London-Wide Nitrogen Dioxide Diffusion Tube Survey

Annual Report 2003

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CASELLA STANGER

Report

London-Wide Nitrogen Dioxide Diffusion Tube Survey

Annual Report 2001

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Prepared for

London Borough of Barking & Dagenham
London Borough of Bexley
London Borough of Brent
London Borough of Camden
Corporation of London
London Borough of Croydon
London Borough of Greenwich
London Borough of Hammersmith
London Borough of Harrow
London Borough of Hillingdon
London Borough of Hounslow
Royal Borough of Kensington & Chelsea
London Borough of Newham
London Borough of Richmond-upon-Thames
City of Westminster

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Executive Summary

Casella Stanger has undertaken the London-Wide Environment Programme (LWEP) since 1986. The LWEP consists of the monitoring, analysis and reporting of key environmental indicators throughout the Greater London region. This report encompasses one of these indicators – nitrogen dioxide (NO_2).

Nitrogen dioxide has been regarded as a one of the main pollutants that needs to be targeted due to high road traffic emission levels in London. London Boroughs have a statutory duty to regularly review and assess air quality. This process is coupled with the Greater London Authority's air quality management schemes that are outlined in the Mayor's strategy, and which takes an over-arching view on London-wide air quality issues. Subsequent air quality management schemes that are to be introduced indicate the necessity for monitored nitrogen dioxide data on a city-wide scale in order to estimate the effect on a spatial and temporal basis. The LWEP is principally provided as a service for the London Boroughs.

In 2003 diffusion tubes were located at 326 monitoring sites over fifteen boroughs. Annual average NO_2 concentrations that were above the 40 $\mu g/m^3$ Air Quality Objective where recorded at 48 urban background and 167 roadside sites. Results from the 2003 survey indicate a marked increase in NO_2 concentrations compared to 2002. On average, NO_2 concentrations at urban background sites have risen by approximately 27%, and at roadside sites by slightly more by 33%. Elevations in annual average NO_2 concentration have additionally been recorded at both UK NO_2 Network and the urban and rural AURN Network sites during 2003. This nationwide enhancement of NO_2 concentrations has been attributed to meteorological conditions, as opposed to the main anthropological source (road transport).

The geographical spread shows higher concentrations in central parts of London and a lower concentration further away from the city centre. A few hot spots are identified in boroughs on the outskirts of the city.

Long-term linear trend analysis continues to display a downward trend in annual mean NO_2 concentrations at urban background and roadside sites for the majority of participating Boroughs even though concentrations were particularly high this year.

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1 Introduction

The London-Wide Environment Programme (LWEP) has been managed by Casella Stanger since 1986, following on from the Company's origins in the Greater London Council's Scientific Services Department.

The LWEP has been an on-going programme consisting of the monitoring, analysis and reporting of key environmental indicators throughout the Greater London region. One of the more important components is the monitoring of nitrogen dioxide (NO_2) by passive diffusion tubes. This is a cost-effective method for assessing the spatial and temporal distribution of NO_2 as well as identifying hotspots in an urban environment.

In recent years it has proven to be a useful tool for local authorities in screening and baseline surveys, particularly with regards to the Review and Assessment of air quality for local air quality management (Part IV of the Environment Act 1995). Additionally, the Greater London Authority (GLA) has been given an important role to play in the air quality management of the City by virtue of the London Air Quality Strategy that must be taken into consideration by the local authorities when carrying out their statutory duties.

In year 2003 a total of 15[1] London Boroughs participated in the nitrogen dioxide London-Wide Environment Programme:

London Borough of Barking & Dagenham
London Borough of Bexley
London Borough of Brent
London Borough of Camden
Corporation of London
London Borough of Croydon
London Borough of Greenwich
London Borough of Hammersmith & Fulham
London Borough of Harrow
London Borough of Hillingdon
London Borough of Hounslow
Royal Borough of Kensington & Chelsea
London Borough of Newham
London Borough of Richmond-upon-Thames
City of Westminster

[1] The London Borough of Barnet also participated in the LWEP programme in 2003; unfortunately due an issue related to their site codes, the results could not be interpreted in this report.

1.1 Objectives

The overall objective of this report is to provide subscribing local authorities with an overview of the NO_2 concentrations recorded as part of the LWEP NO_2 Diffusion Tube Survey in 2003 and to view these results in the broader context of regulatory requirements and previous monitoring data.

This overall objective will be met by:

- Outlining the reasons for undertaking the monitoring of ambient levels of NO_2;
- Outlining relevant existing and future legislative air quality requirements;
- Detailing the NO_2 sampling methods employed by Casella Stanger in undertaking the LWEP NO_2 Diffusion Tube Survey, including the quality assurance and quality control procedures;
- Identifying the geographical spread of annual mean NO_2 concentration of participating boroughs at Background and Roadside sites within Greater London;
- Assessing the long-term trend in NO_2 concentrations recorded as part of the LWEP NO_2 Diffusion Tube Survey since 1986;
- Reporting the annual mean NO_2 concentrations at each site, for all participating boroughs in 2003 and to place these results in the context of other results gathered since 1993;
- Undertaking analysis of the results to assess trends in pollution at Background and Roadside classes for each participating borough;
- Identifying the elevation in NO_2 concentrations at Roadside sites when compared to Background levels in each participating borough;
- Validation of nitrogen dioxide diffusion tubes through the analysis of results from co-located tubes at automatic analysers in London.

2 Formation, Sources and Effects of NO_2

2.1 Formation of atmospheric nitrogen dioxide

NO_2 is generated naturally and by man-made activities. NO_2 can be emitted directly (known as primary NO_2) or can form during a series of chemical reactions in the atmosphere involving NO_x ($NO + NO_2$) and ozone (referred to as secondary NO_2.) NO_2 can, in turn, act as a future source of oxygen in the formation of ozone under photochemical conditions. Due to the nature of the formation of NO_2 in the atmosphere, there is often an inverse relationship between concentrations of ozone and NO_2.

Combustion processes are the main anthropogenic source of NO_x emissions. These include road transport, power generation, and various high-temperature industrial processes.

The concentration of NO_2 in the atmosphere at any given location is influenced by a number of factors. These including the magnitude and proximity of NO_x emissions sources, the proportion of NO_x directly emitted as NO_2, the chemistry leading in the generation and destruction of NO_2, and meteorological conditions that affect the dispersion and accumulation of NO_2. During the winter months, anti-cyclonic weather systems often result in stable, cold weather conditions, which along with oxidation by atmospheric oxygen often produce pollution episodes. The product of such conditions is thought to be responsible for the extremely high NO_2 concentrations recorded over London in December 1991, when levels peaked at over 803.5 $\mu g\ m^{-3}$ in the evening rush hour.

During the summer, increased temperatures and solar radiation serve to increase the rate of photochemical reactions in the atmosphere. The higher the concentration of NO_2 , the more oxygen is available for the production of ozone leading to a general decrease in occurrence of NO_2 when compared to the winter months.

2.2 Emission sources

Emissions inventories are an important means of quantifying emissions of NO_x from different sources at different times. The greatest contributors of nitrogen oxides (NO_x) in the UK are motor vehicles. Estimates indicate that 42% of total emissions were produced by road transport in 2000[2]. Fossil-fuelled power stations contributed around a quarter of the total NO_x in the same year, whilst the remainder came from a variety of sources including industry and domestic activity. The contribution of road transport to NO_x emissions in urban areas is generally higher than the national average. In London 68% of NO_x emissions come from road transport.

Ground level NO_2 concentrations are greatly influenced by road transport, which continues to be the major source of NO_x. There is evidence for significant amounts of NO_2 emitted directly from the tail pipe of diesel vehicles, with levels possibly as high as

[2] Source: DEFRA (2003) Digest of Environmental Protection and Water Statistics. http://www.defra.gov.uk/environment/statistics/des/index.htm

25% of total NO_X emissions.[3] Primary emissions of NO_2 will be particularly significant for slow-moving buses and large HGVs, as well as possibly diesel vans and taxis in the centre of town and cities. The increasing sales of diesel cars in the UK should also be considered when assessing future NO_2 concentrations in urban areas.

2.3 Health Effects

Medical and epidemiological evidence suggests that nitrogen dioxide may have both acute and chronic effects on health.

Experimental evidence has shown that NO_2 probably exerts its biological damage by oxidation, with the primary toxic effect occurring in the respiratory system. Susceptible groups include young children, asthmatics and people with chronic respiratory diseases. It has also been shown that individuals sensitive to allergens will show a significant response to high concentrations of NO_2. Whilst there have been recorded responses in the susceptible groups listed, it has been demonstrated that individuals not suffering from respiratory disease will be, by-and-large, unaffected by air pollution episodes.

