode, the whole of south east England was affected by concentrations above the EU Information threshold (and the UK definition of 'high') of 180 $\mu g\ m^{-3}$. Concentrations in London were in general slightly lower than those in the surrounding networks with the greatest concentrations being measured at background

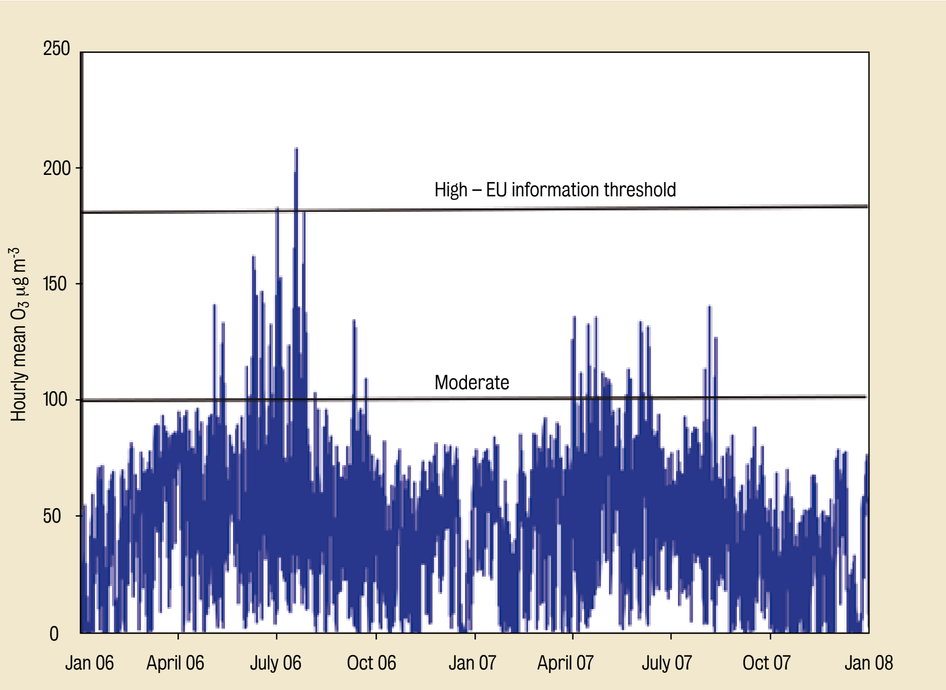


Figure 11 Hourly mean O_3 in outer London and the immediate surrounding area. This is a mean of measurements from Enfield 3 in north London, Kingston 1 and Bromley 5 in south London, Sevenoaks 2 in north west Kent and Windsor and Maidenhead 3 (Ascot) which is a research site owned and operated by Imperial College London. 'Moderate' and 'high' air quality bands indicated.

locations in north London: at Haringey 2 which measured 229 µg m^{-3} and at Enfield 3 which measured 222 µg m^{-3}. The peak concentrations in 2006 were slightly lower than those measured during August 2003 when peak hourly mean concentrations reached 262 µg m^{-3} at Enfield 3 in north London, at the Maidstone 3 rural site in Kent and at the Mid Beds 2 and Dacorum 1 sites in the Hertfordshire and Bedfordshire Network; slightly less than the European peak for the episode of 296 µg m^{-3} which was measured in Belgium (Solberg at al, 2003).

Solberg et al, (2003) suggested that several factors contributed to the elevated peak O_3 concentrations during the August 2003 episode, including drought conditions which reduced the rate of removal of O_3 from the troposphere by plants, CO from wild fires in Siberia which increased summer background O_3 concentrations throughout the northern hemisphere and wild fires in the Iberian peninsula which made a specific contribution to the August 2003 episode. Detailed analysis of the factors that determined the 2006 episode has not yet been undertaken. Derwent et al, (2009) suggested that the 2006 episodes may also have been influenced by emissions from wild fires in Russia which affected PM_{10} concentrations in the UK during spring 2006 (Whitham et al, 2008). However, analysis of back trajectories for 18 July 2006, at the peak of the episode show that the air in London on the 18th had passed through Scandinavia and the high precursor emission areas of northern Germany and the Low Countries during the previous five days, as shown in **Figure 12**, a pattern typical of O_3 episodes in the UK.

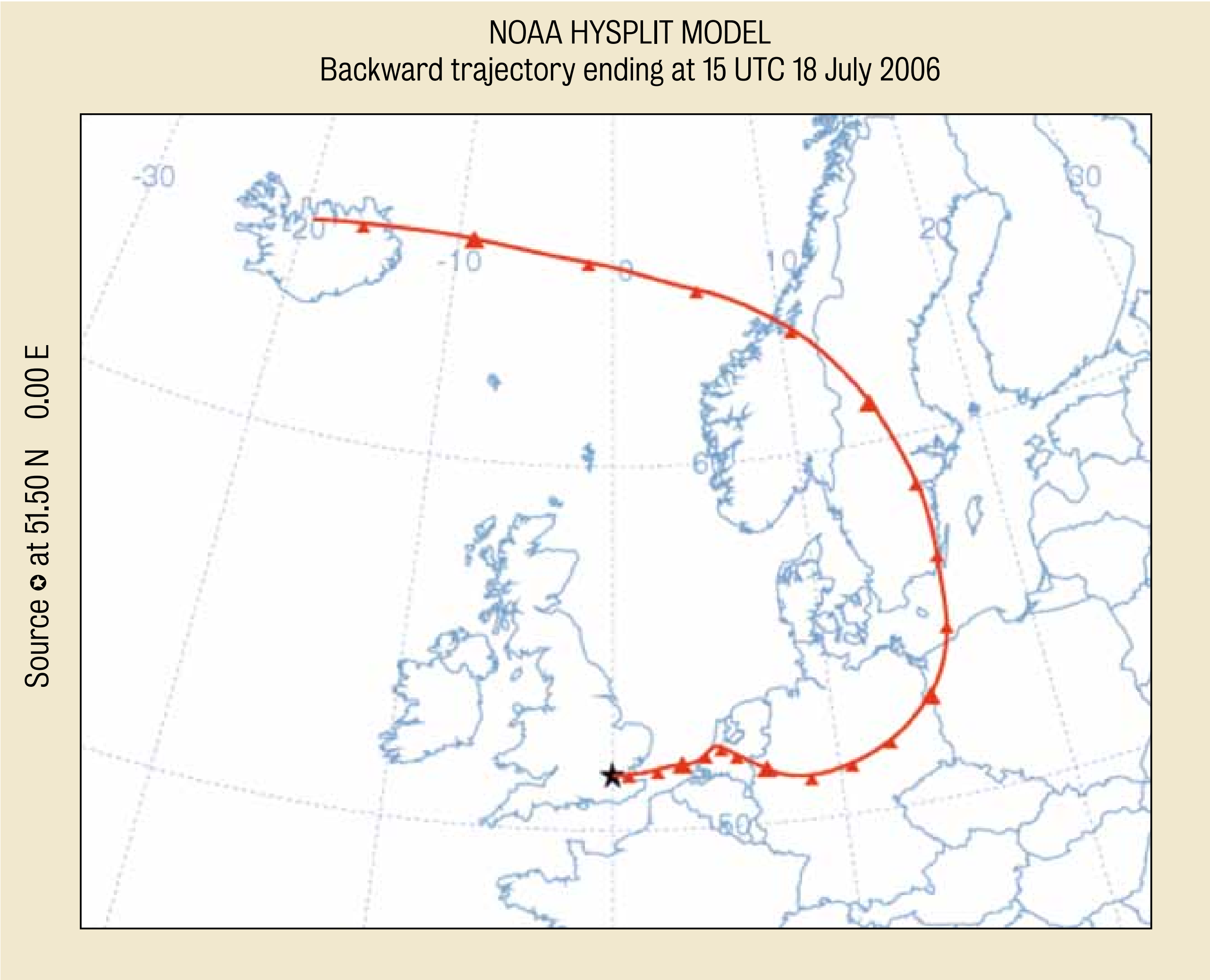


Figure 12 Back trajectory for London for 15.00, 18 July 2006 from NOAA HYSPLIT.

Peak O_3 concentrations in the UK have been considered in detail by AQEG (2008). They found evidence of a clear downward trend in peak O_3 concentrations between 1990 and 2006, which has been attributed to a decrease in the European emissions of O_3 precursors, mainly NO_X and volatile hydrocarbons. Peak hourly mean O_3 concentrations during 2003 and 2006 were less than those measured during the early 1980s, when concentrations were between 298 µg m^{-3} and 414 µg m^{-3} (Targa et al, 2006). The peak concentrations measured in 2003 and 2006 were around half of the UK record concentration of 508 µg m^{-3} which was measured at Harwell during the 1976 heat wave (PORG, 1993).

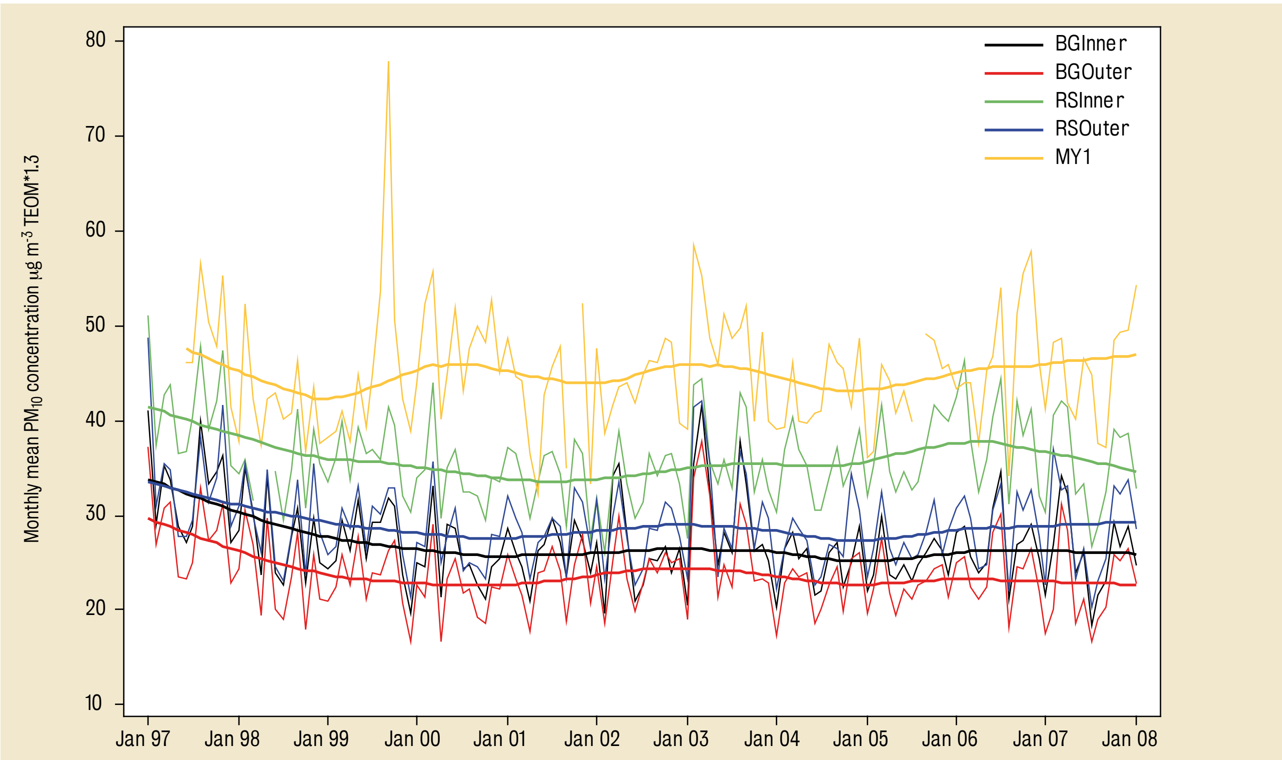
Such epsiodes illustrate the transboundary nature of O_3 episodes and although measures to reduce the emissions of O_3 precursors in London have an important part to play in controlling O_3 across the whole of the UK and Europe, modelling studies indicate that there is almost no scope for effective London-wide control measures focused on reducing O_3 concentrations in London itself. (AQEG 2008).

PM_{10}

PM_{10} comprises particles with different chemical composition from a variety of sources including primary emissions, secondary particles produced by chemical reactions in the atmosphere and particles from natural sources such as windblown dust and sea salt. Mean PM_{10} concentrations are shown in **Figure 13** from TEOM instruments following application of the Defra recommended 1.3 gravimetric correction factor to compensate for losses of volatile particulate from TEOMs. Due to the composite nature of PM_{10}, mean concentrations show far less seasonality than NO_X and O_3 with different components being affected by seasonal meteorological conditions in different ways. Peaks in mean PM_{10} concentrations occur during prolonged periods of stable weather conditions when high-pressure systems bring polluted air masses from Europe across London and the south east, and peak concentrations also occur during wintertime due to poor dispersion of PM_{10} emitted in London. Emissions of PM_{10} from transport sources generally determine the spatial differences in PM_{10} concentrations in London which are superimposed on regional concentrations. Due to the magnitude of the regional PM_{10} component, annual mean concentrations alongside major roads, such as Marylebone Road, are only around twice those experienced at outer London background sites. Although not shown in **Figure 13**, the greatest PM_{10} concentrations in London are not found alongside busy roads but on residential roads close to waste sites where PM_{10} concentrations can breach the AQS Objective and EU Limit Values by a wide margin. Few long-term measurements of $PM_{2.5}$ are available in London but this situation is set to improve following the recent installation of new monitoring equipment by TfL, some London Boroughs and by Defra.

Figure 13 Monthly mean and smoothed PM_{10} concentrations in London.

Note: Decreases in the annual mean PM_{10} concentration at inner London roadside sites arise from decreased concentrations at the Camden 1 kerbside site and are not representative of improvements across inner London.



The annual mean PM_{10} EU Limit Value and AQS objective of 40 µg m^{-3} TEOM*1.3 was breached at eight roadside and industrial monitoring sites during 2006 and at seven such sites during 2007. The more stringent episode based AQS Objective and EU Limit Value is regularly breached alongside major roads in the capital but has been attained at most background sites since the late 1990s. The episode based AQS Objective was breached in London at 20 sites during 2006 and at 19 sites during 2007, again using TEOM*1.3 correction. Using the new Volatile Correction Model (VCM) to correct TEOM measurements confines the breaches of the annual mean Limit Value to sites close to waste management facilities during both 2006 and 2007. Using the VCM, sites close to waste management facilities and the busiest sections of London's trunk road network still exceeded the daily mean Limit Value; however, the number of sites exceeding the daily mean Limit Value decreased from 20 to 15 sites during 2006 and from 19 to 16 sites during 2007. The VCM is described in more detail in Section 5.

Mean PM_{10} concentrations in London decreased during the late 1990's but have been relatively stable since. London is not alone is this regard; throughout north western Europe the PM_{10} decreases experienced during the 1990s have not continued this century. Although considerable efforts have been made to abate emissions of PM_{10} and PM_{10} precursor pollutants in London, the UK and throughout Europe, it is unclear why such abatement measures are not yielding a reduction in measured PM_{10} concentrations (Harrison et al, 2008). Closer examination of the measurements shown in **Figure 13** show evidence of an increase in PM_{10} concentrations at roadside sites since 2000-1 and an increase in the difference between roadside and background concentrations. These changes suggest an increase in PM_{10} concentration arising from London's emissions. Source apportionment of annual mean PM_{10} concentrations also suggest an increase in the concentration of primary PM_{10} emissions in London between 1999 and 2004 and that this is most likely due to increases in emissions from road transport. The apparent rise in primary PM_{10} emissions in London contrasts with emissions inventory predictions based on progressive abatement of PM_{10} emissions and the specific programmes instigated in London including the fitting of particle filters to TfL buses and the associated benefits of the congestion charging scheme (Fuller and Green 2006, Beevers and Carslaw, 2005). As with NO_2, the benefits of abatement may be offset by the increasing proportion of diesels in the UK vehicle fleet; diesels rose from 16% in 1997 to 38% in 2006. Additionally, new commercial vehicles in the UK increased by 41% between 1997 and 2006 and over 97% of commercial vehicles sold in 2006 were diesel. New vehicle sales provide an excellent marker for change in the total vehicle fleet but it is the total fleet that must be considered for emission purposes. Between 1997 and 2005 the total diesel vehicles in the UK increased by 127% and overall sales of diesel fuel in the UK increased by 30%. (SMMT, 2007). However, the proportion of diesel vehicles in the UK new car market remains relatively low compared with the mean of 49% across Europe (SMMT, 2005). It is also possible that changes in non-tailpipe emissions may have contributed to increased primary PM_{10} through increased vehicle weights (SMMT, 2007; Carslaw 2006) and changes in tyre and break technologies.