At present, there are still uncertainties concerning the effects of NO_2 exposure over a broader time scale; this is due to the wide range of modifying influences on the behaviour of a single pollutant. It is difficult statistically to separate the impacts on health of NO_2 from those of other pollutants. During the December 1991 episode, particles were also recorded at high levels. It is probable that a synergistic combination of pollutants gives rise to detrimental health effects, as opposed to individual pollutants acting alone. Research conducted at St Bartholomew's Hospital in London showed that exposure of asthmatics to high SO_2 and NO_2 levels in combination can increase the subject's response to airborne allergens. Many studies estimating the chronic effects of NO_2 use unquantified and indirect measures of exposure, though these studies do suggest that the effects of NO_2 exposure are significant.

[3] Source: AQEG (2003) Nitrogen Dioxide in the United Kingdom (Draft for Consultation)

3 Policy Framework

3.1 Standards and Objectives

Air quality standards relevant to NO_2 concentrations have undergone continuous change, both nationally and on a European level. For Europe, the First Air Quality Daughter Directive sets out limits for annual mean and hourly mean NO_2 concentrations and aims to achieve the objectives by 1st January 2010.

Air quality standards relevant to the UK are found in The Air Quality Strategy for England, Scotland, Wales and Northern Ireland[4] (AQS). The document was published in January 2000, superseding the earlier National Air Quality Strategy[5] (NAQS) published in March 1997, and provides a revised framework for reducing air pollution at national and local levels from a wide range of emission sources. The AQS sets out two Air Quality Objectives (AQOs), one hourly and one annual (Table 1), and are in line with those set in the European Directive, although an earlier date for the objectives to be achieved (of 31st December 2005) has been set.

The standards for the eight pollutants covered by the strategy have been provided by recommendations made by the Government's Expert Panel on Air Quality Standards (EPAQS). The objective levels have been based on medical and scientific evidence of how each pollutant affects human health. Factors such as economic efficiency, practicability, technical feasibility and time-scale have also been taken into consideration by the government administration when setting the final objective values. Objectives for NO_2 are prescribed in the Regulations for the purpose of Local Air Quality Management (LAQM) and thus have direct relevance to the diffusion tube network in London.

Table 1 Air Quality Objectives for nitrogen dioxide in AQS

	AQS Objectives		
	Concentration	**Measured as**	**Date to be Achieved by**
Hourly	200 μg m^3 with a maximum of 18 exceedences*	1 hour mean	31 December 2005
Annual	40 μg m^3	Annual mean	31 December 2005

* Exceedence is defined as 'great than' for the AQS objectives.

LAQM is at the heart of the AQS. Local authorities are charged with reviewing current air quality and assessing whether the relevant AQO will be achieved by 2005. Those authorities that conclude that one or more of the objectives are unlikely to be achieved, will be obliged to declare Air Quality Management Areas (AQMAs) and draw up action

4 DETR (2000) The Air Quality Strategy for England, Scotland, Wales and Northern Ireland - Working together for Clean Air"
5 DoE (1997) The United Kingdom National Air Quality Strategy

plans of how to reduce air pollution. Most London boroughs are declaring AQMAs on the prediction that the annual mean AQO for NO_2 will not be met in 2005.

3.2 The Greater London Authority

The Greater London Authority (GLA), created under the Greater London Authority Act 1999 assumed its responsibilities on 3 July 2000. It was created to give London it's own decision making authority, which is in line with the Government's wider environmental, transport, economic and planning objectives.

As a result, the Mayor has significant decision-making abilities being charged, amongst other things, with the responsibility for the London-wide environment and a duty to promote the health of Londoners. The Mayor has a duty to develop an air quality management strategy, in consultation with the London Boroughs, to deliver improvements to air quality in London. The Strategy for London is required to include proposals and policies from the National AQS as well as any other proposals and policies that the Mayor considers appropriate. The Mayor's Air Quality Strategy was published in September 2003, and states that meeting targets for NO_2 is the primary concern of the strategy.

The strategy recognises that road traffic is the primary cause of air pollution in London and is consequently linked to other relevant strategies and measures taken by Transport for London (TfL), the Greater London Authority, and the London Development Agency (LDA). TfL in particular will be instrumental in tackling this problem by means of measures to reduce traffic, promote cleaner technology, and reduce current emissions and by promoting and adopting alternative fuels. New schemes such as a congestion-charging zone around London and the anticipated Low Emission Zone are likely to lead to environmental benefits. In addition to road traffic, commercial and domestic space heating is another large source of NO_2 though measures needed to reduce this emission source are yet uncertain. Long-term monitoring of NO_2 by diffusion tubes with its geographical spread across London will assist in determining the effect of a number of these policies in the future.

4 NO_2 Sampling and Analysis Methods

4.1 Diffusion Tubes

Diffusion tubes are passive monitoring devices. They are made up of a Perspex cylinder, with 2 stainless steel mesh discs, coated with triethanolamine held inside a polythene cap, which is sealed onto one end of the tube. Diffusion tubes sample NO_2 when ambient concentrations enter and pass through the tube and are absorbed by the triethanolamine (TEA), which is present on the coated discs[6]. There are three main preparation methods for diffusion tubes involving triethanolamine. The diffusion tubes employed in the LWEP programme are prepared by UKAS accredited Gradko International Ltd. using the 50% v/v triethanolamine with acetone method.

Prior to and after sampling, an opaque polythene cap is placed over the opposite end of the diffusion tube to prevent further adsorption onto the discs.

The diffusion tubes are labelled and kept refrigerated in plastic bags prior to and after exposure.

4.2 Monitoring locations

In 2003 a total of 326 monitoring sites were active in the LWEP diffusion tube programme. The locations of the diffusion tubes are chosen? by each authority to reflect the likely exposure of the public to concentrations of nitrogen dioxide. All monitoring site have been classified as either roadside or background depending on the distance from the road[7]. The number of tubes exposed at each site is at the discretion of each local authority involved in the monitoring programme. As NO_2 concentrations in London are mainly attributable to road transport there is a strong bias towards roadside sites as opposed to background sites.

Table 2 Monitoring site classifications

Classification	Symbol	Distance From Road
Roadside	R	0-20m
Background	B	>20m

[6] Source: Chemistry and Microbiology - 'Determination of Nitrogen Dioxide in Environmental Samples'; Stanger Science and Environment. 1991.

[7] Further details of diffusion tube site classifications can be found at in the UK NO_2 Diffusion Tube Network website at:http://www.aeat.co.uk/netcen/airqual/reports/no2man/no2man.html.

4.3 Sampling and Analysis

As results from the LWEP are incorporated into the UK Nitrogen Dioxide Diffusion Tube Survey, the tubes are exposed for a four-to five-week period, consistent with the national survey. Adherence to the changeover dates is important to enable as valid an inter-comparison as possible between boroughs.

Gradko International Ltd additionally undertakes the analysis of exposed diffusion tubes, on behalf of Casella Stanger, by ultra violet spectrophotometry.

4.5 Quality Assurance and Quality Control

The EU Daughter Directive sets data quality objectives for nitrogen dioxide along with other pollutants. Under the Directive, annual mean NO_2 concentration data derived from diffusion tube measurements must demonstrate an accuracy of ± 25 % to enable comparison with the Directive air quality standards for NO_2.

In order to ensure that NO_2 concentrations reported are of a high caliber, strict performance criteria need to be met through the execution of quality assurance and control procedures. A number of factors have been identified as influencing the performance of diffusion tubes including the laboratory preparing and analysing the tubes and the tube preparation method. [8] Quality assurance and control procedures are therefore an integral feature of any monitoring programme, ensuring that uncertainties in the data are minimised and allowing the best estimate of true concentrations to be determined.

Gradko International Ltd conducts rigorous quality control and assurance procedures in order to maintain the highest degree of confidence in their laboratory measurements. These are discussed in more detail below.

Workplace Analysis Scheme for Proficiency (WASP)

Gradko International Ltd participates in the Health and Safety Laboratory WASP[9] NO_2 diffusion tube scheme on a monthly basis. This is a recognised performance-testing programme for laboratories undertaking NO_2 diffusion tube analysis as part of the UK NO_2 monitoring network. The scheme is designed to help laboratories meet the European Standard EN482[10]. The laboratory performance for all months in 2003 was rated 'good' which signifies a high level of accuracy for laboratory measurements.

Network Field Inter-comparison Exercise

Gradko International Ltd also takes part in the Network Field Inter-comparison Exercise, operated by NETCEN, which complements the WASP scheme in assessing sampling and analytical performance of diffusion tubes under normal operating conditions. This involves the regular exposure of a triplet of tubes at an Automatic Urban Network site (AUN) site. NETCEN have established performance criteria for participating laboratories. Of particular interest is the bias relative to the

[8] Compilation of diffusion tube collation studies carried out by local authorities, prepared by Professor Duncan Laxen and Penny Wilson, 2003

[9] Health and Safety Executive, Workplace Analysis Scheme for Proficiency

[10] European Committee for Standardisation (CEN) Workplace Atmospheres, General requirements for the performance of procedures for the chemical measurement of chemical agents, EN482, Brussels, CEN 1994.

chemiluminescent analyser that gives an indication of accuracy. In conjunction with this, a measure of precision is determined by comparing the triplet co-located tube measurements. This value is useful for assessing the uncertainty of results due to sampling and analytical techniques. The performance targets can be seen in Table 3.

The Field Inter-comparison Exercise has historically generated the bias and precision results for each laboratory on an annual basis. This has recently been changed to the results being reported on a monthly basis. This enables a full year's inter-comparison against performance criteria. The summary for the latter half of 2003 for Gradko International Ltd is shown below. The results indicate that Gradko International Ltd diffusion tubes are well within the performance targets set by NETCEN.

Table 3 6-month Summary of NO_2 Network Field Inter-comparison Results, 2003

Bias % Performance Target	Gradko International Result	Precision % Performance Target	Gradko International Result
±25	12	±%10	6.9

Gradko International Ltd perform their own blank exposures that serve as a quality control check on the tube preparation procedure. All results are blank subtracted before they are issued to the relevant Borough.

Casella Stanger conduct an 'in-house' study to establish the bias of the NO_2 diffusion tube sampling method compared against continuous analysers which give more accurate concentrations. This is discussed in more detail in Chapter 9.

5 Overview of Results

5.1 Current Year Results

Table 4 below shows summary statistics for the 326 diffusion tube sites operating in the 2003 LWEP Diffusion Tube Network. Annual mean NO_2 concentrations reveal a marked growth at both background and roadside sites since 2002. Background concentrations elevate to a maximum of 70.3 μg/m^3 and roadside concentrations to 106.5 μg/m$^{3.}$ Accompanying this rise in NO_2 concentrations is a large number of exceedences of the 2005 Air Quality Objective, covering a total of 215 sites. This represents almost a four-fold increase compared to the previous year when a total of 57 sites exceeded the annual mean NO_2 objective. In 2003, roadside diffusion tube locations experience a greater rise in NO_2 levels with 78% of these sites breaching the 40 μg/m^3 limit.

Table 4 Summary statistics for all LWEP diffusion tubes monitoring sites

	Number of sites	Annual Mean NO_2 Conc. (μg/m^3) Range	Number of AQO Exceedences	% Change in what? No. of sites breaching AQO? 2002-2003
Background Sites	115	20.6 - 70.3	48	27
Roadside Sites	211	26.9 - 106.5	167	33

The apparent increase in annual mean NO_2 concentrations recorded in 2003 is not unique to the sites operating in the LWEP Diffusion Tube Network. Both the UK Nitrogen Dioxide Network and the urban and rural AURN automatic NO_2 network have recorded elevated NO_2 concentrations. The rise in LWEP diffusion tube concentrations can therefore be viewed as genuine. This nationwide elevation in NO_2 concentration has been attributed to meteorological conditions during 2003. A recent report published by Air Quality Consultants[11] has sought to investigate whether 2003 was an exceptional pollution year with respect to meteorological conditions. The outcome revealed that in comparison to the past ten years, 2003 was not an anomaly, and pollution concentrations obtained by local authority monitoring should be treated as normal in the review and assessment process.

[11] Was 2003 an exceptional pollution year? UK Trends in nitrogen dioxide, nitrogen oxides and PM_{10}, prepared by Prof Duncan Laxen and Dr. Ben Marner, 2004

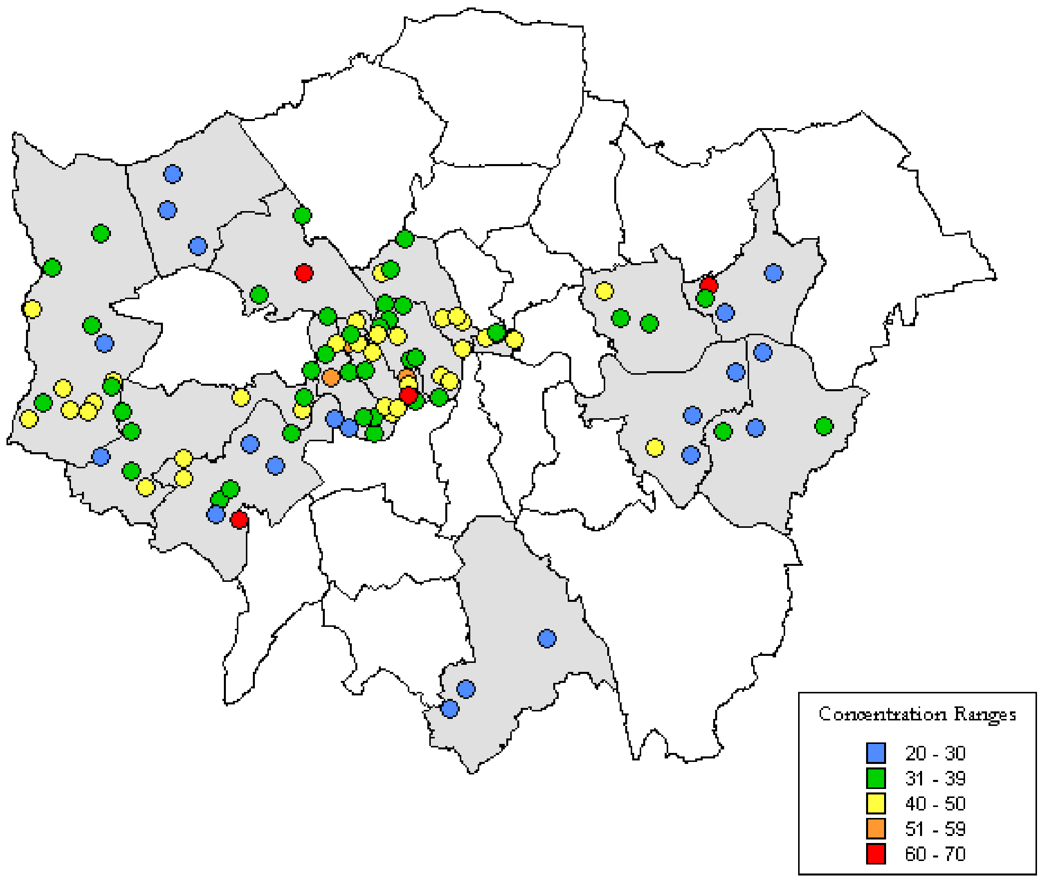
5.4 Nitrogen dioxide concentrations – Geographical spread

Maps 1 and 2 show the geographical spread of the annual mean concentrations for the nitrogen dioxide diffusion tube survey across London. The maps include data only from Boroughs that are part of the London Wide Environment Programme for nitrogen dioxide.

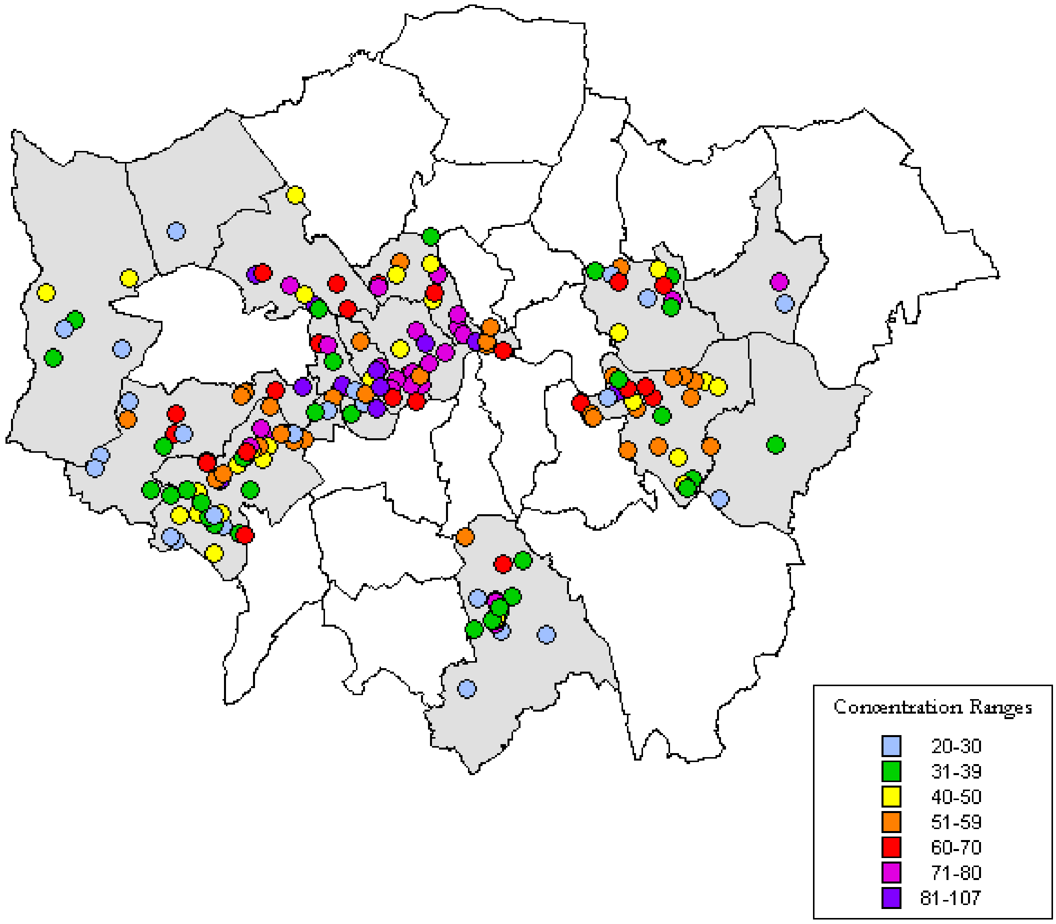
The higher NO_2 levels are concentrated around central parts of London while further away from the centre, the levels tend to decrease. The NO_2 concentration at background sites is predominantly recorded in the 30-40 $\mu g/m^3$ range uniformly spread throughout London. The highest background concentrations are clustered within central London. The geographical spread of NO_2 concentrations at roadside sites is predominantly recorded in the 51-59 $\mu g/m^3$ concentration range. The centre of London maintains the highest levels of NO_2 reaching over 70 $\mu g/m^3$.