IMAGE: BECKY FULLER

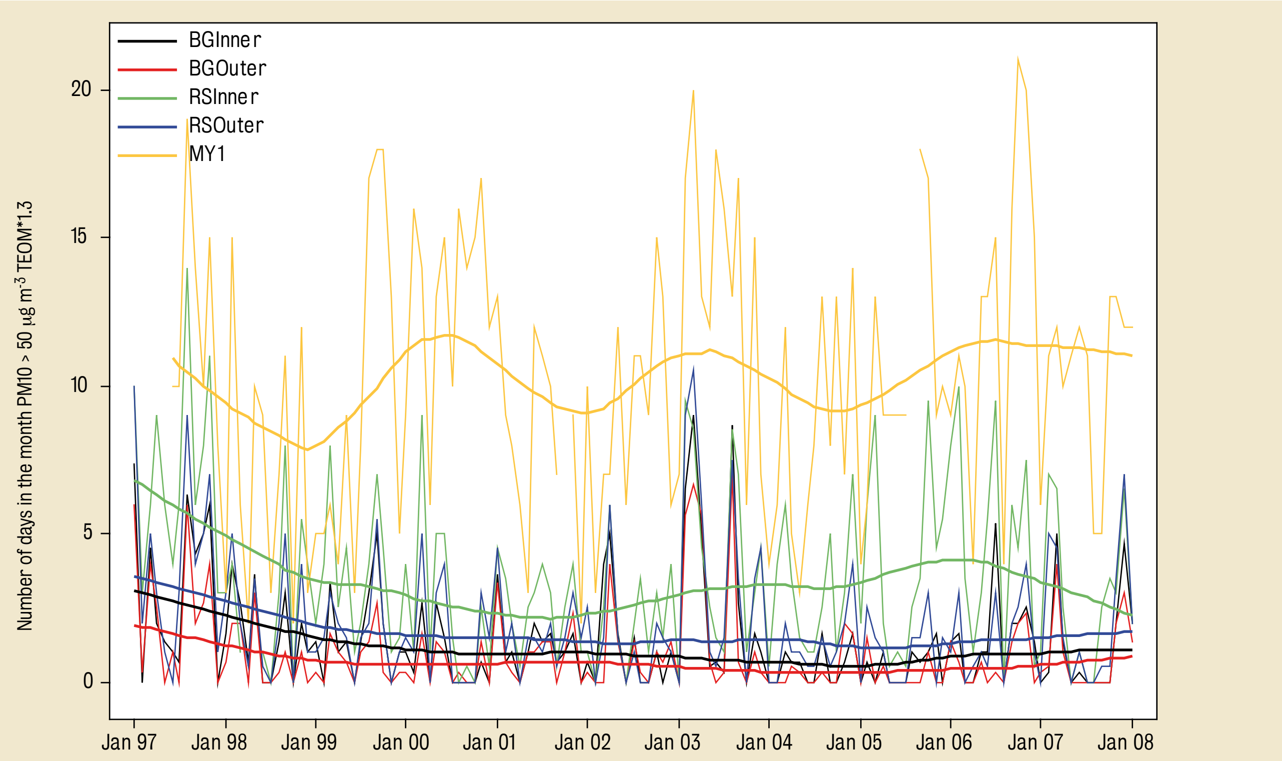


Figure 14 Monthly frequency of daily mean PM_{10} concentrations above 50 µg m^{-3} TEOM*1.3.

Note: decreases in the frequency of daily mean PM_{10} concentrations above 50 µg m^{-3} TEOM*1.3 at inner London roadside sites arise from decreased concentrations at the Camden 1 kerbside site and are not representative of improvements across inner London.

Figure 14 shows the monthly frequency of days with mean PM_{10} above 50 µg m^{-3} TEOM*1.3. The frequency of these episodes declined in the late 1990s and has been relatively stable since with notable episodes during 2003, winter 2006 and winter 2007. Episodes were absent at most sites during the poor summer weather during 2007.

Figure 15 shows the daily mean concentration of PM_{10} during 2006 and 2007 measured by TEOM at the Ealing 2 roadside site in west London. The measured concentration has been apportioned between primary sources, non-primary sources and the TEOM mathematical offset. Primary sources are those that are also sources of NO_X. Non-primary sources will include both secondary and natural PM_{10} (Fuller and Green, 2006; Fuller et al, 2001). It can be seen from Figure 15 that the majority of PM_{10} measured at this site does not come from primary sources. During 2006, PM_{10} episodes (those with mean concentrations above 50 µg m^{-3} TEOM*1.3) were measured throughout the year with the greatest concentrations being measured during the last quarter. A different distribution of episodes was measured during 2007, with episodes mainly occurring during wintertime and an absence of episodes during the poor weather in the late summer. In contrast to the summertime pollution episodes during 2003, the summertime pollution episodes in 2006 were not associated with widespread breaches of the EU Limit Value concentration (A). Guy Fawkes night events caused notable episodes during both 2006 (B) and 2007 (D); the 2006 episode led to the greatest daily mean PM_{10} concentration measured at Ealing 2 during the two years. However the wintertime primary episodes during November and December 2007 caused the EU Limit Value concentration to be exceeded at Ealing 2 (E) and also affected sites throughout London.

Not all PM_{10} episodes are caused by anthropogenic sources. During spring 2006, most of the northern UK experienced a PM_{10} episode caused by Russian forest fires (Whitham et al, 2007) although this episode did not affect London. From a London perspective a more notable episode was caused by dust storms, following a dry period, in the Southern Ukraine that caused the EU Limit Value concentration to be exceeded widely across central Europe. The greatest PM_{10} concentrations during this episode were measured in Slovakia where a peak hourly mean concentration of 1400 µg m^{-3} was measured on the 24 March 2007 (Brimili et al, 2008). In London, PM_{10} concentrations from the episode were around 1/10th of that measured in Eastern Europe, concentrations peaked at around 140 µg m^{-3} TEOM*1.3 during the early hours of Sunday 25 March 2007 (C). The new EU Directive (EC, 2008) allows for the removal of such natural episodes from the assessment of compliance with the Limit Value, however, protocols for the quantification

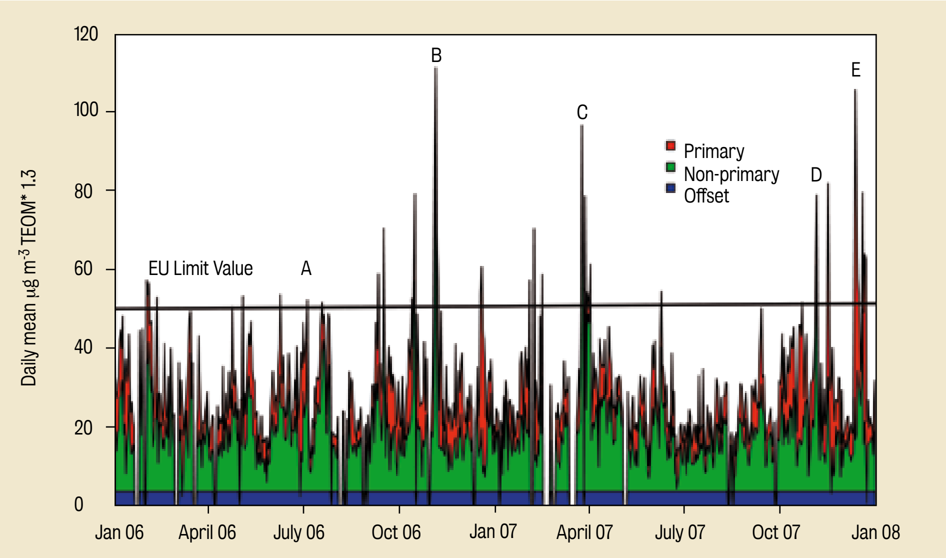


Figure 15 Source apportioned daily mean concentrations of PM_{10} at the roadside site Ealing 2.

Note: concentrations measured by TEOM have been apportioned between primary PM_{10}, non-primary PM_{10} and the TEOM offset.

PM_{10} from natural sources have not yet been established at the EU level. The removal of PM_{10} from natural episodes is an effective weakening of the EU Limit Values and is not consistent the underpinning health evidence upon which the Limit Values were based.

EU and UK air quality policy is focused on the attainment of mass based concentrations for PM_{10} and $PM_{2.5}$, although it is acknowledged that better metrics for the health effects of airborne particles may be developed in the future. Recent Defra funded research in London has looked at short-term health outcomes and changes in daily mean concentrations of different measurements of particle mass concentration and composition. Measurements of particle mass concentrations eg PM_{10} and $PM_{2.5}$ were found to be associated with short-term increases in respiratory health effects while changes in particle number concentrations were associated with cardiovascular effects (Atkinson et al, 2009).

Particle number counts are routinely undertaken by the National Physical Laboratory and King's as part of Defra funded research at the Kensington and Chelsea 1 background site in inner London and at Marylebone Road. Further measurements of particle number at LAQN sites are being funded by TfL as part of the assessment of the London Low Emission Zone. Measurements of particle number concentration from Kensington & Chelsea 1 are shown in **Figure 16**. Particle number concentrations are greatest in winter-time reflecting the primary traffic sources, with lower concentrations measured during the

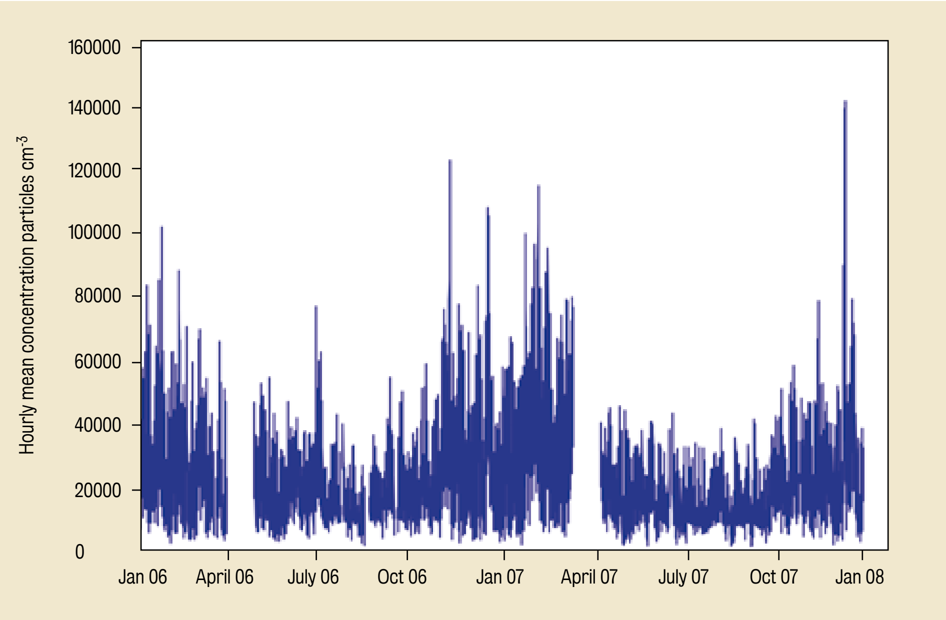


Figure 16 Hourly mean particle number concentrations measured at the Kensington & Chelsea 1 background site in inner London.

summer when atmospheric dispersion is greater. Elevated particle number concentrations were measured during the primary pollution episodes of December 2007 but also during winter 2006-7.

Particle number concentration is only one of the alternative particle metrics that are being studied to achieve a better focus on the physical and chemical properties of PM that responsible for health effects. Further work in this area is described in section 6. The new EU Directive also includes new attainment values for $PM_{2.5}$; an annual mean concentration of 25 µg m^{-3} to be achieved everywhere by 2010, an annual mean concentration of 20 µg m^{-3} to be achieved at background sites by 2015 and requirement to reduce annual mean $PM_{2.5}$ concentrations between 2010 and 2020. In the UK's case this exposure reduction target is likely to be 15-20%. Correction factors for the measurement of $PM_{2.5}$ have not yet been established for the UK, however, limited available measurements suggest that $PM_{2.5}$ concentrations in the UK are less than 25 µg m^{-3} at roadside locations such as Marylebone Road and background concentrations are less than 20 µg m^{-3}. The exposure reduction target is therefore likely to become a main focus for air quality policy.

SO_2

SO_2 is emitted from the combustion of oil and coal. Monthly mean concentrations of SO_2 are shown in **Figure 17**. Concentrations of SO_2 in London showed a clear seasonality during the late 1990s but this is less evident in recent years. SO_2 concentrations in London show a marked reduction across all site types, although the rate of reduction decreased from the turn of the century. SO_2 concentrations were clearly greatest at the Marylebone Road kerbside site and at roadside sites during the 1990s but this differential has diminished reflecting the decrease of sulphur in road fuels.

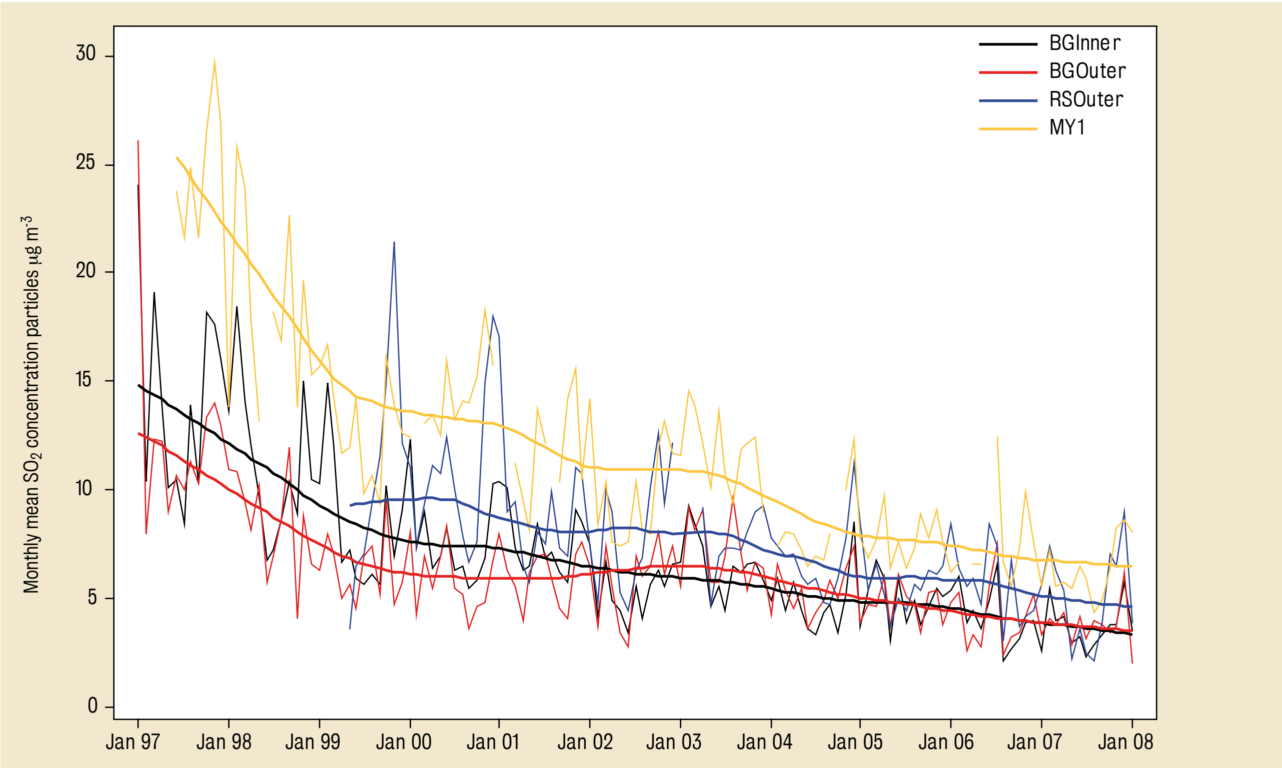


Figure 17 Monthly mean and smoothed SO_2 concentrations in London.

The UK AQS has a 15 minute mean objective for SO_2 of 266 µg m^{-3} based on WHO Guidelines. This 15 minute mean concentration should not be exceeded on more than 35 occasions per year. SO_2 concentrations in London occasionally exceed 266 µg m^{-3}. Such events typically occur during easterly winds when plumes from industry in the east Thames area fall to ground in London. Figure 18 shows the daily maximum 15 mean SO_2 concentration in London during 2006 and 2007. It can be seen that breaches of the AQS objective concentration occurred during both years, however, a far greater frequency of plume grounding events were measured in 2006 when compared with 2007. The most notable plume grounding event occurred during the July 2006 photochemical episode with widespread breaches of the AQS objective concentration over areas of west London.

SO_2 is an important pollutant with health and ecological impacts in its own right but it is also important in the formation of PM_{10} and $PM_{2.5}$ in the atmosphere. Although the AQS Objectives for SO_2 have not been breached in London since 1998, the relative importance of this pollutant may change in the future if new World Health Organisation (WHO) Guidelines are adopted within the UK and Europe. The new WHO Guidelines

(WHO, 2006) adopted a precautionary approach with respect to emerging health evidence and recommend a significant reduction in the maximum daily mean concentration from the current 125 µg m^{-3} to an eventual 20 µg m^{-3}. During 2006, 42 out of 47 LAQN SO_2 monitoring sites exceeded this guideline and the guideline was exceeded at 27 LAQN sites in 2007. All sites achieved the WHO's level 1 and level 2 interim targets. Attainment of the WHO guideline would present a significant challenge to the Environment Agency and local authority regulators.

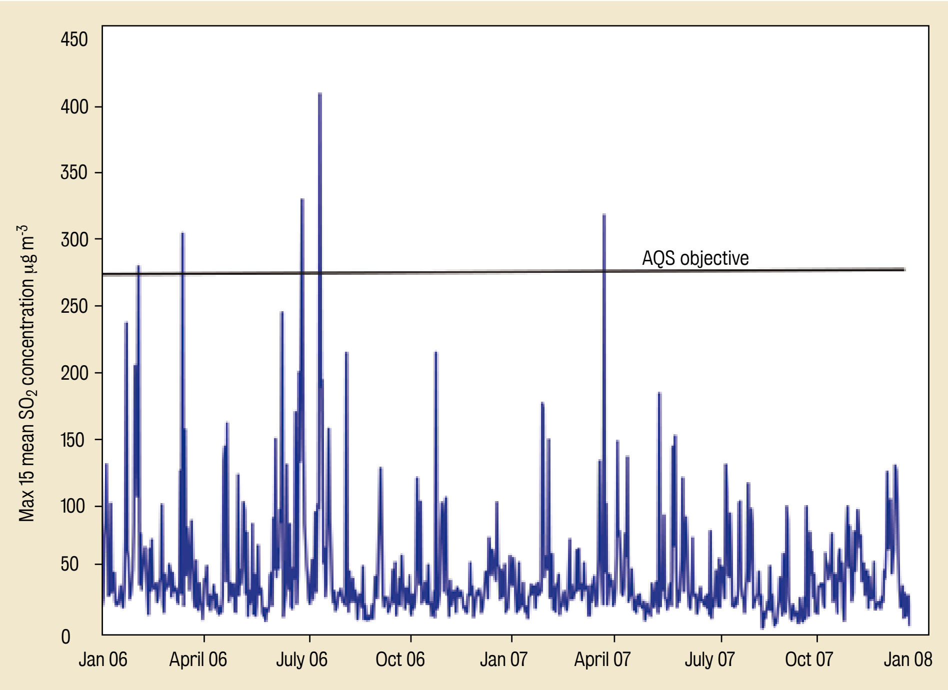


Figure 18 London daily maximum 15 minute SO_2 concentration.