A few boroughs situated away from the city experienced annual mean concentration in the higher concentration bandings at both background and roadside locations. These may indicate local pollution hot spots.

Map 1 Annual Mean Background NO_2 Concentrations, 2003



Map 2 Annual Mean Roadside NO_2 Concentrations, 2003

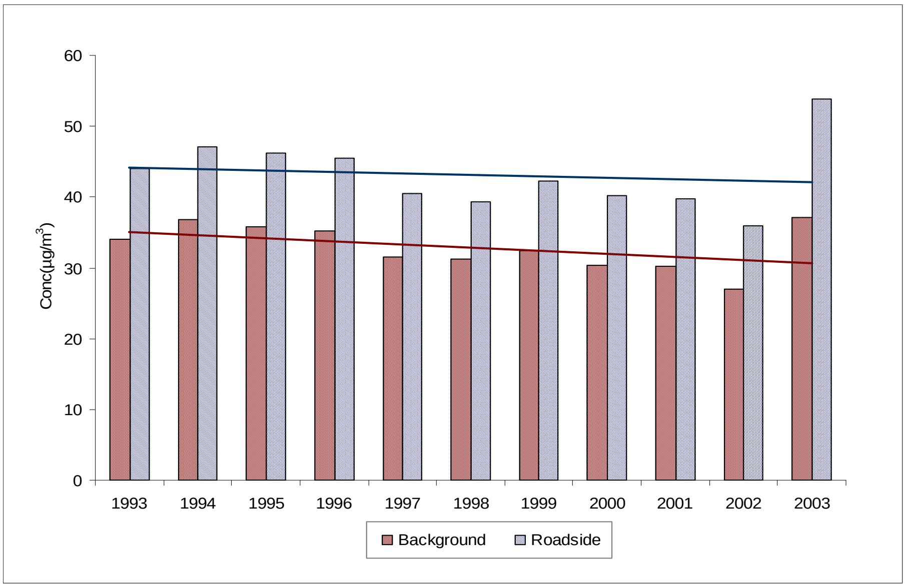


5.2 Long Term Trends

Previous reports have relied on results from 12 sites to establish long-term trends in annual mean NO_2 concentrations recorded at both background and roadside sites from 1986 to the present date. Over the past few years, a number of these sites have become redundant leaving only 9 sites (one of which is background), which may be exploited for long-term analysis of NO_2 concentrations. The introduction of the UK Nitrogen Dioxide Diffusion Tube Survey in 1993 and the resultant increase in exposure time from 2 to 4/5 weeks showed a distinct change in long-term concentrations. The extension in exposure time had the effect of decreasing NO_2 concentrations. In order to strengthen the comparability and representation of long-term trends, data have been collated from diffusion tube sites over a complete data set from 1993 to the present year. This subsequently provides a much large data set comprising of 31 sites for both roadside and background locations. Overall, this improves the inter-year and site comparability of NO_2 concentrations over the past ten years. Long-term diffusion tube data has been assembled from the following authorities:

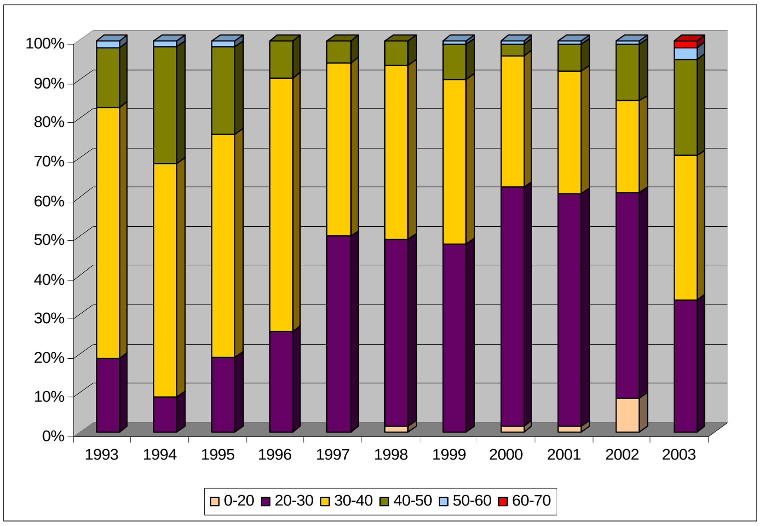
- London Borough of Brent
- London Borough of Camden
- London Borough of Croydon
- London Borough of Harrow
- London Borough of Hounslow
- London Borough of Greenwich
- Royal Borough of Kensington and Chelsea
- London Borough of Richmond
- City of Westminster

Figure 1 Long-term annual mean NO_2 concentrations at selection of background and roadside sites



Long-term background and roadside trends indicate a gradual decline in annual mean NO_2 concentration over time. Background and roadside monitoring sites experience an abrupt increase in annual NO_2 concentration in 2003 reaching the highest concentrations over the eleven-year monitoring period. This is more accentuated at roadside sites that show a growth of 33% in NO_2 concentrations relative to the previous year's results. The rise in background concentration is marginally less at 27%. In terms of the year-to-year variability in annual average NO_2 concentrations, the period between 2002 and 2003 reflects the most notable difference.

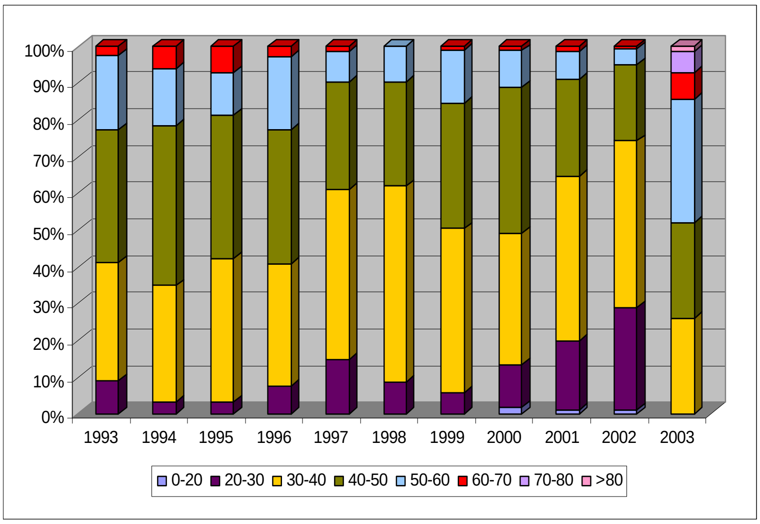
Figure 2 Frequency Distribution of Annual Mean Background NO_2 Concentrations, 1993-2003



In the early part of the programme the largest percentage of annual mean NO_2 concentrations where present in the 30-40 $\mu g/m^3$ banding. Approximately 5% of sites recorded concentration in the 50-60 $\mu g/m^3$ banding. From 1997 to 2002 there is a clear variation in the frequency of each banding. Annual mean NO_2 concentrations in the 50-60 $\mu g/m^3$ and 40-50 $\mu g/m^3$ banding reduce by approximately 50%. Annual mean NO_2 concentrations recorded in the 20-30 $\mu g/m^3$ range gradually increase over this period. In 1998 annual mean NO_2 concentrations drop for the first time to below 20 $\mu g/m^3$, and continue to be recorded in this banding over the next four years. In 2002 annual mean NO_2 concentrations illustrate a change in the proportion of each concentration banding. The 20-30 $\mu g/m^3$ banding are the most frequently recorded concentrations at London sites, with those >20 $\mu g/m^3$ revealing their highest frequency as yet.

The frequency distribution for background sites in 2003 stands out from the previous years with an obvious shift in the proportion of each banding. A new high concentration range of 60-70 $\mu g/m^3$ has been introduced with the loss of the very low concentration banding of 0-20 $\mu g/m^3$. The 20-30 $\mu g/m^3$ range has notably decreased in frequency, whereas the monitoring sites recording concentrations in the 30-40, 40-50 and 50-60 $\mu g/m^3$ have almost doubled. For the first time since long-term records began 1993, background concentrations have reached 60-70 $\mu g/m^3$. The highest percentage of background annual mean NO_2 levels are recorded in the 30-40 $\mu g/m^3$ concentration range. This reflects an approximate 10 $\mu g/m^3$ elevation in concentrations compared with 2002.

Figure 3 Frequency Distribution of Annual Mean Roadside NO_2 Concentrations, 1993-2003



Between 1993 and 1996 the highest percentage of annual mean NO_2 concentrations at roadside were present in the 40-50 $\mu g/m^3$ concentration banding. Approximately 10% of sites recorded concentrations over 60 $\mu g/m^3$ and a very low number showed concentration in the 20-30 $\mu g/m^3$ banding.

A reduction in the frequency of annual mean roadside NO_2 concentrations in the >60$\mu g/m^3$, 50-60 $\mu g/m^3$ and 40-50 $\mu g/m^3$ bands are apparent from 1997 onwards. An elevation in sites recording concentrations in the 30-40 $\mu g/m^3$ band occurs in 1997 remaining at this frequency over the next 5 years. Between 2000 and 2002 sites begin to record concentrations >20 $\mu g/m^3$. In 2002 roadside sites recording in the banding of 20 to 30 $\mu g/m^3$ show a sharp increase, whereas sites recording the higher bandings decline. The annual mean NO_2 concentration at roadside sites is mainly in the 30-40 $\mu g/m^3$ banding.

A distinct change in the proportion of each concentration banding takes place in 2003 reflecting the sizeable elevation in NO_2 levels. The 0-20 $\mu g/m^3$ and 20-30 $\mu g/m^3$ concentration categories have become redundant, with two new bandings in the higher pollution level ranges of 70-80 $\mu g/m^3$ and >80 $\mu g/m^3$ taking their place. Annual mean roadside NO_2 concentrations in the latter banding have a relatively low frequency. The highest percentage of roadside annual mean NO_2 concentrations are recorded in the 50-60 $\mu g/m^3$. This reflects an approximate 20 $\mu g/m^3$ elevation in concentration compared with 2002.

6 Data Analysis

6.1 Introduction

Prior to analysing the results, the entire year's data set for each local authority was validated for outliers and spurious results. Two screening procedures where adopted for this task. Firstly, monthly mean NO_2 concentrations recording under 5 μg/m^3 where removed. Secondly, monthly mean NO_2 concentrations for each diffusion tube site falling outside two standard deviations of the annual mean concentration where rejected. Only diffusion tube sites with at least 9 months of validated monitoring data where then used for further analysis and reporting.

6.2 Data Analysis

6.2.1 2003 Mean Values

Bar charts have been created showing the 2003 annual mean NO_2 concentration recorded at each site included in the LWEP survey. The sites have been classified by distance from the nearest major road into background and roadside. Appendix 1 lists the NO_2 concentration for all the roadside and background sites in each borough. Sites that have exceeded the 40 μg/m^3 2005 air quality objective have been highlighted.

6.2.2 Site Time Series

Time series plots have been created for sites with over 6 years of continuous monitoring data. Each time series plot contains data for sites as grouped by their site class.

6.3 Analysis of Results

6.3.1 Trend Analysis by Site Class

Monitoring sites with a minimum of 8 years continuous data were first identified. Individual concentrations are grouped by site class to provide an arithmetic mean for each site class. The mean annual class concentrations have been plotted and a simple linear trend model applied to assess whether concentrations have generally risen or fallen at background, and roadside locations within each Borough.

6.3.2 Roadside Elevation

Annual mean background concentrations were subtracted from annual mean roadside concentrations to calculate the elevation above background NO_2 concentration. This may provide an indication of the level of NO_2 being received at roadside locations from road transport sources.

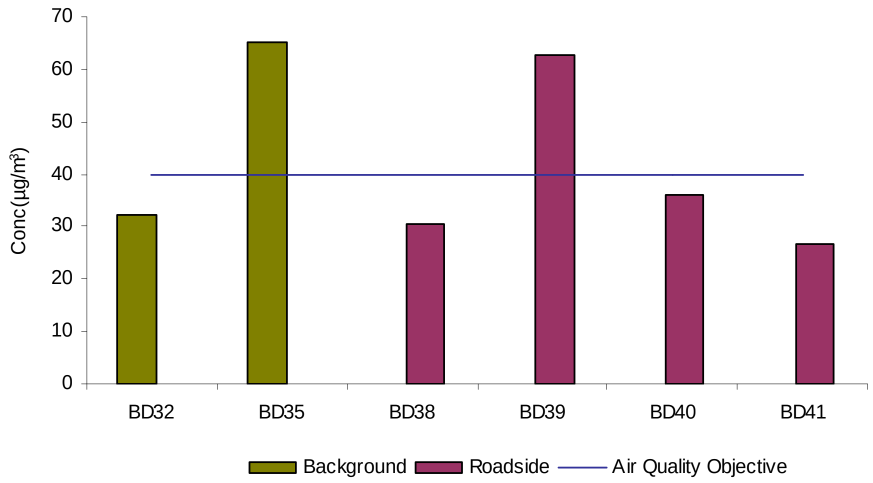
Sites were only included in the calculation of annual mean concentrations for each site class if consistent and valid data were available. Any sites with 1 or more years of absent or invalid data were not used.

7 Reporting of Results – Participating Boroughs

7.1 London Borough of Barking and Dagenham

Annual Mean Values

Figure 4 Barking and Dagenham Background and Roadside Annual Mean NO_2 Concentrations, 2003

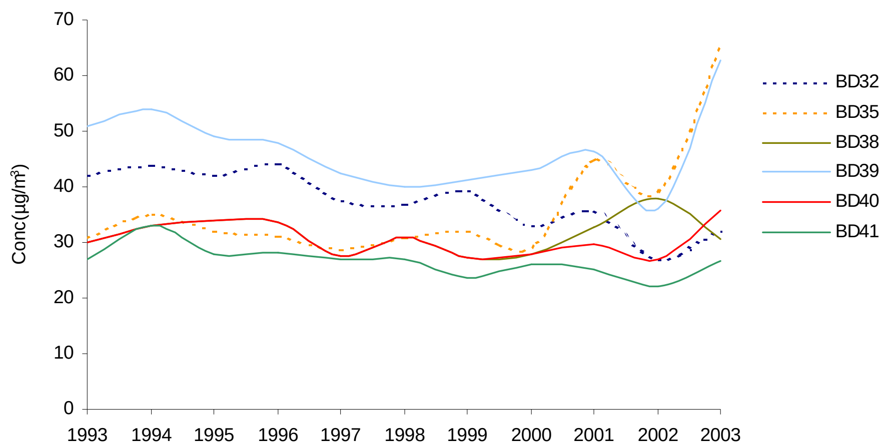


Barking and Dagenham introduced 4 new monitoring sites in 2003, BD42 to BD45. The late commencement of these sites did not permit the inclusion of their results into the analysis.

Background concentrations were recorded between 31.2 and 65.3 µg/m^3. Roadside concentrations vary between 30.6 and 62.8 µg/m^3. The 2005 air quality objective has been exceeded at sites BD35 and BD39. This represents an increase since 2002 where no monitoring site breached the objective.