Benzene and 1,3 Butadiene

The AQS Objectives for benzene and 1,3 butadiene are based on annual mean concentrations reflecting the long-term exposure concerns for these pollutants. All sites met the AQS Objectives for these pollutants.

2. The volatile correction model

During 2006-7 King's developed the Volatile Correction Model (VCM) as a means of correcting TEOM measurements of PM_{10} using FDMS purge measurements, this provided measurements that could be considered equivalent to the reference method. The VCM has been included in the Defra's local air quality management technical guidance (Defra, 2009) as the recommended method for adjusting TEOM measurements for local air quality management.

Background

The UK's EU obligations regarding air quality are set out in The Air Quality Framework Directive (96/62/EC) and in four Daughter Directives. These directives set Limit and Target Values for individual air pollutants along with data quality objectives with respect to 'accuracy' and data capture.

The First Daughter Directive (1999/30/EC) included Limit Values for PM_{10} and also stipulated that PM_{10} should be measured using the reference (gravimetric) method or equivalent. There is however a conflict between the requirement to measure PM_{10} gravimetrically and the requirement for rapid public reporting due to the time between sampling, weighing and reporting the data, which can be up to 21-28 days after the sample was taken. Many member states therefore rely on automated techniques to measure PM_{10}.

In the UK the majority of PM_{10} measurements have been made using the TEOM. The TEOM has the widely acknowledged disadvantage of driving off semi-volatile material such as ammonium nitrate and organic aerosols (Ruppecht E. et al, 1992; Allen et al, 1997; Salter et al, 1999; Soutar et al, 1999; Cyrys et al, 2001; Green et al, 2001; Charron et al, 2003). A 'correction' factor of 1.3 was therefore recommended in the UK for comparison of TEOM PM_{10} measurements with the EU Directive (DETR, 2000).

During 2004 Defra embarked upon a UK Equivalence Programme to determine the equivalence of several automated and non-automated PM_{10} and $PM_{2.5}$ measurement techniques (Harrison, 2006). Several instruments proved equivalent to the European PM_{10} reference method, importantly, the TEOM did not and is therefore not suitable for reporting PM_{10} and for analysis against the EU limit values. The implied need to upgrade or replace TEOMs with an equivalent automated measurement technique has significant cost implications for Defra, the devolved administrations and for local authorities.

With these cost implications in mind, King's used the measurements from the UK Equivalence Programme and those undertaken in the LAQN to develop the VCM (Green et al, 2007). The VCM used measurements of volatile particulate matter from FDMS instruments to correct TEOM measurements for this loss of volatiles.

Model development and testing

The correction of TEOM measurements to produce $TEOM_{VCM}$ was based on the use of volatile particulate matter concentrations measured by FDMS instruments (FDMS purge). The VCM equation is shown below:

$$\mathbf{TEOM_{VCM}\ PM_{10} = TEOM\ PM_{10} - (1.87 \times Regional\ FDMS\ PM_{10}\ purge)}$$

The $TEOM_{VCM}$ was treated using the field test procedure for the demonstration of equivalence to determine equivalence to the gravimetric reference method. The $TEOM_{VCM}$ proved equivalent to the reference method with the small deviations from this guidance recommended by Harrison (2006) for the UK Equivalence Programme. The geographical homogeneity of the volatile particulate matter meant that the FDMS measurements could be made up to 130 km away. The resulting corrected TEOM measurements ($TEOM_{VCM}$) proved equivalent to the European PM_{10} reference method for PM_{10}.

Application of the VCM in London

PM_{10} TEOM measurements from all the sites in the LAQN for 2006 and 2007 were corrected using the model by inputting a mean of all the London purge measurements into the model equation. The results of this correction can be seen in Appendices 3 and 4 along with measurements using the TEOM*1.3 correction.

The TEOM 1.3 factor is known to be a precautionary estimate of the true PM_{10} concentration and it is not representative of site and seasonal variation (Green et al, 2001; Charron et al, 2004). In general the VCM, produces concentrations lower than the TEOM*1.3 correction factor for measurements made during 2006 and 2007, as reported in Section 4. In 2006, six sites that breached the annual mean Limit Value using TEOM*1.3 met this criteria using the VCM. This figure was three for 2007. Similarly during 2006 there were 5 sites that breached the daily mean Limit Value using TEOM*1.3 but attained it using the VCM. In 2007 this figure was three. A detailed comparison of PM10 concentrations obtained using TEOM*1.3 and VCM can be found in Appendix 2.

Although the VCM produces lower concentrations than the TEOM*1.3 correction for 2006 and 2007, this is not the case for every year. **Figure 19** shows modelled results for VCM and TEOM*1.3 corrections for 2003 from Beevers et al, (2008). The number of days with mean PM_{10} above 50 µg m^{-3} is shown along a north-south transect (Enfield to Sutton) through central London. It can be seen from Figure 19 that application of the VCM to 2003 suggests a widespread increase in the number of sites exceeding the daily mean Limit Value when compared with TEOM*1.3. VCM corrections suggest a risk that the Limit Value was breached at all roadside sites and at background locations across many parts of London during 2003 (Beevers et al, 2008). The different behaviour of the VCM during 2003 when, compared with 2006 and 2007, can be explained by the magnitude and frequency of nitrate episodes during 2003. Owing to the elevated sample temperature these episodes were not measured by TEOMs but would have been detected by FDMS (and hence the VCM).

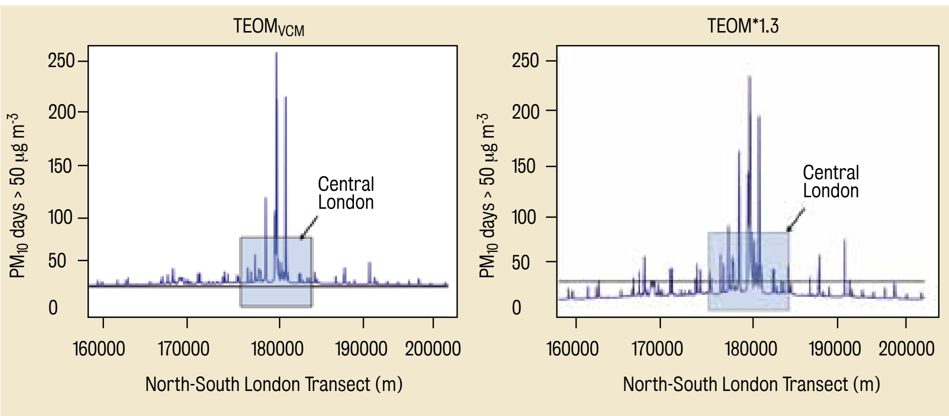


Figure 19 PM_{10} transects across London for 2003, showing the number of daily means exceeding 50 µg m^{-3} using the VCM (left) and TEOM*1.3 (right). The EU Limit Value is also shown.

3. The London Atmospheric Emissions Inventory

The London Atmospheric Emissions Inventory (LAEI) is a comprehensive database of geographically referenced emissions from all sources of air pollutants in and around the Greater London area and is funded by the GLA.

It is important that emission inventories contain the most detailed information possible and are updated continuously, since any uncertainties or errors will be passed on to subsequent analysis work (i.e., dispersion model results) and, in turn, air quality management decisions. For this reason the LAEI is regularly updated. The latest LAEI is for the year 2006 and is a revision of the LAEI 2004 that was released in February 2008.

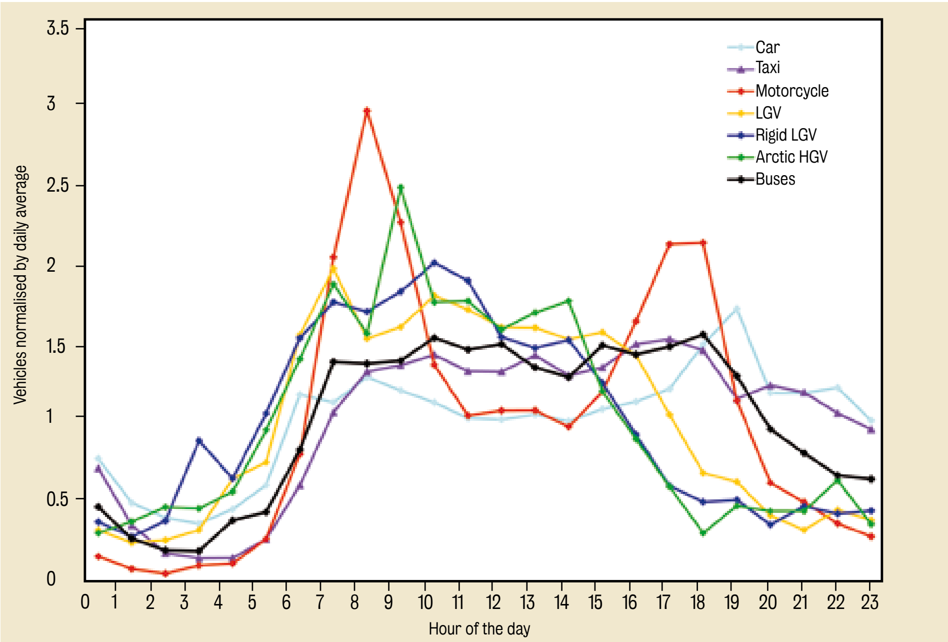
The modelling team at King's have for a number of years calculated the traffic emissions for the LAEI and follow the same general methodology for each LAEI revision. The pollutants considered are: benzene (C_6H_6), 1,3-Butadiene (C_4H_6), carbon dioxide (CO_2), carbon monoxide (CO), non-methane volatile organic compounds or hydrocarbons (NMVOC), oxides of nitrogen (NO_X), primary nitrogen dioxide (NO_2), particles PM_{10} (exhaust and tyre and brake wear), particles $PM_{2.5}$ (exhaust and tyre and brake wear), sulphur dioxide (SO_2), methane (CH_4), polycyclic aromatic hydrocarbons (PAH) and nitrous oxide (N_2O). The traffic emissions are calculated on a road link by road link basis and include all major roads within London, up to and including the M25. A brief description of the main updates in the 2006 inventory is provided here. A full explanation of the LAEI traffic emissions methodology can be found in Beevers et al, (2007).

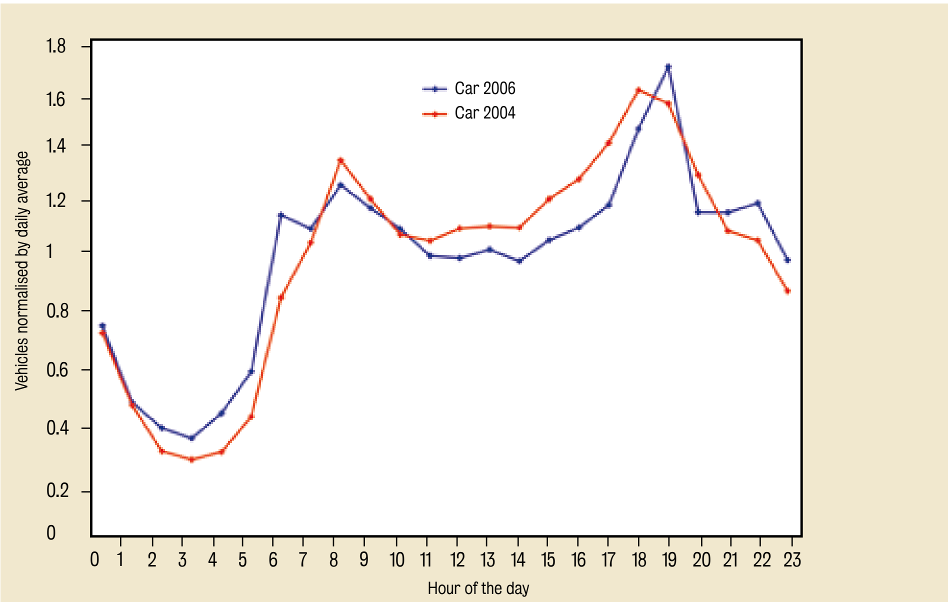
Manual traffic counts

A total of 1746 manual traffic count sites are included in the calculation of the traffic emissions for the LAEI. The manual counts are made for a period of 12 to 16 hours and consist of an hourly vehicle count broken down into 11 different vehicle categories (motorcycles, cars, LGVs, taxis, buses/coaches, HGV rigid 2axle, HGV rigid 3axle, HGV rigid 4+axle, HGV articulated 3+4axle, HGV articulated 5axle and HGV articulated 6+axle). The traffic data surveyed at these sites are collected by a number of organisations (TfL, MVA on behalf of TfL and Department for Transport (DfT)) and are updated on a systematic basis. For each version of the LAEI, the most recent traffic survey data are used wherever possible. For the LAEI 2006 just under 50% of the manual count sites were updated.

Diurnal Profiles

The diurnal profiles used to expand manual traffic counts to annual average daily traffic (AADT) equivalents have also been updated for the latest version of the LAEI, see **Figure 20a** for the congestion charging scheme (CCS) profiles. The traffic 2006 profiles are similar to those used in the LAEI 2004 and so suggest that the diurnal traffic counts across London have changed little between 2004 and 2006 (**Figure 20b** shows a comparison of car profiles for the CCS for the two years).





Figures 20a-20b Vehicle flows normalized by daily average flow for different vehicle types.

Minor road vehicle distance

The vehicle distance travelled on minor roads has been re-calculated based on the latest estimates provided by TfL. The total vehicle distance used for the LAEI 2006, estimated for all roads in Greater London, is 31.15 billion vehicle km (bvkm) and is much lower than the corresponding Dft estimated figure of 32.96 bvkm (note, the vehicle distance travelled in the LAEI 2004 was based on a DfT estimation). The TfL vehicle km estimate has been used in preference to that from the DfT since TfL has detailed estimates of London's traffic flows and believes that, unlike in the rest of the UK, traffic in London is not increasing every year. The minor road vehicle distance for the LAEI 2006 is therefore very different to that of the LAEI 2004 (**Table 1**), with 13% of the total vehicle distance driven within London being on minor roads in 2006 compared to 20% in 2004.

LAEI version	Major roads bvkm	Minor roads bvkm	Total GLA bvkm
2003	6.8	6.1	32.8
2004	26.2	6.5	32.7
2006	27.2	4.0	31.1

Table 2 Vehicle distance estimated for major and minor roads within Greater London.

Vehicle speeds

Vehicle speeds on the major road network have also been updated using 2006 data from the TfL floating car measurements in inner and outer London as well as the CCS speed survey. This update led to slight changes in speed however the average speed for LAEI 2006 remained unchanged from LAEI 2004 at 35 km h^{-1}.

Vehicle stock

There have also been a number of minor updates to the vehicle stock proportions since the LAEI 2004. The new information is based on the UK National Atmospheric Emissions Inventory (NAEI) fleet composition data. Car size proportions have been updated to the following based on TfL's Automatic Number Plate Recognition (ANPR) data from early 2007:

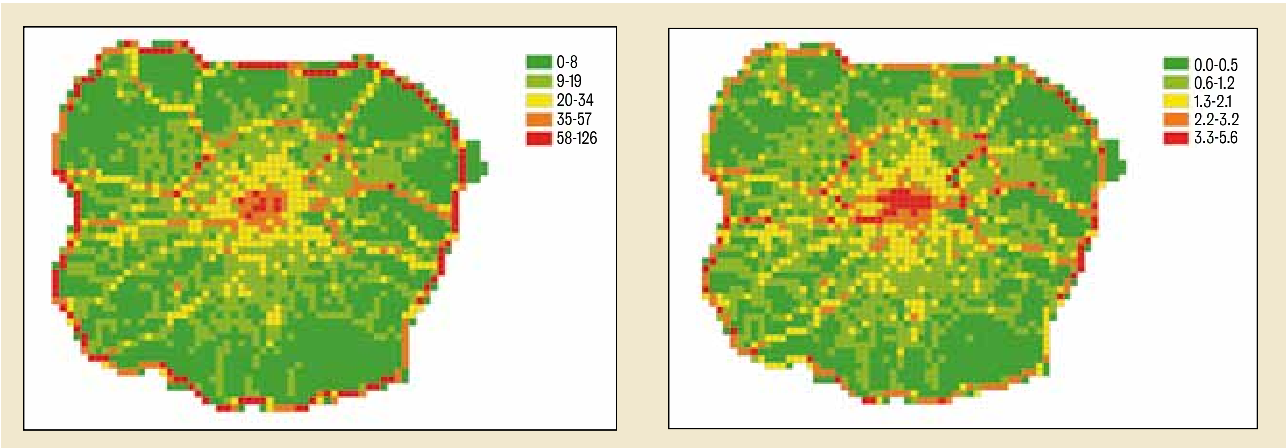
- Petrol cars: small=34%; medium=51%; large=15%
- Diesel cars: small=72%; large=28%

In addition, the fuel-based proportions of diesel and petrol cars and LGVs have been updated for all years based on the latest data from the NAEI. Changes for cars are not very big compared to LAEI 2004 but the proportion of diesel LGVs is higher in 2004 and 2006 than previously assumed.

Emission factors

Emission factors for all pollutants, except CO_2, remained unchanged compared to LAEI 2004. The DfT has recently released a new set of emission factors based on the most up-to-date vehicle test data. Some sensitivity tests were carried out for incorporating the new factors into the LAEI and several issues were identified. It was decided that these data are unsuitable for use in the LAEI until the issues are resolved following DfT's recent consultation process. In addition this maintains consistency between LAEI and NAEI 2006.

Please see **www.london.gov.uk** for more details of the release date for the LAEI 2006.



LAEI 2006 emmissions of NO_X (left) and PM_{10} (right) tonnes $year^{-1}$.

4. Oxidative potential – a new measurement of particle health effects?

Although there are few left standing who are willing to argue against an association between exposure to small elevated concentrations of ambient particles and a range of health effects, there is still considerable head scratching about how this can be so. In essence, the mechanisms of particulate matter (PM) related health effects are still not well understood.

Whilst the majority of epidemiological studies make use of ambient PM mass concentration, this measurement ignores sources and constituents, and, therefore, biological activity of particles. From a toxicological perspective much of the mass of PM consists of biologically inert material: sodium chloride, crustal dust, ammonium sulphates and nitrates. In contrast, the relatively low mass of transition metals and organic species are likely to contribute much more to the health effects reported in the literature.

One hypothesis gaining rapid support is that many of the adverse health effects of PM are associated with oxidative stress, initiated by the formation of reactive oxygen species (ROS) at the surface of the lung. The growing literature on specific health effects in association with cellular oxidative stress, including the ability of PM to induce pro-inflammatory effects in the nose, lung and cardiovascular system is persuasive. High levels of ROS cause a change in the redox status of cells and their surrounding environment, thereby triggering a cascade of events associated with inflammation and, at higher concentrations, cell death.

For a number of years now we have proposed the need for alternative measures of the biologically effective dose of PM, as well as more health relevant PM metrics (Kelly, 2003). Consequently, to quantify the oxidative potential of ambient PM, as well as to address the components driving the observed activity, our laboratory at King's established an in vitro screening system. This simple approach involves the incubation of PM samples within a synthetic respiratory tract lining fluid (RTLF). The layer of fluid represents the first physical interface encountered by inhaled materials and, importantly, it contains high concentrations of a number of antioxidants. Hence, by examining the extent to which PM depletes antioxidants from this RTLF model with time provides not only a quantitative output of PM oxidative activity, but also reflects reactions likely to occur in vivo at the air-lung interface.

The assay itself is relatively straightforward. Following extraction of PM from a variety of filter matrices, particle suspensions are added to the synthetic RTLF, containing equimolar concentrations of the antioxidants urate, ascorbate and glutathione (200 µM), at PM concentrations ranging from 10-50 µg/ml. The capacity of the particles to deplete ascorbate and reduced glutathione from this model is then monitored over a 4h period, with the final concentrations of these antioxidants quantified by reverse phase high-pressure liquid chromatography.

Further characterization of the oxidative activity is achieved by performing co-incubations with metal ion chelators and antioxidant enzymes which provides information on the transition metals driving the generation of various ROS.

Given that any measure of particle oxidative capacity needs to be robust over time it is important to ensure intra-assay standardization between experiments. To achieve this, we routinely run a number of particle-free and particle controls, the later consisting of residual oil fly ash (ROFA), as a positive control and an inert carbon black as a negative control. Blank filters or foams are also routinely extracted and run through the assay system. The results of a typical experiment examining the oxidative activity of ambient fine ($PM_{0.1-2.5}$) and coarse ($PM_{2.5-10}$) samples are illustrated in **Figure 21** which shows greater depletion of anti-oxidants, and therefore greater oxidative capacity, in samples collected from high traffic areas when compared to those collected from low traffic environments. Equally importantly, substantial oxidative capacity is also present in samples from the coarse fraction.

Determination of antioxidant depletion using this model provides a robust, rapid and highly repeatable acellular screening method for obtaining quantitative measures of PM oxidative potential on an equal mass basis. To date we have utilised this method to screen a range of ambient PM samples obtained from established monitoring sites across London and farther afield. Results obtained to date suggest that traffic-derived particles have substantially more oxidative potential than PM collected at background settings.

Having established the feasibility and utility of this approach a key objective of our current work is to determine if it is possible to perform oxidative potential measurements on daily PM samples; the daily variation in these measurements will then be examined in light of daily changes in the concentration of co-pollutants at this site, as well as meteorological variables.

Building upon the work previously funded by the US Health Effects Institute King's are archiving all TEOM filters exposed within the LAQN to enable future analysis of changes in oxidative activity of PM in London. During 2009 we hope to be able to expand the archive to include TEOM filters exposed in neighbouring local authority air quality monitoring networks.

Clearly the ultimate aim of this work is to identify which physical and chemical properties of particles (or unidentified confounding environmental influences) are driving the health impact, what patho-physiological mechanisms are operative, and, importantly, what air quality regulations should be adopted to deal with the health risks.

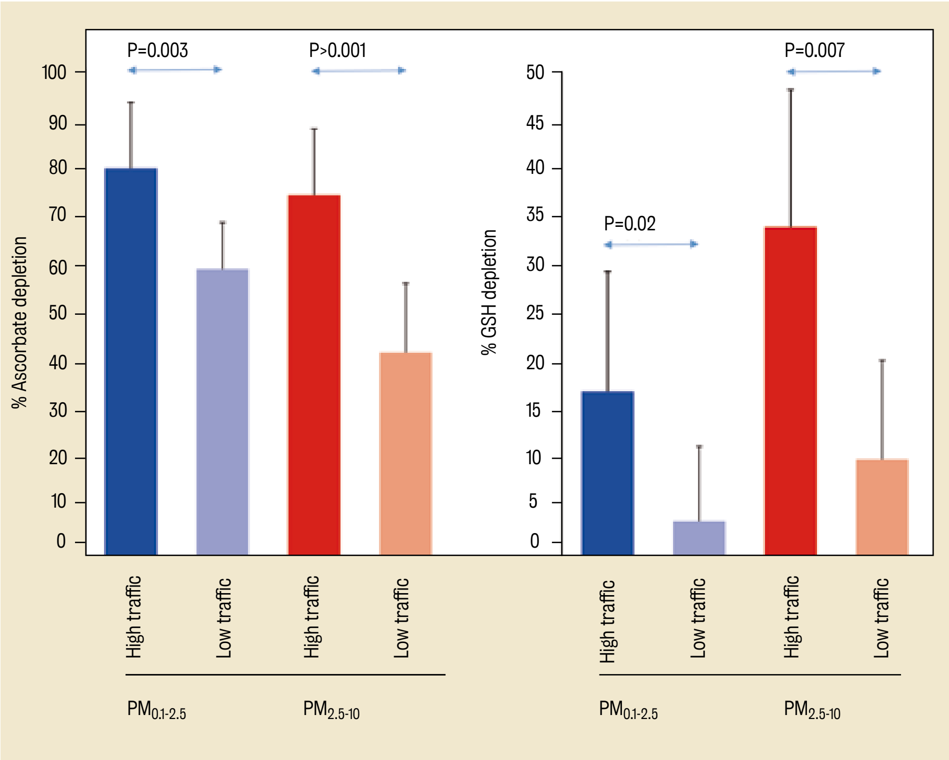


Figure 21 PM oxidative activity (measured as the depletion of ascorbate or glutathione from a model RTLF solution) for fine and coarse particles collected at high traffic or low traffic sites in London.

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IMAGE: ADAM GLASS

Appendix 1: Network changes 2006-7

New monitoring sites

← A new monitoring site was opened in Camden in June 2007 as part of a study to evaluate the effectiveness of a paint developed to reduce NO_x from the air. The site contains two co-located NO_x analysers, **Camden 4** and **Camden 5**, next to a wall at a background location. There are three stages to the study, firstly a control where the two analysers should record very similar levels with the sample inlets next to each other at a distance of 1.5m from the wall. Once it has been established that the measurements match well, one sample line will be moved to a position 10 cm from the wall to assess concentrations prior to painting. The other sample inlet will remain in the original position. The third stage of monitoring will take place after the paint has been applied to determine any difference between measurements from the two analysers to measure the potential reduction in NO_x concentrations.

→ A new kerbside monitoring site, **Barking and Dagenham 3**, was opened in March 2007 next to the A214 Northern Relief Road near Barking in the west of the borough. The site monitors NO_2 and PM_{10} particulate by BAM.

→ The London Borough of Brent relocated their Brent 3 site in Harlesden into a nearby primary school where it was reopened as **Brent 6** in November 2006. Much of the equipment remains the same, monitoring NO_2, SO_2 and PM_{10} particulate by TEOM. The relocation enables the assessment of pollution levels experienced by an important receptor, as children are considered to be particularly susceptible to the health effects of air pollution.

← A new site operated by City of London at Wallbrook Wharf joined the LAQN in April 2007. **City of London 6** is located in a busy street canyon close to the bridge beneath Cannon Street Station. It monitors NO_2 and CO.

← **Tower Hamlets 4** is an important new site located on the northern approach to the Blackwall Tunnel, opened in September 2006 and is funded by Transport for London (TfL) to help assess the air quality effects of the Low Emission Zone (LEZ). The site measures PM_{10} and $PM_{2.5}$ particulate by FDMS, NO_2, O_3, particle number and black carbon.

↓ Islington 1 was closed in early 2007 and reopened as **Islington 6** in March 2007 at a new background site at an Ecology Centre near Arsenal underground station. The site measures PM_{10} particulate by TEOM and NO_2.

→ Greenwich added another site to their extensive monitoring programme in the east of the borough in Plumstead. **Greenwich 13** is a roadside site, located in the grounds of a primary school, measuring a range of pollutants; NO_2, O_3, PM_{10} particulate by FDMS and $PM_{2.5}$ by FDMS. It was opened in January 2006.

↑ The LAQN continued its extension westwards with the opening of three roadside sites in Reading. This adds to the measurements available in Berkshire, where three sites are already part of the LAQN in the Royal Borough of Windsor and Maidenhead. **Reading 1** was opened on Caversham Road in November 2006 close to a busy roundabout. **Reading 2**, which opened in May 2007 is located on King's Road, in Reading's largest declared Air Quality Management Area (AQMA) and **Reading 3** followed in December 2007, located on Oxford Road to assess the impact of the introduction of bio-ethanol fuel on one of Reading's main bus routes. All three sites measure NO_2 and PM_{10} particulate by BAM.

↓ King's College started data management for two sites in South Oxfordshire district council in 2006, with measurements made available from 1 January. These are two roadside sites; **South Oxfordshire 1** in Henley and **South Oxfordshire 2** in Wallingford. An additional roadside site, **South Oxfordshire 3** was opened in Watlington in July 2007. All sites have been set up to monitor areas where elevated NO_2 concentrations have been detected from diffusion tube studies. As a result of the continuous monitoring programme, Henley and Wallingford have since been declared Air Quality Management Areas (AQMA). These sites further extend the coverage of the LAQN, to the north of the Reading.

↑ Two new sites were opened in Waltham Forest. **Waltham Forest 4** was opened at the Crooked Billet Roundabout by the North Circular in November 2007 and measures NO_2 and PM_{10} particulate by TEOM. **Waltham Forest 5** is a new urban background site opened in Leyton, in the south of the borough in September 2007. This site measures NO_2, SO_2 and PM_{10} particulate by FDMS.

← In February 2007 a site in the City of Westminster was affiliated to the LAQN. **Westminster 4** is a roadside site on Charing Cross Road, just south of Leicester Square underground station. Monitoring NO_2, the site is of interest for its location within the congestion charge zone and increases LAQN coverage of air quality monitoring in central London.

New monitoring equipment

A new BAM was installed to measure PM_{10} particulate at **Thurrock 2** in Purfleet in April 2006. The site was previously monitoring NO_2 only.

The **Barking and Dagenham 2** site had a NO_2 analyser installed in November 2007. This is a useful addition to compliment the existing PM_{10} particulate measurements that have been made at the site since October 1999.

In January 2007, Wandsworth Council upgraded the TEOM at the **Wandsworth 4** site to an FDMS.

Redbridge Council had a new $PM_{2.5}$ BAM installed at their **Redbridge 4** site in February 2007. This adds to the existing PM_{10} particulate, NO_2, SO_2 and CO data already available from this site.

→ O_3 analysers were installed at **Brent 4**, **Greenwich 8**, **Greenwich 9** and **Hackney 6** in May 2006 to help with the assessment of the impact of the Low Emission Zone (LEZ). New $PM_{2.5}$ TEOMs were also added around the same time at Brent 4, Greenwich 8 and Hackney 6 as part of the study. **Greenwich 9** already has a $PM_{2.5}$ FDMS. This additional equipment was funded by TfL as part of the same project as the **Tower Hamlets 4** site.

A new FDMS was installed at **Hammersmith and Fulham 1** at Hammersmith Broadway in April 2007 in place of the existing TEOM.

Appendix 2: LAQN monitoring sites

Site name	Opening date	Closing date	Type	CO	NO_2	SO_2	O_3	PM_{10}	$PM_{2.5}$	Data quality
A3 – AURN	March 1997	Sept 2009	R	y	y			T		**A
Barking & Dag'ham 1 – Rush Green	November 1999		S		y	y				**
Barking & Dag'ham 2 – Scrattons Farm	Sept 1993		S					T		**
Barking & Dagenham 3 – North Street	March 2007		K		y			B		**
Barnet 1 – Tally Ho Corner	Dec 1998		K		y			T		**
Barnet 2 – Finchley	August 2000		U		y			T		**
Barnet 3 – Strawberry Vale	August 2000	May 2002	U		y			T		**
Bexley 1 – Slade Green	May 1994		S	y	y	y	y	T		**/**A
Bexley 2 – Belvedere	January 1998		S		y			TF		**
Bexley 3 – Thamesmead	January 1998		S						T	**
Bexley 4 – Erith	April 1999		I		y			T		**
Bexley 5 – Bedonwell	October 1999	April 2004	S	y	y	y				**
Bexley 7 – Thames Rd North	April 2004		R		y		y	TF	T	**
Bexley 8 – Thames Rd South	April 2004		R		y		y	T	T	**
Bloomsbury – AURN	January 1992		U	y	y	y	y	T	T	**A
Brent 1 – Kingsbury	January 1996		S	y	y	y	y	T		**
Brent 2 – Ikea	June 2001	June 2003	R		y	y		T		**
Brent 3 – Harlesden	October 2001	Nov 2006	R		y	y		T		**
Brent 4 – Ikea	June 2003		R		y	y		T		**
Brent 5 – Neasden Lane	Feb 2004		I		y			T		**
Brent 6 – John Keble Primary School	Nov 2006		R		y	y		T		**
Brentwood 1 – Town Hall	August 1995		U		y					**
Bromley 1 – Rent office	January 1993	Jan 1996	U	y	y		y			**
Bromley 5 – Biggin Hill	April 1996		S				y			**
Bromley 7 – Central	July 1998		R	y	y			B		**
Camden 1 – Swiss Cottage	April 1996		K		y			T		**AA
Camden 3 – Shaftesbury Avenue	April 2000		R		y			T		**
Camden 4 – St Martin's College Nox 1	June 2007		U		y					**
Camden 5 – St Martin's College Nox 2	June 2007		U		y					**
Castle Point 1 – Town Centre	May 1996		U		y	y				**
City of London 1 – Senator House	October 2001		U		y	y	y			*
City of London 3 – Sir John Cass School	January 2003		U		y			B		*
City of London 6 – Wallbrook Wharf	April 2007		R	y	y					**
Croydon 2 – Purley Way	August 1994		R		y					**
Croydon 3 – Thornton Heath	June 1997		S				y	T		**
Croydon 4 – George Street	Sept 1999		R		y			T		**
Croydon 5 – Norbury	October 2000		K		y					**
Croydon 6 – Euston Road	January 2001		S		y					**
Crystal Palace 1 – C Palace Parade	Sept 1999		R	y	y	y		T		**
Ealing 1 – Ealing Town Hall	March 1995		U		y	y	y			**
Ealing 2 – Acton Town Hall	September 1996		R	y	y		y	TF	T	**
Ealing 6 – Hangar Lane	August 2003		R		y					**

Site name	Opening date	Closing date	Type	CO	NO_2	SO_2	O_3	PM_{10}	$PM_{2.5}$	Data quality
Ealing 7 – Southall	July 2004		U		y			T		**
Ealing 8 – Horn Lane	February 2005		I					T		**
Ealing 9 – Court Way, Acton	April 2005	June 2006	R		y					**
Ealing Mobile 4 – Hamilton Road	November 1998	March 1999	R		y	y		T		**
Ealing Mobile 5 – Southall	March 1999	June 2001	R		y	y		T		**
Enfield 1 – Bushhill Park	June 1995		S		y					**
Enfield 2 – Church Street	December 1997	Sept 2006	R	y	y			B		**
Enfield 3 – Salisbury School Ponders End	November 1998		U	y	y	y	y	B		**
Enfield 4 – Derby Road, Upper Edmonton	February 2000		R		y	y		B		**
Enfield 5 – A406 Bowes Road	July 2004		R					T		**
Greenwich 10 – A206, Burrage Grove	October 2004		R		y			T		**
Greenwich 12 – Millennium Village	August 2004		U		y			F	F	**
Greenwich 13 – Plumstead High Street	January 2006		R		y		y	F	F	**
Greenwich 4 – Eltham	January 1994		S		y	y	y	T		**/**AA
Greenwich 5 – Trafalgar Road	November 1996		R		y			T		**
Greenwich 7 – Blackheath	March 2002		R		y			T		**
Greenwich 8 – Woolwich Flyover	July 2004		R		y			T		**
Greenwich 9 – Westhorne Ave	October 2004		R		y			F	F	**
Greenwich Bexley 6 – A2 Falconwood	October 2000		R		y		y	T	T	**
Hackney 4 – Clapton	October 1993		U	y	y		y		T	**
Hackney 6 – Old Street	May 2000		R		y			T		**
Hammersmith & Fulham 1 – H'smith B'dway	August 1999		R		y	y		F		**
Hammersmith & Fulham 2 – Brook Green	July 2003		U		y			T		**
Hammersmith & Fulham 3 – Scrubs Lane	March 2005	October 2005	K		y			T		**
Haringey 1 – Town Hall	November 1994		R		y	y		T		**/**AA
Haringey 2 – Priory Park	March 1996		S		y		y	B		**/**AA
Haringey 3 – Bounds Green	June 1999	March 2001	R		y	y		B		**
Harlington – AURN	January 2004		U	y	y		y	T		**A
Harrow 1 – Stanmore	April 1999		U		y	y		T		**
Harrow 2 – North Harrow	June 2003		R		y			T		**
Havering 1 – Rainham, A1306	December 1995		R		y					**
Havering 2 – Harold Hill	March 1998	Nov 2000	S					B		**
Havering 3 – Romford	December 1998		R		y			T		**
Heathrow Airport	January 1999		U		y	y	y	T		**A
Hillingdon – AURN	August 1996		S	y	y	y	y	T		**A
Hillingdon 1 – South Ruislip	January 1994		R		y			T		**
Hillingdon 2 – Hillingdon Hospital	September 2002		R		y			T		**
Hillingdon 3 – Oxford Avenue	March 2005		R		y			T		**
Hounslow 1 – Brentford	April 1993	January 2003	R	y	y		y			**AA
Hounslow 2 – Cranford	January 1999		S		y	y	y	T		**
Hounslow 3 – Brentford	March 1999	January 2003	R					T		**
Hounslow 4 – Chiswick High Rd	August 1999		R		y	y		T		**