Site Time Series

Figure 5 Barking and Dagenham Background and Roadside Time Series, 1993-2003

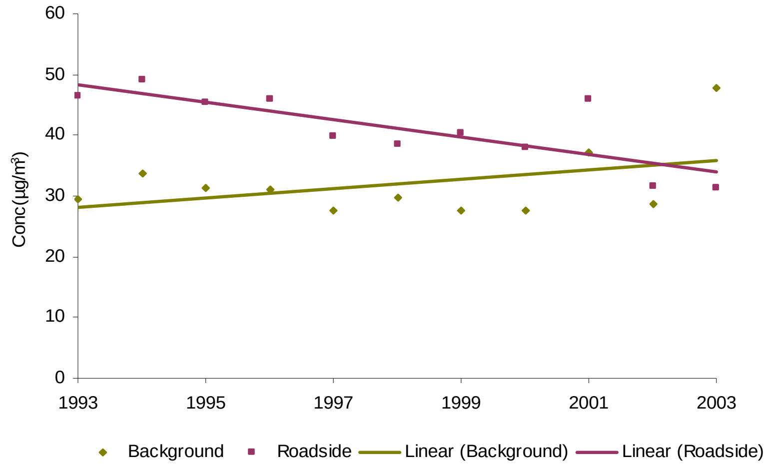


The roadside sites BD32 and BD39 and the background site BD35 follow a very similar trend from 1993 to 2003. Background sites BD40 and BD41 additionally display a comparable trend. In 2001 BD35 and BD39 show a marked increase in annual mean

NO_2 concentration. All sites show a sharp decrease in concentration in 2002, except BD38.[12] All background and roadside sites, except BD41, display an increase in annual mean NO_2 concentrations in 2003 compared to the previous year's results. Sites BD32 and BD39 show the most noticeable elevation in NO_2 concentration of approximately 40%.

Trend Analysis

Figure 6 Barking and Dagenham Trend Analysis, 1993-2003



Long-term background concentrations display an upward trend in 2003. Roadside sites continue to follow a downward trend from 1993 to 2003 with concentrations declining by 19% of this time period.

Roadside Elevation

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Elevation above background (µg/m³)	17.2	15.3	14.2	15.0	12.2	8.8	12.6	10.3	8.7	9.9	-9.7

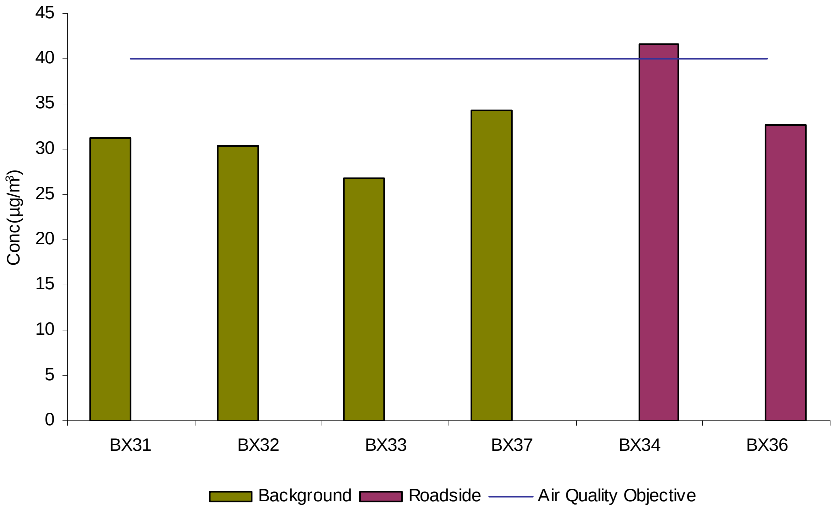
Roadside elevation generally decreases after 1996. From 2001 onwards there is a further decrease in roadside elevation; this is most apparent in 2003 when levels plummet substantially. This is an artefact of the very high background concentrations at Barking and Dagenham during 2003.

[12] The local authority may wish to consider reclassifying BD35 as a roadside site, as the distance from the road of 15m does not meet the criteria for a background location.

7.2 London Borough of Bexley

Annual Mean Values

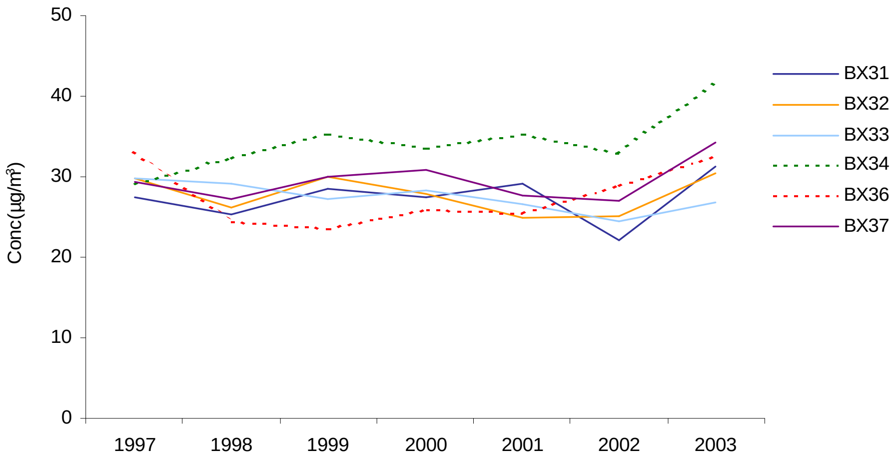
Figure 7 Bexley Background and Roadside Annual Mean NO_2 Concentrations, 2003



Bexley did not introduce any new monitoring sites in 2003.
Background concentrations vary between 26.8 and 34.3 µg/m^3. Roadside concentrations range between 32.6 and 41.7 µg/m^3. The 2005 air quality objective was exceeded at one monitoring sites BC34. This is an increase compared to last year when no site recorded over 40 µg/m^3.

Time Series

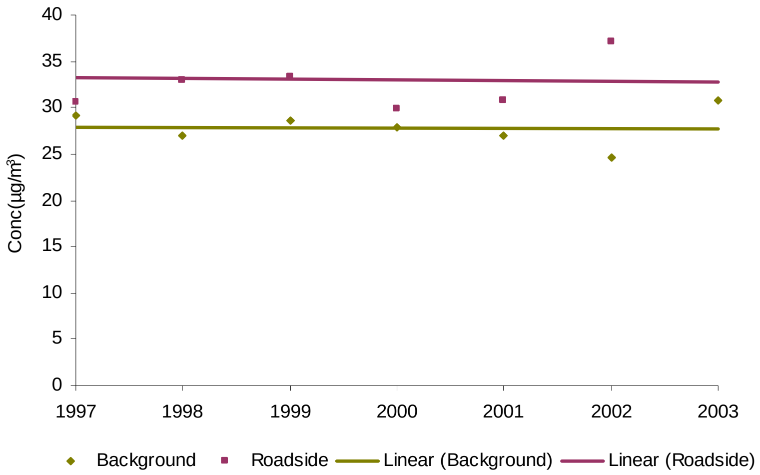
Figure 8 Bexley Background and Roadside Time Series, 1993-2003



In 2003 BX37 takes the lead, recording the highest annual mean background concentration, rising steadily since 1999. The remaining background sites display an undulating trend from 1997 onwards, experiencing a marked increase in NO_2 concentration in 2003. BX34 maintains the highest roadside NO_2 concentrations since 1993 and shows an appreciable rise in NO_2 concentration in 2003. BX36 shows a gradual increase in annual mean NO_2 concentration from 1999 to 2003.

Trend Analysis

Figure 9 Bexley Background and Roadside Trend analysis, 1993-2003



Long-term background and roadside annual mean NO_2 concentrations display a relatively consistent trend around 30 µg/m^3 from 1993 to 2003.

Roadside Elevation

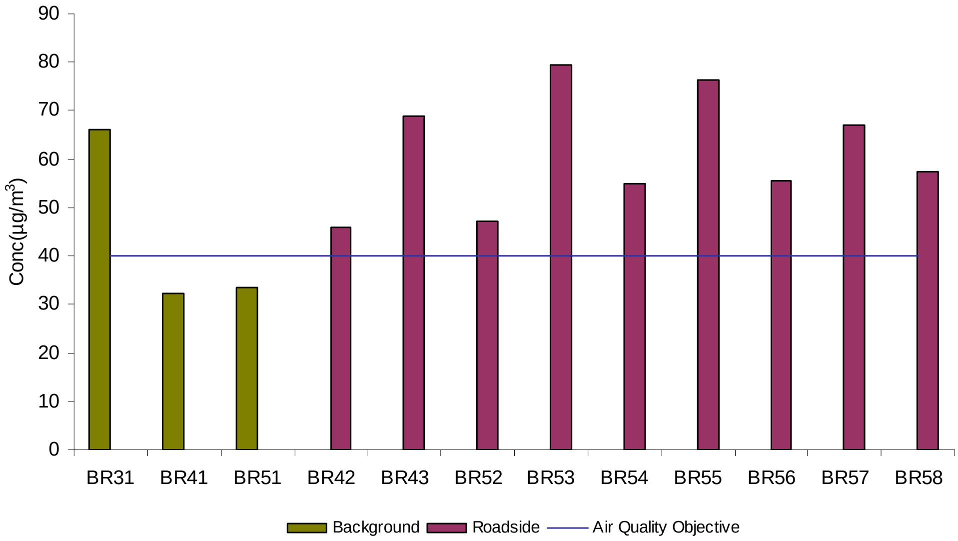
	1997	1998	1999	2000	2001	2002	2003
Elevation above Background (µg/m^3)	8.0	3.7	4.3	5.5	3.0	6.2	6.5

The roadside elevation in NO_2 concentration drops by almost 50% between 1997 and 1998, then gradually increases by approximately 1 µg/m^3 over the next 3 years. After a minor reduction in 2001, the elevation above background concentration doubles in 2002 and continues rise slightly in 2003.