Site name	Opening date	Closing date	Type	CO	NO_2	SO_2	O_3	PM_{10}	$PM_{2.5}$	Data quality
Hounslow 5 – Brentford Roadside	June 2003		R		y			T		**
Islington 1 – Upper Street	May 1994		U		y			T		**
Islington 2 – Holloway Road	July 2000		R	y	y			T		**
Islington 4 – Foxham Gardens	April 2006		U					G		*
Islington 5 – Duncan Terrace	August 2006		R					G		*
Islington 6 – Arsenal	March 2007		U		y			T		**
Kens & Chelsea 1 – North Kensington	March 1995		U	y	y	y	y	TFG		**AA
Kens & Chelsea 2 – Cromwell Rd	May 1998		R	y	y	y		T		**/**A
Kens & Chelsea 3 – Knightsbridge	March 2000		R		y					**
Kens & Chelsea 4 – King's Rd	September 2000		R		y					**
Kens & Chelsea 5 – Earl's Court Road	May 2002		R					G		*
Kingston 1 – Chessington	January 1996		S				y			**
Kingston 2 – Town Centre	April 1996	June 2000	R		y			T		**
Lambeth 1 – Christchurch Road	September 2000		R		y	y		B		*
Lambeth 2 – Vauxhall Cross	December 2001	July 2003	R		y	y		B		*
Lambeth 3 – Loughborough Junct	December 2001		U		y	y		B		*
Lambeth 4 – Brixton Road	December 2003		K		y	y		B		*
Lambeth 5 – Vauxhall Cross	February 2005		R		y	y		B		*
Lewisham 1 – Catford	August 1996		U		y	y	y			**
Lewisham 2 – New Cross	March 2002		R		y	y		T		**
Marylebone Rd	May 1997		K	y	y	y	y	TF G*2	T	**AA
Mole Valley 1 – Leatherhead	April 1996	February 1999	RU		y	y		T		**
Mole Valley 2 – Lower Ashtead	April 1997	July 2006	S		y			T		**
Mole Valley 3 – Dorking	October 2001		U		y			T		**
Reading AURN – New Town	October 2003		U	y	y	y	y	T		**A
Reading 1 – Caversham Road	November 2006		R		y			B		**
Reading 2 – Kings Road	May 2007		R		y			B		**
Reading 3 – Oxford Road	December 2007		R		y			B		**
Redbridge 1 – Perth Terrace	November 1999		U		y		y	B		*
Redbridge 2 – Ilford Broadway	December 1999	June 2003	K	y	y					*
Redbridge 3 – Fullwell Cross	November 1999		K		y			B		*
Redbridge 4 – Gardner Close	November 1999		R	y	y	y		B		*
Redbridge 5 – A406 Woodford	November 2003		R	y	y			B		*
Reigate and Banstead 1 – Horley	July 2000		S		y			T		**
Reigate and Banstead 2 – Horley South	August 2003		S		y					**
Reigate and Banstead 3 – Poles Lane	February 05		RU		y		y			**
Richmond 1 – Castlenau	June 2000		R		y			T		**
Richmond 2 – Barnes Wetlands	March 2001		S		y		y	T		**
Sevenoaks 1 – Background	January 1998		U	y	y	y	y	T		**
Sevenoaks 2 – Bat & Ball	August 05		R		y			T		**
South Oxfordshire 1 – Henley	January 2006		R		y					**

Site name	Opening date	Closing date	Type	CO	NO_2	SO_2	O_3	PM_{10}	$PM_{2.5}$	Data quality
South Oxfordshire 2 – Wallingford	January 2006		R		y					**
South Oxfordshire 3 – Watlington	July 2007		R		y					**
Southwark 1 – Elephant & Castle	March 1993		U	y	y	y	y	T		**
Southwark 2 – Old Kent Road	May 1994	June 2006	R	y	y	y		T		*/**AA
Sutton 1 – Town Centre	April 1995	April 2002	R	y	y	y		T		**AA
Sutton 2 – North Cheam	April 1995	May 2002	U		y					**
Sutton 3 – Carshalton	May 1995		S		y		y			**
Sutton 4 – Wallington	July 2002		K		y			T		**
Sutton 5 – Beddington Lane	December 2005		I		y			T		**
Teddington – AURN	August 1996		S		y	y	y			**A
Thurrock 1 – Grays	January 1995		U	y	y	y	y	T		**A
Thurrock 2 – Purfleet	May 2003		R		y					**
Thurrock 3 – Stanford	August 2003		R		y			T		**
Tower Hamlets 1 – Poplar	January 1994		U		y	y	y	T		**
Tower Hamlets 2 – Mile End Rd	March 1994		R	y	y					**AA
Tower Hamlets 3 – Bethnal Green	October 1999		U		y			T		**
Tower Hamlets 4 – Blackwall	September 2006		R		y		y	F	F	**
Waltham Forest 1 – Dawlish Road	July 1998		U		y	y		T		**
Waltham Forest 3 – Chingford	July 2003		R		y	y		T		**
Waltham Forest 2 – Mobile	July 1998	October 2001	R		y	y		T		*
Waltham Forest 4 – Crooked Billet	November 2007		K		y			T		**
Waltham Forest 5 – Leyton	September 2007		U		y			F		**
Wandsworth 1 – Garett Lane	January 1995	February 1996	R							**
Wandsworth 2 – Town Hall	October 1994		U	y	y	y	y			**
Wandsworth 3 – Roehampton	October 1994	November 00	RU			y	y			**
Wandsworth 4 – High Street	January 1998		R	y	y			F		**
West London – AURN	January 119987		U	y	y					**A
Westminster – AURN	July2001		U	y	y	y	y			**A
Westminster 4 – Charing Cross Library	February 2007		R		y					*
Windsor & Maidenhead 1 – Maidenhead	March 05		R		y					**
Windsor & Maidenhead 2 – Windsor	February 05		R		y					**
Windsor & Maidenhead 3 – Ascot IC	October 05		RU		y		y			**

KEY
T = TEOM
B = Beta Attenuation
G = Gravimetric
F = FDMS
AA = Affiliated to UK AURN. Final data set published by DEFRA
A = AURN DEFRA funded. Final data set published by DEFRA
*= Locality Standard
**= Traceability to National Standards
Deployments of the Richmond mobile site (Richmond 3+) are not individually listed

SITE KEY
K = Kerbside
R = Roadside
U = Urban background
S = Suburban
Ru = Rural

Appendix 3: Detailed results 2006

CO				
Site	**Type**	**Data Capture %**	**Max 8h means >=8.6 mgm^{-3} (10ppm)**	**Achieved?**
A3 AURN	R	94	0	YES
Bexley 1	S	93	0	YES
Bloomsbury AURN	U	91	0	YES
Brent 1	S	94	0	YES
Bromley 7	R	53	0	NA
Crystal Palace 1	R	85	0	NA
Ealing 2	R	92	0	YES
Elmbridge 1	U	16	0	NA
Enfield 2	R	68	0	NA
Enfield 3	U	89	0	NA
Hackney 4	U	88	0	NA
Harlington AURN	U	98	0	YES
Heathrow Airport	U	94	0	YES
Hillingdon AURN	S	93	0	YES
Hounslow 5	R	62	0	NA
Islington 2	R	83	0	NA
Kens and Chelsea 1	U	92	0	YES
Kens and Chelsea 2	R	91	0	YES
Marylebone Rd	K	64	0	NA
Reading AURN	U	96	0	YES
Redbridge 4	R	93	0	YES
Redbridge 5	R	59	0	NA
Richmond 25	R	55	0	NA
Richmond 27	R	42	0	NA
Sevenoaks 1	U	96	0	YES
Southwark 1	U	66	0	NA
Southwark 2	R	10	0	NA
Thurrock 1	U	94	0	YES
Tower Hamlets 2	R	84	0	NA
Wandsworth 2	U	66	0	NA
Wandsworth 4	R	96	0	YES
West London AURN	U	80	0	NA
Westminster AURN	U	39	0	NA

KEY
K = Kerbside
R = Roadside
U = Urban background
S = Suburban
Ru = Rural

NO_x

Site	Type	Annual mean NO_x μgm^{-3} (as NO_2)
A3 AURN	R	146
Barking & Dagenham 1	S	50
Barnet 1	K	167
Barnet 2	U	62
Bexley 1	S	60
Bexley 2	S	52
Bexley 4	I	70
Bexley 7	R	98
Bexley 8	R	79
Bloomsbury AURN	U	97
Brent 1	S	51
Brent 3	R	100
Brent 4	R	288
Brent 5	I	125
Brent 6	R	126
Brentwood 1	U	42
Bromley 7	R	94
Camden 1	K	185
Camden 3	R	151
Castle Point 1	U	36
City of London 1	U	82
City of London 2	K	628
City of London 3	U	95
City of London 4	R	267
City of London 7	U	129
Croydon 2	R	135
Croydon 4	R	102
Croydon 5	K	167
Croydon 6	S	65
Crystal Palace 1	R	113
Ealing 1	U	71
Ealing 2	R	142
Ealing 6	R	304
Ealing 7	U	54
Ealing 9	R	87
Elmbridge 1	U	65
Elmbridge 2	R	116
Enfield 1	S	51
Enfield 2	R	70
Enfield 3	U	55
Enfield 4	R	102
Greenwich 10	R	105

Site	Type	Annual mean NO_X μgm^{-3} (as NO_2)
Greenwich 12	U	73
Greenwich 13	R	83
Greenwich 4	S	45
Greenwich 5	R	123
Greenwich 7	R	117
Greenwich 8	R	229
Greenwich 9	R	111
Greenwich Bexley 6	R	121
Hackney 4	U	92
Hackney 6	R	141
Hammersmith and Fulham 1	R	230
Hammersmith and Fulham 2	U	60
Haringey 1	R	85
Haringey 2	S	53
Harlington AURN	U	64
Harrow 1	U	42
Harrow 2	R	105
Havering 1	R	84
Havering 3	R	87
Heathrow Airport	U	107
Hillingdon 1	R	100
Hillingdon 2	R	74
Hillingdon 3	R	98
Hillingdon AURN	S	107
Hounslow 2	S	63
Hounslow 4	R	169
Hounslow 5	R	144
Islington 1	U	70
Islington 2	R	164
Kens and Chelsea 1	U	60
Kens and Chelsea 2	R	183
Kens and Chelsea 3	R	219
Kens and Chelsea 4	R	222
Lambeth 1	R	119
Lambeth 3	U	59
Lambeth 4	K	527
Lambeth 5	R	175
Lewisham 1	U	105
Lewisham 2	R	146
Marylebone Rd	K	308
Mole Valley 2	S	42
Mole Valley 3	U	39
Reading 1	R	87

Site	Type	Annual mean NO_X μgm^{-3} (as NO_2)
Reading AURN	U	33
Redbridge 1	U	58
Redbridge 3	K	130
Redbridge 4	R	97
Redbridge 5	R	119
Reigate and Banstead 1	S	46
Reigate and Banstead 2	S	56
Reigate and Banstead 3	RU	27
Richmond 1	R	77
Richmond 2	S	48
Richmond 25	R	81
Richmond 26	R	104
Richmond 27	R	68
Sevenoaks 1	U	34
Sevenoaks 2	R	77
South Oxfordshire 1	R	79
South Oxfordshire 2	R	142
Southwark 1	U	74
Southwark 2	R	154
Sutton 3	S	49
Sutton 4	K	176
Sutton 5	I	79
Teddington AURN	S	37
Thurrock 1	U	56
Thurrock 2	R	191
Thurrock 3	R	79
Tower Hamlets 1	U	60
Tower Hamlets 2	R	142
Tower Hamlets 3	U	99
Waltham Forest 1	U	57
Waltham Forest 3	R	61
Wandsworth 2	U	102
Wandsworth 4	R	89
West London AURN	U	84
Westminster AURN	U	84
Windsor and Maidenhead 1	R	125
Windsor and Maidenhead 2	R	105
Windsor and Maidenhead 3	RU	25

NO_2

Site	Type	Data capture %	Annual mean < 40 μgm^{-3}	Annual mean achieved?	No more than 18 occurrences of hourly mean > =200 μgm^{-3} (104.6ppb)	Hourly mean achieved?
A3 AURN	R	93	60	NO	0	YES
Barking & Dagenham 1	S	90	32	YES	0	YES
Barnet 1	K	87	72	NA	9	NA
Barnet 2	U	94	38	YES	1	YES
Bexley 1	S	88	36	NA	0	NA
Bexley 2	S	98	32	YES	3	YES
Bexley 4	I	96	35	YES	3	YES
Bexley 7	R	97	43	NO	0	YES
Bexley 8	R	88	38	NA	0	NA
Bloomsbury AURN	U	93	57	NO	0	YES
Brent 1	S	94	30	YES	0	YES
Brent 3	R	61	50	NA	1	NA
Brent 4	R	81	79	NA	9	NA
Brent 5	I	98	44	NO	0	YES
Brent 6	R	10	43	NA	0	NA
Brentwood 1	U	98	28	YES	0	YES
Bromley 7	R	59	50	NA	0	NA
Camden 1	K	92	73	NO	38	NO
Camden 3	R	75	72	NA	4	NA
Castle Point 1	U	97	25	YES	0	YES
City of London 1	U	94	49	NO	0	YES
City of London 2	K	72	123	NA	268	NO
City of London 3	U	87	57	NA	0	NA
City of London 4	R	71	100	NA	314	NO
City of London 7	U	87	67	NA	1	NA
Croydon 2	R	96	48	NO	0	YES
Croydon 4	R	93	54	NO	0	YES
Croydon 5	K	94	64	NO	1	YES
Croydon 6	S	98	35	YES	0	YES
Crystal Palace 1	R	84	46	NA	0	NA
Ealing 1	U	91	40	NO	0	YES
Ealing 2	R	95	63	NO	29	NO
Ealing 6	R	87	95	NA	244	NO
Ealing 7	U	93	33	YES	0	YES
Ealing 9	R	37	44	NA	6	NA
Elmbridge 1	U	16	39	NA	0	NA
Elmbridge 2	R	99	52	NO	1	YES
Enfield 1	S	86	33	NA	2	NA
Enfield 2	R	67	43	NA	1	NA
Enfield 3	U	93	33	YES	0	YES
Enfield 4	R	95	47	NO	1	YES

Site	Type	Data capture %	Annual mean < 40 μgm^{-3}	Annual mean achieved?	No more than 18 occurrences of hourly mean > =200 μgm^{-3} (104.6ppb)	Hourly mean achieved?
Greenwich 10	R	99	52	NO	2	YES
Greenwich 12	U	89	35	NA	2	NA
Greenwich 13	R	92	41	NO	0	YES
Greenwich 4	S	94	30	YES	0	YES
Greenwich 5	R	95	60	NO	0	YES
Greenwich 7	R	96	47	NO	0	YES
Greenwich 8	R	96	74	NO	23	NO
Greenwich 9	R	82	44	NA	0	NA
Greenwich Bexley 6	R	97	44	NO	1	YES
Hackney 4	U	80	49	NA	6	NA
Hackney 6	R	81	68	NA	13	NA
Hammersmith and Fulham 1	R	93	84	NO	43	NO
Hammersmith and Fulham 2	U	97	39	YES	0	YES
Haringey 1	R	81	44	NA	0	NA
Haringey 2	S	97	33	YES	0	YES
Harlington AURN	U	98	37	YES	2	YES
Harrow 1	U	96	27	YES	0	YES
Harrow 2	R	86	44	NA	1	NA
Havering 1	R	96	41	NO	0	YES
Havering 3	R	98	39	YES	1	YES
Heathrow Airport	U	86	52	NA	0	NA
Hillingdon	S	90	49	NO	0	YES
Hillingdon 1	R	92	43	NO	1	YES
Hillingdon 2	R	98	38	YES	0	YES
Hillingdon 3	R	60	45	NA	0	NA
Hounslow 2	S	90	37	YES	0	YES
Hounslow 4	R	99	69	NO	3	YES
Hounslow 5	R	82	55	NA	3	NA
Islington 1	U	98	45	NO	0	YES
Islington 2	R	92	67	NO	4	YES
Kens and Chelsea 1	U	95	38	YES	0	YES
Kens and Chelsea 2	R	87	84	NA	6	NA
Kens and Chelsea 3	R	98	95	NO	390	NO
Kens and Chelsea 4	R	99	96	NO	136	NO
Lambeth 1	R	100	60	NO	0	YES
Lambeth 3	U	97	36	YES	0	YES
Lambeth 4	K	88	218	NA	3930	NO
Lambeth 5	R	68	83	NA	5	NA
Lewisham 1	U	88	55	NA	0	NA
Lewisham 2	R	80	68	NA	27	NO
Marylebone Rd	K	93	112	NO	676	NO
Mole Valley 2	S	44	28	NA	0	NA

Site	Type	Data capture %	Annual mean < 40 μgm^{-3}	Annual mean achieved?	No more than 18 occurrences of hourly mean > =200 μgm^{-3} (104.6ppb)	Hourly mean achieved?
Mole Valley 3	U	91	25	YES	0	YES
Reading 1	R	10	37	NA	0	NA
Reading AURN	U	71	20	NA	0	NA
Redbridge 1	U	63	35	NA	0	NA
Redbridge 3	K	87	56	NA	2	NA
Redbridge 4	R	92	44	NO	0	YES
Redbridge 5	R	94	61	NO	59	NO
Reigate and Banstead 1	S	98	29	YES	0	YES
Reigate and Banstead 2	S	96	32	YES	0	YES
Reigate and Banstead 3	RU	98	19	YES	0	YES
Richmond 1	R	99	42	NO	0	YES
Richmond 2	S	86	30	NA	0	NA
Richmond 25	R	55	44	NA	0	NA
Richmond 26	R	51	50	NA	0	NA
Richmond 27	R	42	32	NA	0	NA
Sevenoaks 1	U	99	21	YES	0	YES
Sevenoaks 2	R	91	33	YES	0	YES
South Oxfordshire 1	R	89	37	NA	0	NA
South Oxfordshire 2	R	62	49	NA	18	NA
Southwark 1	U	82	43	NA	0	NA
Southwark 2	R	13	62	NA	0	NA
Sutton 3	S	88	30	NA	0	NA
Sutton 4	K	96	78	NO	100	NO
Sutton 5	I	74	38	NA	0	NA
Teddington AURN	S	94	23	YES	0	YES
Thurrock 1	U	92	33	YES	0	YES
Thurrock 2	R	95	74	NO	26	NO
Thurrock 3	R	98	35	YES	0	YES
Tower Hamlets 1	U	85	40	NA	0	NA
Tower Hamlets 2	R	95	61	NO	6	YES
Tower Hamlets 3	U	99	49	NO	0	YES
Waltham Forest 1	U	86	35	NA	0	NA
Waltham Forest 3	R	97	33	YES	0	YES
Wandsworth 2	U	94	51	NO	0	YES
Wandsworth 4	R	96	47	NO	3	YES
West London AURN	U	93	51	NO	0	YES
Westminster AURN	U	93	51	NO	6	YES
Windsor and Maidenhead 1	R	94	50	NO	0	YES
Windsor and Maidenhead 2	R	93	45	NO	3	YES
Windsor and Maidenhead 3	RU	99	18	YES	0	YES

O_3				
Site	**Type**	**Data capture %**	**No more than 10 days where maximum rolling 8hr mean >= 100 μgm^{-3} (50ppb)**	**Achieved?**
Bexley 1	S	90	24	NO
Bexley 7	R	95	16	NO
Bexley 8	R	93	14	NO
Bloomsbury	U	92	15	NO
Brent 1	S	94	38	NO
Brent 4	R	54	2	NA
Bromley 5	S	81	25	NO
City of London 1	U	94	24	NO
Croydon 3	S	96	30	NO
Ealing 1	U	99	28	NO
Ealing 2	R	94	3	YES
Elmbridge 1	U	16	0	NA
Enfield 3	U	94	40	NO
Greenwich 13	R	92	26	NO
Greenwich 4	S	93	33	NO
Greenwich 8	R	59	12	NO
Greenwich 9	R	42	5	NA
Greenwich Bexley 6	R	96	14	NO
Hackney 4	U	23	0	NA
Hackney 6	R	55	12	NO
Haringey 2	S	69	26	NO
Harlington AURN	U	88	26	NO
Heathrow Airport	U	89	22	NO
Hillingdon AURN	S	93	10	YES
Hounslow 2	S	92	31	NO
Kens and Chelsea 1	U	90	34	NO
Kingston 1	S	69	33	NO
Lewisham 1	U	95	9	YES
Marylebone Rd	K	91	0	YES
Reading AURN	U	94	29	NO
Redbridge 1	U	98	27	NO
Reigate and Banstead 3	RU	57	35	NO
Richmond 2	S	95	26	NO
Richmond 25	R	55	22	NO
Richmond 27	R	42	2	NA
Sevenoaks 1	U	99	43	NO
Southwark 1	U	38	0	NA
Sutton 3	S	93	31	NO
Teddington AURN	S	94	42	NO
Thurrock 1	U	94	25	NO
Tower Hamlets 1	U	99	42	NO

Site	Type	Data Capture %	No more than 10 days where maximum rolling 8hr mean >= 100 μgm^{-3} (50ppb)	Achieved?
Tower Hamlets 4	R	15	0	NA
Wandsworth 2	U	95	24	NO
Westminster AURN	U	93	27	NO
Windsor and Maidenhead 3	RU	99	42	NO

PM_{10}						
Site	**Type**	**Data capture %**	**Annual mean less than 40 μgm^{-3}**	**Annual mean achieved?**	**No more than 35 days where daily mean >= 50 μgm^{-3}**	**Daily mean achieved?**
A3 AURN	R	98	34	YES	30	YES
Barking and Dagenham 2	S	90	26	YES	17	YES
Barnet 1	K	96	28	YES	14	YES
Barnet 2	U	99	26	YES	15	YES
Bexley 1	S	91	26	YES	8	YES
Bexley 2	S	99	25	YES	10	YES
Bexley 2 (FDMS)	S	31	25	NA	9	NA
Bexley 4	I	94	43	NO	106	NO
Bexley 7	R	95	40	NO	77	NO
Bexley 7 (FDMS)	R	92	31	YES	44	NO
Bexley 8	R	98	34	YES	61	NO
Bloomsbury AURN	U	98	30	YES	21	YES
Brent 1	S	99	23	YES	7	YES
Brent 3	R	61	32	NA	19	NA
Brent 4	R	92	43	NO	99	NO
Brent 5	I	99	70	NO	191	NO
Brent 6	R	11	29	NA	1	NA
Bromley 7	R	92	21	YES	5	YES
Camden 1	K	86	37	NA	52	NO
Camden 3	R	78	37	NA	39	NO
City of London 2	K	74	44	NA	85	NO
City of London 3	U	75	25	NA	10	NA
City of London 4	R	72	36	NA	38	NO
Croydon 3	S	92	23	YES	6	YES
Croydon 4	R	99	30	YES	17	YES
Crystal Palace 1	R	89	28	NA	14	NA
Ealing 2	R	96	30	YES	20	YES
Ealing 2 (FDMS)	R	99	26	YES	24	YES
Ealing 7	U	39	25	NA	4	NA
Ealing 8	I	99	74	NO	224	NO
Elmbridge 1	U	5	17	NA	0	NA
Enfield 2	R	65	25	NA	8	NA
Enfield 3	U	92	22	YES	8	YES
Enfield 4	R	90	30	YES	30	YES
Enfield 5	R	92	31	YES	28	YES
Greenwich 10	R	99	28	YES	18	YES
Greenwich 13	R	77	25	NA	18	NA
Greenwich 4	S	97	24	YES	11	YES
Greenwich 5	R	99	28	YES	16	YES
Greenwich 7	R	99	32	YES	30	YES

Site	Type	Data capture %	Annual mean less than 40 µgm^{-3}	Annual mean achieved?	No more than 35 days where daily mean >= 50 µgm^{-}	Daily mean achieved?
Greenwich 8	R	99	47	NO	110	NO
Greenwich 9	R	44	29	NA	16	NA
Greenwich Bexley 6	R	95	31	YES	33	YES
Hackney 6	R	93	36	YES	40	NO
Hammersmith and Fulham 1	R	94	35	YES	35	YES
Hammersmith and Fulham 2	U	99	25	YES	9	YES
Haringey 1	R	86	27	NA	16	NA
Haringey 2	S	95	25	YES	11	YES
Harlington AURN	U	99	26	YES	9	YES
Harrow 1	U	97	21	YES	5	YES
Harrow 2	R	92	31	YES	21	YES
Havering 3	R	95	24	YES	7	YES
Heathrow Airport	U	85	31	NA	27	NA
Hillingdon AURN	S	97	29	YES	21	YES
Hillingdon 1	R	94	29	YES	23	YES
Hillingdon 2	R	83	25	NA	8	NA
Hillingdon 3	R	91	25	YES	11	YES
Hounslow 2	S	93	23	YES	4	YES
Hounslow 4	R	99	29	YES	20	YES
Hounslow 5	R	98	36	YES	50	NO
Islington 1	U	97	24	YES	6	YES
Islington 2	R	99	35	YES	32	YES
Islington 4	U	56	30	NA	14	NA
Islington 5	R	40	37	NA	17	NA
Kens and Chelsea 1	U	99	26	YES	15	YES
Kens and Chelsea 1 (FDMS)	U	95	22	YES	13	YES
Kens and Chelsea 2	R	98	40	NO	60	NO
Kens and Chelsea 5	K	86	40	NA	62	NO
Lambeth 1	R	87	25	NA	10	NA
Lambeth 3	U	88	22	NA	9	NA
Lambeth 4	K	80	40	NA	56	NO
Lambeth 5	R	76	66	NA	199	NO
Lewisham 2	R	80	30	NA	21	NA
Marylebone Rd	K	97	47	NO	151	NO
Marylebone Road (FDMS)	K	49	33	NA	17	NA
Mole Valley 2	S	52	22	NA	1	NA
Mole Valley 3	U	70	23	NA	4	NA
Reading AURN	U	94	23	YES	6	YES
Redbridge 1	U	94	26	YES	16	YES
Redbridge 3	K	89	30	NA	27	NA
Redbridge 4	R	94	29	YES	19	YES
Redbridge 5	R	97	30	YES	21	YES

Site	Type	Data capture %	Annual mean less than 40 μgm^{-3}	Annual mean achieved?	No more than 35 days where daily mean >= 50 μgm^{-}	Daily mean achieved?
Reigate and Banstead 1	S	98	24	YES	5	YES
Richmond 1	R	94	27	YES	8	YES
Richmond 2	S	99	25	YES	17	YES
Richmond 25	R	53	28	NA	7	NA
Richmond 27	R	42	24	NA	7	NA
Sevenoaks 1	U	99	22	YES	3	YES
Sevenoaks 2	R	99	27	YES	10	YES
Southwark 1	U	88	28	NA	15	NA
Southwark 2	R	30	39	NA	18	NA
Sutton 4	K	98	33	YES	21	YES
Sutton 5	I	95	35	YES	49	NO
Thurrock 1	U	98	23	YES	7	YES
Thurrock 3	R	99	26	YES	13	YES
Tower Hamlets 1	U	95	25	YES	16	YES
Tower Hamlets 3	U	99	26	YES	15	YES
Tower Hamlets 4	R	23	34	NA	16	NA
Waltham Forest 1	U	88	26	NA	7	NA
Waltham Forest 3	R	97	25	YES	10	YES
Wandsworth 4	R	99	29	YES	28	YES

NOTE: TEOM measurements have been multiplied by 1.3 and BAM measurements have been multiplied by 0.83.

VCM PM_{10} Annual

			TEOM x1.3		VCM	
Site	Type	Data capture %	Annual mean less than 40 μgm^{-3}	Annual mean achieved?	Annual mean less than 40 μgm^{-3}	Annual mean achieved?
A3 AURN	R	98	34	YES	30	YES
Barking and Dagenham 2	S	90	26	YES	23	YES
Barnet 1	K	96	28	YES	25	YES
Barnet 2	U	99	26	YES	23	YES
Bexley 1	S	91	26	YES	23	YES
Bexley 2	S	99	25	YES	22	YES
Bexley 4	I	94	43	NO	36	YES
Bexley 7	R	95	40	NO	35	YES
Bexley 8	R	98	34	YES	30	YES
Bloomsbury AURN	U	98	30	YES	26	YES
Brent 1	S	99	23	YES	21	YES
Brent 3	R	61	32	NA	29	NA
Brent 4	R	92	43	NO	37	YES
Brent 5	I	99	70	NO	57	NO
Brent 6	R	11	29	NA	25	NA
Camden 1	K	86	37	NA	32	NA
Camden 3	R	78	37	NA	31	NA
City of London 2	K	74	44	NA	38	NA
City of London 4	R	72	36	NA	31	NA
Croydon 3	S	92	23	YES	21	YES
Croydon 4	R	99	30	YES	26	YES
Crystal Palace 1	R	89	28	NA	25	NA
Ealing 2	R	96	30	YES	27	YES
Ealing 7	U	39	25	NA	24	NA
Ealing 8	I	99	74	NO	61	NO
Enfield 5	R	92	31	YES	27	YES
Greenwich 10	R	99	28	YES	25	YES
Greenwich 4	S	97	24	YES	22	YES
Greenwich 5	R	99	28	YES	25	YES
Greenwich 7	R	99	32	YES	28	YES
Greenwich 8	R	99	47	NO	39	YES
Greenwich Bexley 6	R	95	31	YES	27	YES
Hackney 6	R	93	36	YES	31	YES
Hammersmith and Fulham 1	R	94	35	YES	30	YES
Hammersmith and Fulham 2	U	99	25	YES	23	YES
Haringey 1	R	86	27	NA	24	NA
Harlington AURN	U	99	26	YES	23	YES
Harrow 1	U	97	21	YES	20	YES
Harrow 2	R	92	31	YES	27	YES

			TEOM x1.3		VCM	
Site	**Type**	**Data capture %**	**Annual mean less than 40 μgm^{-3}**	**Annual mean achieved?**	**Annual mean less than 40 μgm^{-3}**	**Annual mean achieved?**
Havering 3	R	95	24	YES	22	YES
Heathrow Airport	U	85	31	NA	28	NA
Hillingdon AURN	S	97	29	YES	26	YES
Hillingdon 1	R	94	29	YES	26	YES
Hillingdon 2	R	83	25	NA	23	NA
Hillingdon 3	R	91	25	YES	23	YES
Hounslow 2	S	93	23	YES	21	YES
Hounslow 4	R	99	29	YES	26	YES
Hounslow 5	R	98	36	YES	31	YES
Islington 1	U	97	24	YES	22	YES
Islington 2	R	99	35	YES	30	YES
Kens and Chelsea 1	U	99	26	YES	23	YES
Kens and Chelsea 2	R	98	40	NO	34	YES
Lewisham 2	R	80	30	NA	26	NA
Marylebone Rd	K	97	47	NO	39	YES
Mole Valley 2	S	52	22	NA	21	NA
Mole Valley 3	U	70	23	NA	21	NA
Reading AURN	U	94	23	YES	21	YES
Reigate and Banstead 1	S	98	24	YES	22	YES
Richmond 1	R	94	27	YES	24	YES
Richmond 2	S	99	25	YES	22	YES
Richmond 25	R	53	28	NA	26	NA
Richmond 27	R	42	24	NA	21	NA
Sevenoaks 1	U	99	22	YES	20	YES
Sevenoaks 2	R	99	27	YES	24	YES
Southwark 1	U	88	28	NA	25	NA
Southwark 2	R	30	39	NA	35	NA
Sutton 4	K	98	33	YES	29	YES
Sutton 5	I	95	35	YES	31	YES
Thurrock 1	U	98	23	YES	21	YES
Thurrock 3	R	99	26	YES	23	YES
Tower Hamlets 1	U	95	25	YES	23	YES
Tower Hamlets 3	U	99	26	YES	24	YES
Waltham Forest 1	U	88	26	NA	23	NA
Waltham Forest 3	R	97	25	YES	23	YES
Wandsworth 4	R	99	29	YES	25	YES

VCM PM_{10} Daily

			TEOM x1.3		VCM	
Site	Type	Data capture %	No more than 35 days where daily mean >= 50 μgm^{-3}	Daily mean achieved?	No more than 35 days where daily mean >= 50 μgm^{-3}	Daily mean achieved?
A3 AURN	R	98	30	YES	20	YES
Barking and Dagenham 2	S	90	17	YES	13	YES
Barnet 1	K	96	14	YES	12	YES
Barnet 2	U	99	15	YES	15	YES
Bexley 1	S	91	8	YES	9	YES
Bexley 2	S	99	10	YES	12	YES
Bexley 4	I	94	106	NO	84	NO
Bexley 7	R	95	77	NO	63	NO
Bexley 8	R	98	61	NO	47	NO
Bloomsbury AURN	U	98	21	YES	18	YES
Brent 1	S	99	7	YES	7	YES
Brent 3	R	61	19	NA	16	NA
Brent 4	R	92	99	NO	61	NO
Brent 5	I	99	191	NO	168	NO
Brent 6	R	11	1	NA	1	NA
Camden 1	K	86	52	NO	38	NO
Camden 3	R	78	39	NO	29	NA
City of London 2	K	74	85	NO	43	NO
City of London 4	R	72	38	NO	28	NA
Croydon 3	S	92	6	YES	8	YES
Croydon 4	R	99	17	YES	18	YES
Crystal Palace 1	R	89	14	NA	7	NA
Ealing 2	R	96	20	YES	20	YES
Ealing 7	U	39	4	NA	5	NA
Ealing 8	I	99	224	NO	182	NO
Enfield 5	R	92	28	YES	22	YES
Greenwich 10	R	99	18	YES	21	YES
Greenwich 4	S	97	11	YES	10	YES
Greenwich 5	R	99	16	YES	16	YES
Greenwich 7	R	99	30	YES	26	YES
Greenwich 8	R	99	110	NO	71	NO
Greenwich Bexley 6	R	95	33	YES	30	YES
Hackney 6	R	93	40	NO	31	YES
Hammersmith and Fulham 1	R	94	35	YES	26	YES
Hammersmith and Fulham 2	U	99	9	YES	10	YES
Haringey 1	R	86	16	NA	12	NA
Harlington	U	99	9	YES	13	YES
Harrow 1	U	97	5	YES	7	YES
Harrow 2	R	92	21	YES	20	YES
Havering 3	R	95	7	YES	9	YES

			TEOM x1.3		VCM	
Site	Type	Data capture %	No more than 35 days where daily mean >= 50 μgm^{-3}	Daily mean achieved?	No more than 35 days where daily mean >= 50 μgm^{-3}	Daily mean achieved?
Heathrow Airport	U	85	27	NA	22	NA
Hillingdon AURN	S	97	21	YES	17	YES
Hillingdon 1	R	94	23	YES	20	YES
Hillingdon 2	R	83	8	NA	9	NA
Hillingdon 3	R	91	11	YES	7	YES
Hounslow 2	S	93	4	YES	6	YES
Hounslow 4	R	99	20	YES	20	YES
Hounslow 5	R	98	50	NO	31	YES
Islington 1	U	97	6	YES	7	YES
Islington 2	R	99	32	YES	25	YES
Kens and Chelsea 1	U	99	15	YES	13	YES
Kens and Chelsea 2	R	98	60	NO	38	NO
Lewisham 2	R	80	21	NA	19	NA
Marylebone Rd	K	97	151	NO	71	NO
Mole Valley 2	S	52	1	NA	2	NA
Mole Valley 3	U	70	4	NA	4	NA
Reading AURN	U	94	6	YES	6	YES
Reigate and Banstead 1	S	98	5	YES	7	YES
Richmond 1	R	94	8	YES	13	YES
Richmond 2	S	99	17	YES	13	YES
Richmond 25	R	53	7	NA	8	NA
Richmond 27	R	42	7	NA	6	NA
Sevenoaks 1	U	99	3	YES	3	YES
Sevenoaks 2	R	99	10	YES	9	YES
Southwark 1	U	88	15	NA	15	NA
Southwark 2	R	30	18	NA	14	NA
Sutton 4	K	98	21	YES	18	YES
Sutton 5	I	95	49	NO	28	YES
Thurrock 1	U	98	7	YES	8	YES
Thurrock 3	R	99	13	YES	13	YES
Tower Hamlets 1	U	95	16	YES	11	YES
Tower Hamlets 3	U	99	15	YES	16	YES
Waltham Forest 1	U	88	7	NA	9	NA
Waltham Forest 3	R	97	10	YES	10	YES
Wandsworth 4	R	99	28	YES	22	YES