7.4 London Borough of Brent

Annual Mean Values

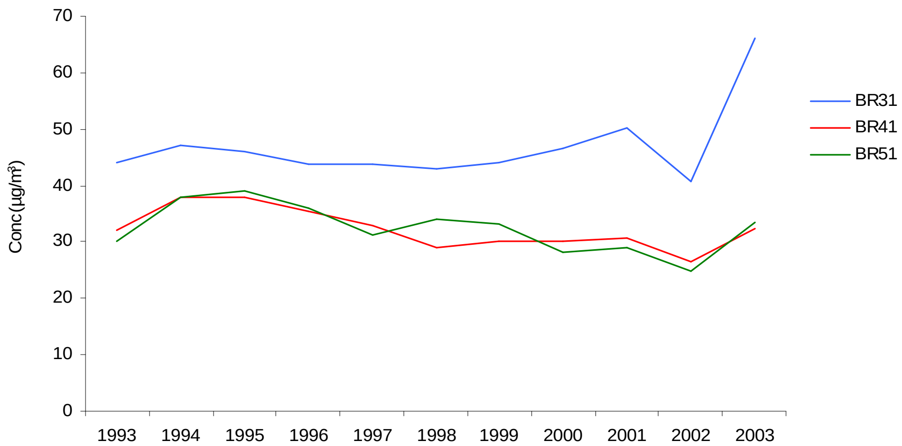
Figure 10 Brent Background and Roadside Annual Mean NO_2 Concentrations, 2003



Brent did not introduce any new monitoring sites in 2003.
Background concentrations vary between 32.3 and 66.1 µg/m^3. Roadside concentrations range between 46.1 and 79.4 µg/m^3. Ninety percent of Brent's monitoring sites exceed the 2005 air quality objective. This is an increase since last year where 30% of sites recorded concentrations over 40 µg/m^3.

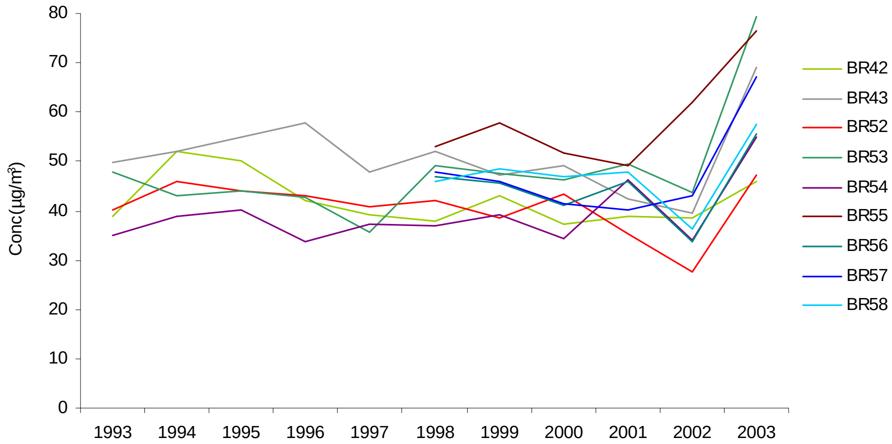
Site Time Series

Figure 11 Brent Background Time Series, 1993-2003



Background sites show a small decrease in annual mean NO_2 concentrations from 1994 to 2000. Following a rise in NO_2 levels between 2000 and 2001, background sites show a drop in concentration between 2001 and 2002. Background sites experience a 30% rise in annual mean NO_2 concentration in 2003 with site BR31 showing the most pronounced increase. In 2003 this site records the highest annual mean NO_2 concentration throughout the eleven-year monitoring period of 66.1 µg/m^3.

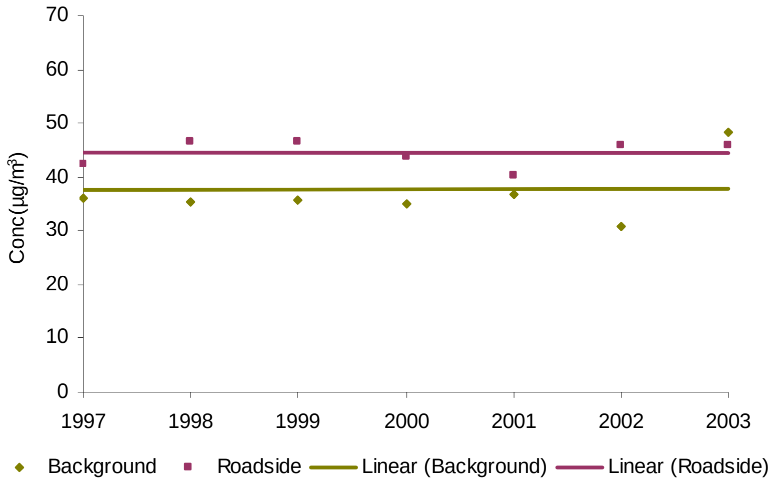
Figure 12 Brent Roadside Time Series, 1993-2003



Concentrations at roadside locations fluctuate between 1993 and 2002 with no obvious trend. Mean NO_2 concentrations at BR55 and BR57 increase between 2001 and 2002, whereas the remaining roadside sites show a decrease. Roadside sites show a marked increase in annual mean concentration between 2002 and 2003 of approximately 35%. In 2003 all roadside diffusion tube sites, except BR42, record their highest concentrations since monitoring commenced 1993 and in some cases 1998.

Trend Analysis by Site Class

Figure 13 Brent Roadside Time Series, 1993-2003



Trend analysis indicates that long-term roadside levels of NO_2 have remained fairly constant between 1997 and 2003 at both background and roadside sites.

Roadside Elevation

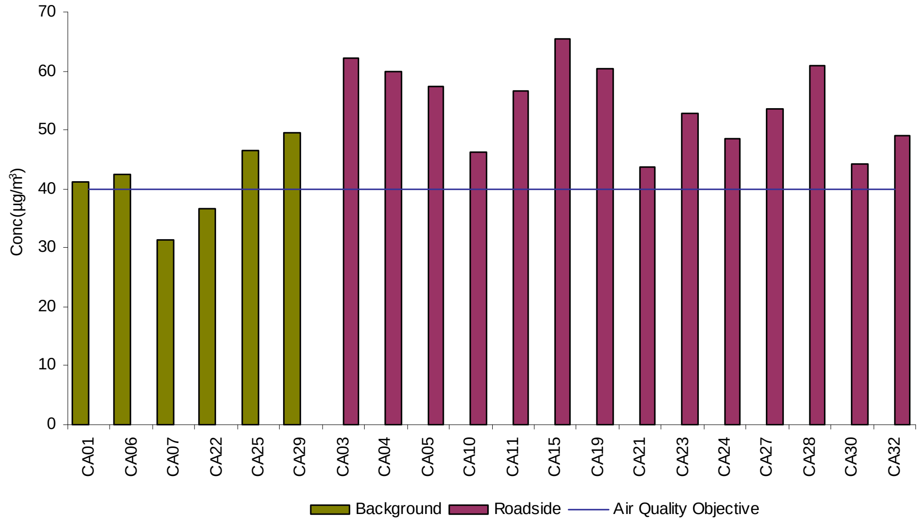
	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Elevation above background (µg/m³)	7.0	5.4	5.6	5.5	4.2	10.4	10.1	8.5	7.3	9.2	11.9

The elevation above background NO_2 concentration shows a steady reduction from 1993 to 1997. After rising in 1998 concentrations decrease until 2001 then begin to rise again. The roadside NO_2 elevation reaches an all time high in 2003 of 11.9 µg/m³.