$PM_{2.5}$

Site	Type	Instrument	Data capture %	Annual mean μgm^{-3}
Bexley 1	S	TEOM	98	12
Bexley 2	S	TEOM	99	12
Bexley 3	S	TEOM	99	12
Bexley 7	R	TEOM	98	14
Bexley 8	R	TEOM	99	14
Bloomsbury AURN	U	TEOM	97	14
Brent 4	R	TEOM	58	18
Ealing 2	R	TEOM	76	13
Greenwich 12 (F)	R	TEOM	26	22
Greenwich 13 (F)	R	TEOM	37	14
Greenwich 8	R	TEOM	64	20
Greenwich 9 (F)	R	TEOM	79	19
Greenwich Bexley 6	R	TEOM	96	14
Hackney 4	U	TEOM	96	15
Hackney 6	R	TEOM	60	16
Marylebone Road	K	TEOM	97	21
Tower Hamlets 4 (F)	R	TEOM	29	19

SO_2				
Site	**Type**	**Data capture %**	**No more than 35 occurrences of 15min mean >= 266 μgm^{-3}**	**Achieved?**
Barking & Dagenham 1	S	83	0	NA
Bexley 1	S	93	1	YES
Bloomsbury AURN	U	91	0	YES
Brent 1	S	93	0	YES
Brent 3	R	59	0	NA
Brent 4	R	85	0	NA
Brent 6	R	11	0	NA
Castle Point 1	U	97	0	YES
City of London 1	U	93	0	YES
Croydon 4	R	35	0	NA
Crystal Palace 1	R	85	1	NA
Ealing 1	U	93	0	YES
Elmbridge 1	U	16	0	NA
Enfield 3	U	72	0	NA
Enfield 4	R	89	0	NA
Greenwich 4	S	93	0	YES
Hammersmith and Fulham 1	R	97	0	YES
Haringey 1	R	97	0	YES
Harrow 1	U	94	0	YES
Havering 3	R	98	1	YES
Hillingdon AURN	S	94	0	YES
Hounslow 2	S	87	1	NA
Hounslow 4	R	99	0	YES
Kens and Chelsea 1	U	94	0	YES
Kens and Chelsea 2	R	85	0	NA
Lambeth 1	R	94	0	YES
Lambeth 3	U	89	0	NA
Lambeth 4	K	87	0	NA
Lambeth 5	R	88	0	NA
Lewisham 1	U	93	0	YES
Lewisham 2	R	84	0	NA
Marylebone Rd	K	88	0	NA
Reading AURN	U	94	0	YES
Redbridge 4	R	93	0	YES
Richmond 25	R	50	1	NA
Richmond 27	R	38	0	NA
Sevenoaks 1	U	99	1	YES
Southwark 1	U	72	0	NA
Southwark 2	R	10	0	NA
Teddington AURN	S	94	1	YES

Site	Type	Data capture %	No more than 35 occurrences of 15min mean >= 266 μgm^{-3}	Achieved?
Thurrock 1	U	94	0	YES
Thurrock 3	R	95	0	YES
Tower Hamlets 1	U	99	0	YES
Tower Hamlets 3	U	98	0	YES
Waltham Forest 1	U	95	1	YES
Waltham Forest 3	R	82	0	NA
Wandsworth 2	U	88	0	NA
Westminster AURN	U	85	0	NA

Appendix 4: Detailed results 2007

CO				
Site	**Type**	**Data capture %**	**Max 8h means >=8.6 mgm^{-3} (10ppm)**	**Achieved?**
A3 AURN	R	72	0	NA
Bexley 1	S	97	0	YES
Bloomsbury AURN	U	84	0	NA
Brent 1	S	98	0	YES
Bromley 7	R	94	0	YES
City of London 6	R	46	0	NA
Crystal Palace 1	R	92	0	YES
Ealing 2	R	99	0	YES
Enfield 3	U	95	0	YES
Hackney 4	U	99	0	YES
Harlington AURN	U	96	0	YES
Heathrow Airport	U	19	0	NA
Hillingdon AURN	S	69	0	NA
Hounslow 5	R	52	0	NA
Islington 2	R	99	0	YES
Kens and Chelsea 1	U	98	0	YES
Kens and Chelsea 2	R	96	0	YES
Marylebone Rd	K	96	0	YES
Reading AURN	U	70	0	NA
Redbridge 4	R	93	0	YES
Redbridge 5	R	91	0	YES
Richmond 27	R	97	0	YES
Sevenoaks	U	95	0	YES
Southwark 1	U	85	0	NA
Thurrock 1	U	90	0	YES
Tower Hamlets 2	R	84	0	NA
Wandsworth 2	U	95	0	YES
Wandsworth 4	R	63	0	NA
West London AURN	U	66	0	NA
Westminster AURN	U	92	0	YES

NO_x

Site	Type	Annual mean NOX μgm^{-3} (IAS NO_2)
A3 AURN	R	136
Barking & Dagenham 1	S	55
Barking & Dagenham 2	S	149
Barking & Dagenham 3	K	112
Barnet 1	K	155
Barnet 2	U	67
Bexley 1	S	64
Bexley 2	S	56
Bexley 4	I	80
Bexley 7	R	108
Bexley 8	R	87
Bloomsbury AURN	U	116
Brent 1	S	60
Brent 4	R	272
Brent 5	I	135
Brent 6	R	122
Brentwood 1	U	42
Bromley 7	R	87
Camden 1	K	193
Camden 3	R	167
Camden 4	U	124
Camden 5	U	121
Castle Point 1	U	38
City of London 1	U	85
City of London 3	U	97
City of London 6	R	373
Croydon 2	R	140
Croydon 4	R	116
Croydon 5	K	186
Croydon 6	S	69
Crystal Palace 1	R	127
Ealing 1	U	76
Ealing 2	R	135
Ealing 6	R	324
Ealing 7	U	55
Elmbridge 2	R	105
Enfield 1	S	56
Enfield 3	U	58
Enfield 4	R	114
Greenwich 10	R	124
Greenwich 12	U	75
Greenwich 13	R	96

Site	Type	Annual mean NOX μgm^{-3} (IAS NO_2)
Greenwich 4	S	49
Greenwich 5	R	137
Greenwich 7	R	130
Greenwich 8	R	231
Greenwich 9	R	120
Greenwich Bexley 6	R	140
Hackney 4	U	95
Hackney 6	R	143
Hammersmith and Fulham 1	R	237
Hammersmith and Fulham 2	U	65
Haringey 1	R	88
Haringey 2	S	57
Harlington	U	77
Harrow 1	U	44
Harrow 2	R	119
Havering 1	R	84
Havering 3	R	68
Heathrow Airport	U	127
Hillingdon 1	R	118
Hillingdon 2	R	104
Hillingdon 3	R	88
Hillingdon AURN	S	105
Hounslow 2	S	69
Hounslow 4	R	155
Hounslow 5	R	165
Islington 1	U	73
Islington 2	R	162
Islington 6	U	79
Kens and Chelsea 1	U	65
Kens and Chelsea 2	R	160
Kens and Chelsea 3	R	231
Kens and Chelsea 4	R	217
Lambeth 1	R	132
Lambeth 3	U	59
Lambeth 4	K	564
Lambeth 5	R	211
Lewisham 1	U	112
Lewisham 2	R	150
Marylebone Rd	K	279
Mole Valley 3	U	44
Reading 1	R	98
Reading 2	R	237
Reading 3	R	182

Site	Type	Annual mean NOX μgm^{-3} (IAS NO_2)
Reading AURN	U	44
Redbridge 1	U	61
Redbridge 3	K	144
Redbridge 4	R	97
Redbridge 5	R	114
Reigate and Banstead 1	S	51
Reigate and Banstead 2	S	67
Reigate and Banstead 3	RU	32
Richmond 1	R	85
Richmond 2	S	52
Richmond 27	R	83
Sevenoaks 1	U	39
Sevenoaks 2	R	80
South Oxfordshire 1	R	89
South Oxfordshire 2	R	175
South Oxfordshire 3	R	118
Southwark 1	U	81
Sutton 3	S	60
Sutton 4	K	197
Sutton 5	I	89
Teddington AURN	S	49
Thurrock 1	U	65
Thurrock 2	R	188
Thurrock 3	R	90
Tower Hamlets 1	U	62
Tower Hamlets 2	R	173
Tower Hamlets 3	U	99
Tower Hamlets 4	R	240
Waltham Forest 1	U	58
Waltham Forest 3	R	67
Waltham Forest 4	K	289
Waltham Forest 5	U	193
Wandsworth 2	U	117
Wandsworth 4	R	74
West London AURN	U	71
Westminster 4	R	208
Westminster AURN	U	68
Windsor and Maidenhead 1	R	129
Windsor and Maidenhead 2	R	120
Windsor and Maidenhead 3	RU	36

NO_2						
Site	**Type**	**Data capture %**	**Annual mean < 40 μgm^{-3}**	**Annual mean achieved?**	**No more than 18 occurrences of hourly mean >=200 μgm^{-3} (104.6ppb)**	**Hourly mean achieved?**
A3 AURN	R	72	61	NA	13	NA
Barking & Dagenham 1	S	80	30	NA	2	NA
Barking & Dagenham 2	S	7	47	NA	0	NA
Barking & Dagenham 3	K	57	49	NA	18	NA
Barnet 1	K	100	67	NO	15	YES
Barnet 2	U	97	36	YES	8	YES
Bexley 1	S	95	34	YES	0	YES
Bexley 2	S	99	31	YES	0	YES
Bexley 4	I	97	36	YES	6	YES
Bexley 7	R	97	41	NO	3	YES
Bexley 8	R	97	36	YES	1	YES
Bloomsbury AURN	U	78	61	NA	6	NA
Brent 1	S	96	32	YES	8	YES
Brent 4	R	88	71	NA	21	NO
Brent 5	I	92	48	NO	7	YES
Brent 6	R	82	52	NA	16	NA
Brentwood 1	U	92	28	YES	0	YES
Bromley 7	R	96	47	NO	2	YES
Camden 1	K	97	77	NO	113	NO
Camden 3	R	93	75	NO	24	NO
Camden 4	U	49	58	NA	5	NA
Camden 5	U	48	58	NA	6	NA
Castle Point 1	U	99	24	YES	0	YES
City of London 1	U	91	48	NO	2	YES
City of London 3	U	99	54	NO	0	YES
City of London 6	R	46	108	NA	187	NO
Croydon 2	R	98	46	NO	0	YES
Croydon 4	R	99	59	NO	22	NO
Croydon 5	K	97	66	NO	14	YES
Croydon 6	S	98	34	YES	1	YES
Crystal Palace 1	R	93	50	NO	0	YES
Ealing 1	U	97	39	YES	8	YES
Ealing 2	R	94	57	NO	31	NO
Ealing 6	R	45	90	NA	64	NO
Ealing 7	U	74	31	NA	0	NA
Elmbridge 2	R	31	43	NA	0	NA
Enfield 1	S	86	33	NA	6	NA
Enfield 3	U	94	32	YES	0	YES
Enfield 4	R	90	47	NO	4	YES
Greenwich 10	R	88	58	NA	7	NA

Site	Type	Data capture %	Annual mean < 40 μgm^{-3}	Annual mean achieved?	No more than 18 occurrences of hourly mean >=200 μgm^{-3} (104.6ppb)	Hourly mean achieved?
Greenwich 12	U	98	37	YES	5	YES
Greenwich 13	R	98	45	NO	4	YES
Greenwich 4	S	96	30	YES	0	YES
Greenwich 5	R	27	64	NA	6	NA
Greenwich 7	R	100	49	NO	5	YES
Greenwich 8	R	95	71	NO	58	NO
Greenwich 9	R	99	45	NO	3	YES
Greenwich Bexley 6	R	98	48	NO	0	YES
Hackney 4	U	99	49	NO	28	NO
Hackney 6	R	94	64	NO	4	YES
Hammersmith and Fulham 1	R	98	83	NO	38	NO
Hammersmith and Fulham 2	U	95	37	YES	0	YES
Haringey 1	R	96	42	NO	21	NO
Haringey 2	S	94	32	YES	3	YES
Harlington AURN	U	94	37	YES	4	YES
Harrow 1	U	97	28	YES	3	YES
Harrow 2	R	96	46	NO	14	YES
Havering 1	R	99	39	YES	1	YES
Havering 3	R	8	43	NA	1	NA
Heathrow Airport	U	98	53	NO	9	YES
Hillingdon 1	R	77	49	NA	21	NO
Hillingdon 2	R	27	44	NA	0	NA
Hillingdon 3	R	97	43	NO	5	YES
Hillingdon AURN	S	98	45	NO	8	YES
Hounslow 2	S	96	34	YES	12	YES
Hounslow 4	R	82	65	NA	0	NA
Hounslow 5	R	98	63	NO	19	NO
Islington 1	U	19	46	NA	0	NA
Islington 2	R	98	67	NO	34	NO
Islington 6	U	59	41	NA	0	NA
Kens and Chelsea 1	U	99	39	YES	17	YES
Kens and Chelsea 2	R	95	71	NO	2	YES
Kens and Chelsea 3	R	98	94	NO	440	NO
Kens and Chelsea 4	R	99	91	NO	77	NO
Lambeth 1	R	95	61	NO	0	YES
Lambeth 3	U	83	36	NA	0	NA
Lambeth 4	K	89	226	NA	4242	NO
Lambeth 5	R	39	82	NA	30	NO
Lewisham 1	U	91	53	NO	8	YES
Lewisham 2	R	92	60	NO	11	YES
Marylebone Rd	K	98	102	NO	452	NO

Site	Type	Data capture %	Annual mean < 40 µgm^{-3}	Annual mean achieved?	No more than 18 occurrences of hourly mean >=200 µgm^{-3} (104.6ppb)	Hourly mean achieved?
Mole Valley 3	U	99	25	YES	0	YES
Reading 1	R	73	41	NA	0	NA
Reading 2	R	24	68	NA	14	NA
Reading 3	R	7	50	NA	0	NA
Reading AURN	U	96	23	YES	2	YES
Redbridge 1	U	94	33	YES	0	YES
Redbridge 3	K	99	60	NO	8	YES
Redbridge 4	R	93	43	NO	6	YES
Redbridge 5	R	85	51	NA	12	NA
Reigate and Banstead 1	S	99	29	YES	0	YES
Reigate and Banstead 2	S	96	34	YES	0	YES
Reigate and Banstead 3	RU	99	21	YES	0	YES
Richmond 1	R	95	43	NO	7	YES
Richmond 2	S	96	31	YES	0	YES
Richmond 27	R	98	38	YES	0	YES
Sevenoaks 1	U	98	22	YES	0	YES
Sevenoaks 2	R	99	34	YES	2	YES
South Oxfordshire 1	R	80	44	NA	0	NA
South Oxfordshire 2	R	81	57	NA	71	NO
South Oxfordshire 3	R	41	48	NA	3	NA
Southwark 1	U	99	44	NO	1	YES
Sutton 3	S	97	33	YES	2	YES
Sutton 4	K	94	83	NO	264	NO
Sutton 5	I	93	37	YES	7	YES
Teddington AURN	S	95	28	YES	0	YES
Thurrock 1	U	87	34	NA	3	NA
Thurrock 2	R	96	68	NO	48	NO
Thurrock 3	R	99	37	YES	0	YES
Tower Hamlets 1	U	99	37	YES	8	YES
Tower Hamlets 2	R	84	67	NA	38	NO
Tower Hamlets 3	U	99	45	NO	3	YES
Tower Hamlets 4	R	21	73	NA	8	NA
Waltham Forest 1	U	77	33	NA	1	NA
Waltham Forest 3	R	28	33	NA	0	NA
Waltham Forest 4	K	13	81	NA	12	NA
Waltham Forest 5	U	13	63	NA	26	NO
Wandsworth 2	U	94	53	NO	4	YES
Wandsworth 4	R	65	40	NA	0	NA
West London AURN	U	73	46	NA	0	NA
Westminster 4	R	89	86	NA	71	NO
Westminster AURN	U	77	37	NA	0	NA

Site	Type	Data capture %	Annual mean < 40 μgm^{-3}	Annual mean achieved?	No more than 18 occurrences of hourly mean >=200 μgm^{-3} (104.6ppb)	Hourly mean achieved?
Windsor and Maidenhead 1	R	99	50	NO	2	YES
Windsor and Maidenhead 2	R	95	47	NO	3	YES
Windsor and Maidenhead 3	RU	96	24	YES	0	YES

O_3

Site	Type	Data capture %	No more than 10 days where maximum rolling 8hr mean >= 100 μgm^{-3} (50ppb)	Achieved?
Bexley 1	S	95	14	NO
Bexley 7	R	95	9	YES
Bexley 8	R	95	4	YES
Bloomsbury AURN	U	85	3	NA
Brent 1	S	99	17	NO
Brent 4	R	92	0	YES
Bromley 5	S	96	25	NO
City of London 1	U	95	4	YES
Croydon 3	S	82	9	NA
Ealing 1	U	99	11	NO
Ealing 2	R	97	0	YES
Enfield 3	U	81	19	NO
Greenwich 13	R	99	10	YES
Greenwich 4	S	98	15	NO
Greenwich 8	R	86	4	NA
Greenwich 9	R	99	2	YES
Greenwich Bexley 6	R	95	3	YES
Hackney 4	U	99	7	YES
Hackney 6	R	94	1	YES
Haringey 2	S	81	15	NO
Harlington AURN	U	89	8	NA
Heathrow Airport	U	24	0	NA
Hillingdon AURN	S	98	17	NO
Hounslow 2	S	87	5	NA
Kens and Chelsea 1	U	97	14	NO
Kingston 1	S	91	19	NO
Lewisham 1	U	98	3	YES
Marylebone Rd	K	98	2	YES
Reading AURN	U	96	15	NO
Redbridge 1	U	98	7	YES
Reigate and Banstead 3	RU	99	21	NO
Richmond 2	S	96	15	NO
Richmond 27	R	99	10	YES
Sevenoaks 1	U	92	36	NO
Southwark 1	U	96	4	YES
Sutton 3	S	99	12	NO
Teddington	S	96	19	NO
Thurrock 1	U	96	12	NO
Tower Hamlets 1	U	95	12	NO
Tower Hamlets 4	R	87	0	NA
Wandsworth 2	U	99	5	YES
Westminster AURN	U	95	10	YES
Windsor and Maidenhead 3	RU	98	19	NO

PM_{10}

Site	Type	Data capture %	Annual mean less than 40 μgm^{-3}	Annual mean achieved?	No more than 35 days where daily mean > = 50 μgm^{-3}	Daily mean achieved?
A3 AURN	R	73	32	NA	18	NA
Barking and Dagenham 2	S	93	26	YES	14	YES
Barking and Dagenham 3	K	55	31	NA	16	NA
Barnet 1	K	99	26	YES	12	YES
Barnet 2	U	99	22	YES	9	YES
Bexley 1	S	98	25	YES	14	YES
Bexley 2	S	98	23	YES	12	YES
Bexley 2 (FDMS)	S	61	27	NA	19	NA
Bexley 4	I	99	52	NO	148	NO
Bexley 7	R	95	34	YES	49	NO
Bexley 7 (FDMS)	R	81	23	NA	25	NA
Bexley 8	R	98	31	YES	38	NO
Bloomsbury AURN	U	89	29	NA	15	NA
Brent 1	S	96	21	YES	9	YES
Brent 4	R	97	38	YES	59	NO
Brent 5	I	93	50	NO	131	NO
Brent 6	R	96	28	YES	15	YES
Bromley 7	R	94	22	YES	8	YES
Camden 1	K	99	35	YES	41	NO
Camden 3	R	92	40	NO	51	NO
City of London 3	U	90	31	YES	31	YES
Croydon 3	S	83	22	NA	7	NA
Croydon 4	R	98	32	YES	31	YES
Crystal Palace 1	R	90	29	YES	17	YES
Ealing 2	R	97	30	YES	26	YES
Ealing 2 (FDMS)	R	97	26	YES	27	YES
Ealing 7	U	92	24	YES	15	YES
Ealing 8	I	96	53	NO	173	NO
Enfield 3	U	60	21	NA	6	NA
Enfield 4	R	85	31	NA	35	NA
Enfield 5	R	88	30	NA	21	NA
Greenwich 10	R	94	27	YES	14	YES
Greenwich 13 (FDMS)	R	13	22	NA	1	NA
Greenwich 4	S	77	21	NA	5	NA
Greenwich 5	R	99	27	YES	17	YES
Greenwich 7	R	99	30	YES	24	YES
Greenwich 8	R	98	43	NO	89	NO
Greenwich 9 (FDMS)	R	36	25	NA	10	NA
Greenwich Bexley 6	R	94	30	YES	31	YES
Hackney 6	R	94	33	YES	24	YES
Hammersmith and Fulham 1	R	25	33	NA	7	NA

Site	Type	Data capture %	Annual mean less than 40 μgm^{-3}	Annual mean achieved?	No more than 35 days where daily mean > = 50 μgm^{-3}	Daily mean achieved?
Hammersmith and Fulham 1 (FDMS)	R	37	29	NA	16	NA
Hammersmith and Fulham 2	U	97	25	YES	16	YES
Haringey 1	R	74	28	NA	16	NA
Haringey 2	S	68	26	NA	13	NA
Harlington AURN	U	77	24	NA	12	NA
Harrow 1	U	98	20	YES	6	YES
Harrow 2	R	98	29	YES	20	YES
Havering 3	R	2	14	NA	0	NA
Heathrow Airport	U	96	29	YES	18	YES
Hillingdon 1	R	98	28	YES	22	YES
Hillingdon 2	R	28	29	NA	9	NA
Hillingdon 3	R	95	25	YES	14	YES
Hillingdon AURN	S	73	26	NA	5	NA
Hounslow 2	S	95	22	YES	16	YES
Hounslow 4	R	92	27	YES	17	YES
Hounslow 5	R	97	34	YES	48	NO
Islington 1	U	18	21	NA	0	NA
Islington 2	R	97	33	YES	23	YES
Islington 4	U	83	28	NA	23	NA
Islington 5	R	92	37	YES	49	NO
Islington 6	U	77	25	NA	9	NA
Kens and Chelsea 1	U	98	25	YES	15	YES
Kens and Chelsea 1 (FDMS)	U	97	20	YES	16	YES
Kens and Chelsea 2	R	94	35	YES	26	YES
Kens and Chelsea 5	K	90	40	NO	69	NO
Lambeth 1	R	85	28	NA	19	NA
Lambeth 3	U	70	25	NA	11	NA
Lambeth 4	K	86	39	NA	59	NO
Lambeth 5	R	85	67	NA	211	NO
Lewisham 2	R	93	30	YES	26	YES
Marylebone Rd	K	98	44	NO	121	NO
Marylebone Road (FDMS)	K	14	40	NA	14	NA
Mole Valley 3	U	93	22	YES	7	YES
Reading 1	R	76	27	NA	18	NA
Reading 3	R	7	36	NA	7	NA
Reading AURN	U	17	22	NA	1	NA
Reading AURN (FDMS)	U	27	25	NA	10	NA
Redbridge 1	U	96	24	YES	15	YES
Redbridge 3	K	85	27	NA	15	NA
Redbridge 4	R	90	28	YES	20	YES
Redbridge 5	R	95	27	YES	20	YES
Reigate and Banstead 1	S	99	23	YES	9	YES

Site	Type	Data capture %	Annual mean less than 40 μgm^{-3}	Annual mean achieved?	No more than 35 days where daily mean > = 50 μgm^{-3}	Daily mean achieved?
Richmond 1	R	97	26	YES	17	YES
Richmond 2	S	96	22	YES	12	YES
Richmond 27	R	99	26	YES	20	YES
Sevenoaks 1	U	99	19	YES	2	YES
Sevenoaks 2	R	99	26	YES	9	YES
Southwark 1	U	99	26	YES	19	YES
Sutton 4	K	99	34	YES	40	NO
Sutton 5	I	93	35	YES	49	NO
Thurrock 1	U	99	22	YES	10	YES
Thurrock 2	R	70	37	NA	51	NO
Thurrock 3	R	99	25	YES	13	YES
Tower Hamlets 1	U	92	25	YES	12	YES
Tower Hamlets 3	U	97	26	YES	18	YES
Tower Hamlets 4	R	98	35	YES	61	NO
Waltham Forest 1	U	86	26	NA	12	NA
Waltham Forest 3	R	7	19	NA	0	NA
Waltham Forest 3 (FDMS)	R	20	30	NA	14	NA
Waltham Forest 4	K	14	38	NA	13	NA
Waltham Forest 5	U	24	32	NA	15	NA
Wandsworth 4	R	8	19	NA	0	NA
Wandsworth 4 (FDMS)	R	38	27	NA	13	NA

NOTE: TEOM measurements have been multiplied by 1.3 and BAM measurements have been multiplied by 0.83.

VCM PM_{10} Annual

			TEOM x1.3		VCM	
Site	Type	Data capture %	Annual mean less than 40 µgm-3	Annual mean achieved?	Annual mean less than 40 µgm-3	Annual mean achieved?
A3 AURN	R	73	32	NA	28	NA
Barking and Dagenham 2	S	93	26	YES	24	YES
Barnet 1	K	99	26	YES	24	YES
Barnet 2	U	99	22	YES	20	YES
Bexley 1	S	98	25	YES	23	YES
Bexley 2	S	98	23	YES	21	YES
Bexley 4	I	99	52	NO	44	NO
Bexley 7	R	95	34	YES	30	YES
Bexley 8	R	98	31	YES	27	YES
Bloomsbury AURN	U	89	29	NA	26	NA
Brent 1	S	96	21	YES	19	YES
Brent 4	R	97	38	YES	33	YES
Brent 5	I	93	50	NO	42	NO
Brent 6	R	96	28	YES	25	YES
Camden 1	K	99	35	YES	31	YES
Camden 3	R	92	40	NO	34	YES
Croydon 3	S	83	22	NA	20	NA
Croydon 4	R	98	32	YES	28	YES
Crystal Palace 1	R	90	29	YES	26	YES
Ealing 2	R	97	30	YES	26	YES
Ealing 7	U	92	24	YES	22	YES
Ealing 8	I	96	53	NO	44	NO
Enfield 5	R	88	30	NA	26	NA
Greenwich 10	R	94	27	YES	24	YES
Greenwich 4	S	77	21	NA	19	NA
Greenwich 5	R	99	27	YES	24	YES
Greenwich 7	R	99	30	YES	27	YES
Greenwich 8	R	98	43	NO	37	YES
Greenwich Bexley 6	R	94	30	YES	27	YES
Hackney 6	R	94	33	YES	29	YES
Hammersmith and Fulham 1	R	25	33	NA	30	NA
Hammersmith and Fulham 2	U	97	25	YES	22	YES
Haringey 1	R	74	28	NA	26	NA
Harlington	U	77	24	NA	22	NA
Harrow 1	U	98	20	YES	19	YES
Harrow 2	R	98	29	YES	26	YES
Heathrow Airport	U	96	29	YES	26	YES

			TEOM x1.3		VCM	
Site	Type	Data capture %	Annual mean less than 40 µgm-3	Annual mean achieved?	Annual mean less than 40 µgm-3	Annual mean achieved?
Hillingdon 1	R	98	28	YES	25	YES
Hillingdon 2	R	28	29	NA	28	NA
Hillingdon 3	R	95	25	YES	23	YES
Hillingdon AURN	S	73	26	NA	23	NA
Hounslow 2	S	95	22	YES	20	YES
Hounslow 4	R	92	27	YES	24	YES
Hounslow 5	R	97	34	YES	30	YES
Islington 2	R	97	33	YES	29	YES
Islington 6	U	77	25	NA	23	NA
Kens and Chelsea 1	U	98	25	YES	23	YES
Kens and Chelsea 2	R	94	35	YES	31	YES
Lewisham 2	R	93	30	YES	27	YES
Marylebone Rd	K	98	44	NO	38	YES
Mole Valley 3	U	93	22	YES	20	YES
Reading AURN	U	17	22	YES	20	NA
Reigate and Banstead 1	S	99	23	YES	21	YES
Richmond 1	R	97	26	YES	23	YES
Richmond 2	S	96	22	YES	20	YES
Richmond 27	R	99	26	YES	23	YES
Sevenoaks Background	U	99	19	YES	18	YES
Sevenoaks Roadside	R	99	26	YES	23	YES
Southwark 1	U	99	26	YES	23	YES
Sutton 4	K	99	34	YES	29	YES
Sutton 5	I	93	35	YES	31	YES
Thurrock 1	U	99	22	YES	21	YES
Thurrock 3	R	99	25	YES	23	YES
Tower Hamlets 1	U	92	25	YES	23	YES
Tower Hamlets 3	U	97	26	YES	24	YES
Waltham Forest 1	U	86	26	NA	24	NA
Waltham Forest 4	K	14	38	NA	34	NA

VCM PM_{10} Daily

			TEOM x1.3		VCM	
Site	Type	Data capture %	Annual mean less than 40 μgm^{-3}	Annual mean achieved?	Annual mean less than 40 μgm^{-3}	Annual mean achieved?
A3 AURN	R	98	34	NA	30	NA
Barking and Dagenham 2	S	90	26	YES	23	YES
Barnet 1	K	96	28	YES	25	YES
Barnet 2	U	99	26	YES	23	YES
Bexley 1	S	91	26	YES	23	YES
Bexley 2	S	99	25	YES	22	YES
Bexley 4	I	94	43	NO	36	NO
Bexley 7	R	95	40	NO	35	NO
Bexley 8	R	98	34	NO	30	YES
Bloomsbury AURN	U	98	30	NA	26	NA
Brent 1	S	99	23	YES	21	YES
Brent 3	R	61	32	NO	29	NO
Brent 4	R	92	43	NO	37	NO
Brent 5	I	99	70	YES	57	YES
Brent 6	R	11	29	NO	25	NO
Camden 1	K	86	37	NO	32	YES
Camden 3	R	78	37	NA	31	NA
City of London 2	K	74	44	YES	38	YES
City of London 4	R	72	36	YES	31	YES
Croydon 3	S	92	23	YES	21	YES
Croydon 4	R	99	30	YES	26	YES
Crystal Palace 1	R	89	28	NO	25	NO
Ealing 2	R	96	30	NA	27	NA
Ealing 7	U	39	25	YES	24	YES
Ealing 8	I	99	74	NA	61	NA
Enfield 5	R	92	31	YES	27	YES
Greenwich 10	R	99	28	YES	25	YES
Greenwich 4	S	97	24	NO	22	NO
Greenwich 5	R	99	28	YES	25	YES
Greenwich 7	R	99	32	YES	28	YES
Greenwich 8	R	99	47	NA	39	NA
Greenwich Bexley 6	R	95	31	YES	27	YES
Hackney 6	R	93	36	NA	31	NA
Hammersmith and Fulham 1	R	94	35	NA	30	NA
Hammersmith and Fulham 2	U	99	25	YES	23	YES
Haringey 1	R	86	27	YES	24	YES
Harlington AURN	U	99	26	YES	23	YES
Harrow 1	U	97	21	NA	20	NA
Harrow 2	R	92	31	YES	27	YES
Havering 3	R	95	24	NA	22	NA

			TEOM x1.3		VCM	
Site	Type	Data capture %	Annual mean less than 40 μgm^{-3}	Annual mean achieved?	Annual mean less than 40 μgm^{-3}	Annual mean achieved?
Heathrow Airport	U	85	31	YES	28	YES
Hillingdon AURN	S	97	29	YES	26	YES
Hillingdon 1	R	94	29	YES	26	YES
Hillingdon 2	R	83	25	NO	23	NO
Hillingdon 3	R	91	25	YES	23	YES
Hounslow 2	S	93	23	NA	21	NA
Hounslow 4	R	99	29	YES	26	YES
Hounslow 5	R	98	36	YES	31	YES
Islington 1	U	97	24	YES	22	YES
Islington 2	R	99	35	NO	30	NO
Kens and Chelsea 1	U	99	26	YES	23	YES
Kens and Chelsea 2	R	98	40	NA	34	NA
Lewisham 2	R	80	30	YES	26	YES
Marylebone Rd	K	97	47	YES	39	YES
Mole Valley 2	S	52	22	YES	21	YES
Mole Valley 3	U	70	23	YES	21	YES
Reading AURN	U	94	23	YES	21	YES
Reigate and Banstead 1	S	98	24	YES	22	YES
Richmond 1	R	94	27	YES	24	YES
Richmond 2	S	99	25	NO	22	YES
Richmond 25	R	53	28	NO	26	NO
Richmond 27	R	42	24	YES	21	YES
Sevenoaks 1	U	99	22	YES	20	YES
Sevenoaks 2	R	99	27	YES	24	YES
Southwark 1	U	88	28	YES	25	YES
Southwark 2	R	30	39	NA	35	NA
Sutton 4	K	98	33	NA	29	NA

$PM_{2.5}$

Site	Type	Data capture %	Annual Mean μgm^{-3}
Bexley 1	TEOM	100	11
Bexley 2	TEOM	95	11
Bexley 3	TEOM	99	12
Bexley 7	TEOM	89	13
Bexley 8	TEOM	99	13
Bloomsbury AURN	TEOM	88	14
Brent 4	TEOM	98	18
Ealing 2	TEOM	98	11
Greenwich 13 (FDMS)	FDMS	83	17
Greenwich 8	TEOM	99	19
Greenwich 9 (FDMS)	FDMS	90	19
Greenwich and Bexley 6	TEOM	95	14
Hackney 4	TEOM	93	13
Hackney 6	TEOM	72	14
Marylebone Road	TEOM	95	22
Redbridge 4	BAM	77	18
Tower Hamlets 4	FDMS	97	20

SITE KEY
K = Kerbside
R = Roadside
U = Urban background
S = Suburban
Ru = Rural

SO_2

Site	Type	Data Capture %	No more than 35 occurrences of 15min mean >= 266 μgm^{-3}	Achieved?
Barking & Dagenham 1	S	77	0	NA
Bexley 1	S	98	0	YES
Bloomsbury AURN	U	82	0	NA
Brent 1	S	95	0	YES
Brent 4	R	88	0	NA
Brent 6	R	85	0	NA
Castle Point 1	U	96	0	YES
City of London 1	U	81	0	NA
Crystal Palace 1	R	86	0	NA
Ealing 1	U	95	0	YES
Enfield 3	U	71	0	NA
Enfield 4	R	62	1	NA
Greenwich 4	S	92	0	YES
Hammersmith and Fulham 1	R	19	0	NA
Haringey 1	R	98	0	YES
Harrow 1	U	93	0	YES
Havering 3	R	2	0	NA
Hillingdon	S	72	0	NA
Hounslow 2	S	93	0	YES
Hounslow 4	R	98	0	YES
Kensington and Chelsea 1	U	96	0	YES
Kensington and Chelsea 2	R	94	0	YES
Lambeth 1	R	92	0	YES
Lambeth 3	U	81	0	NA
Lambeth 4	K	82	0	NA
Lambeth 5	R	67	0	NA
Lewisham 1	U	98	0	YES
Lewisham 2	R	93	0	YES
Marylebone Rd	K	98	0	YES
Reading AURN	U	68	0	NA
Redbridge 4	R	91	0	YES
Richmond 27	R	96	0	YES
Sevenoaks 1	U	98	0	YES
Southwark 1	U	85	0	NA
Teddington AURN	S	64	0	NA
Thurrock 1	U	97	0	YES
Thurrock 3	R	99	0	YES
Tower Hamlets 1	U	99	0	YES
Tower Hamlets 3	U	95	0	YES
Waltham Forest 1	U	80	0	NA
Waltham Forest 3	R	21	0	NA
Waltham Forest 5	U	24	0	NA
Wandsworth 2	U	94	0	YES
Westminster AURN	U	91	0	YES

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