7.5 London Borough of Camden

Annual Mean Values

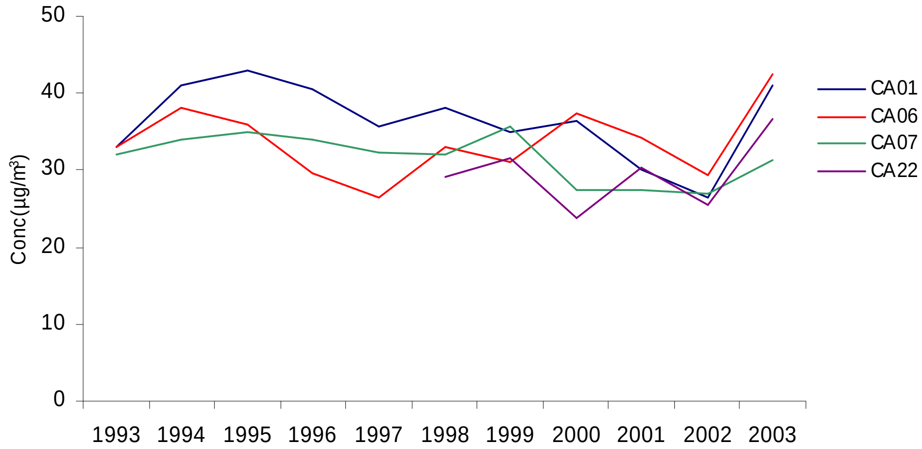
Figure 14 Camden Background and Roadside Annual Mean NO_2 Concentrations, 2003



Camden introduced four new roadside sites in 2003, CA32 to CA36[13]. The sites CA33, CA35 and CA36 became active half way through the year, subsequently their data capture does meet the 75% criterion required for reporting.
Background concentrations vary between 31.3 and 49.5 µg/m^3. Roadside concentrations vary between 43.7 and 60.9 µg/m^3. Ninety percent of Camden's monitoring sites exceeded the 2005 air quality objective in 2003. This is represents a significant increase compared with last years results where 30% recorded concentrations over 40 µg/m^3.

Site Time Series

Figure 15 Camden Background Time Series, 1993-2003

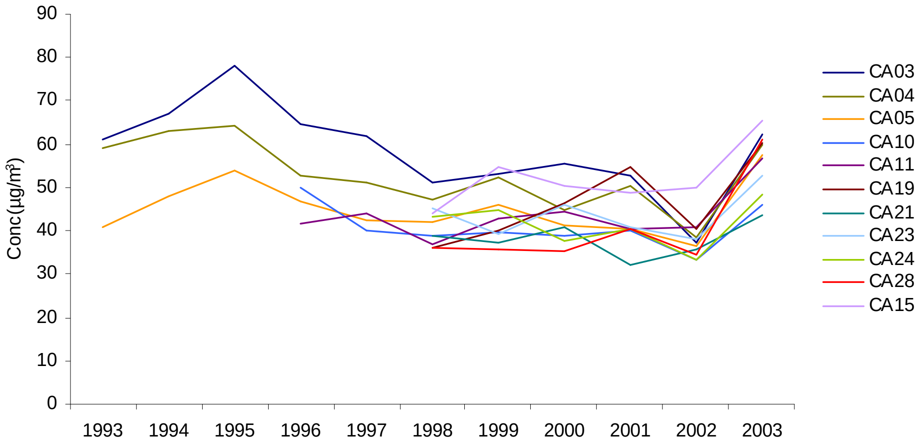


CA01 and CA06 appear to follow a similar rolling trend throughout the eleven-year period. CA07 maintains a stable level of NO_2 up to 1998. The annual mean NO_2 concentration rises in 1999, and decreases gradually from then onwards. CA22 follows an almost identical pattern to CA07 until 2000 when levels continue to rise, and then fall in

13 CA02 and CA31 became redundant in 2003.

2001. Between 2001 and 2002 all background sites reveal a slight reduction in mean NO_2 concentration. A notable rise in annual mean NO_2 concentration takes place in 2003 at sites CA01, CA06 and CA22. CA07 experiences a smaller increase in concentration.

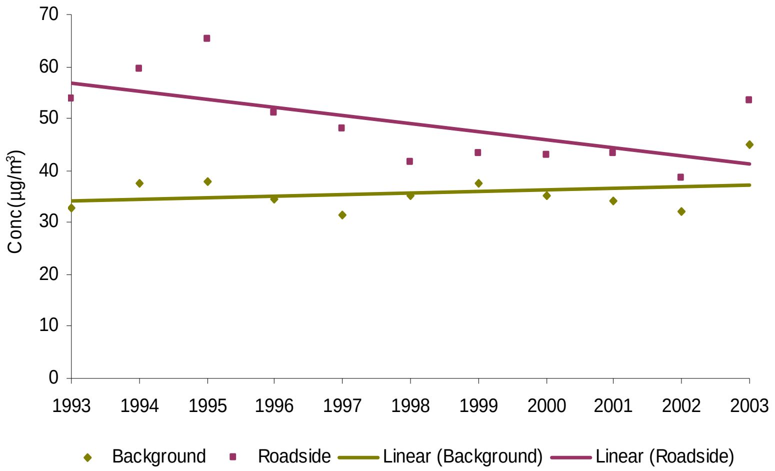
Figure 16 Camden Roadside Time Series, 1993-2003



CA03, CA04 and CA05 follow a similar trend, gradually decreasing in concentration from 1995 onwards. NO_2 concentrations at CA19 and CA28 peak in 2001 and then drop in 2002. The other sites show no clear trends. Between 2001 and 2002 sites CA11, CA15 and CA21 record an increase in annual mean NO_2 concentration, whereas the remaining sites experience a decrease. The annual mean NO_2 concentration increases at all roadside sites in 2003 by approximately 29%.

Trend Analysis

Figure 17 Camden Trend Analysis, 1993-2003



Long-term background concentrations display a positive trend with annual mean NO_2 levels increasing by 21% between 1993 and 2003. Roadside sites continue to follow a downward trend.

Roadside Elevation

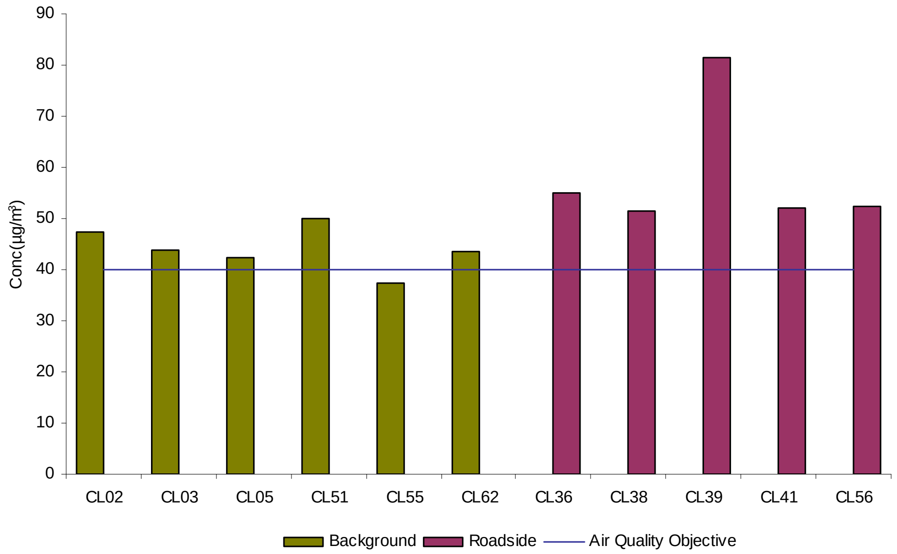
	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Elevation above background (µg/m^3)	21.0	21.7	27.3	16.6	16.5	6.3	5.5	8.1	9.1	6.3	13.4

A steady reduction in roadside elevation is apparent from 1996 to 2002. In 2003 the elevation above background NO_2 concentration doubles reaching the highest figure in six years.

7.6 Corporation of London

Annual Mean Values

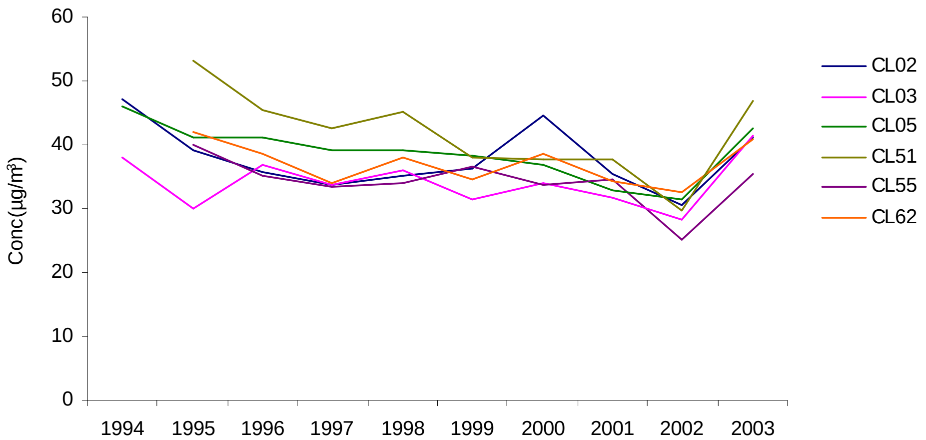
Figure 18 Corporation of London Background and Roadside Annual Mean NO_2 Concentrations, 2003



The Corporation of London did not introduce any new monitoring sites in 2003. Background concentrations vary between 37.3 and 50.1 µg/m³. Roadside concentrations range between 55.1 and 81.6 µg/m³. The 2005 air quality objective was exceeded at 90% of monitoring sites. This is a significant increase compared to last year where the objective was breached at only 18% of diffusion tube locations.

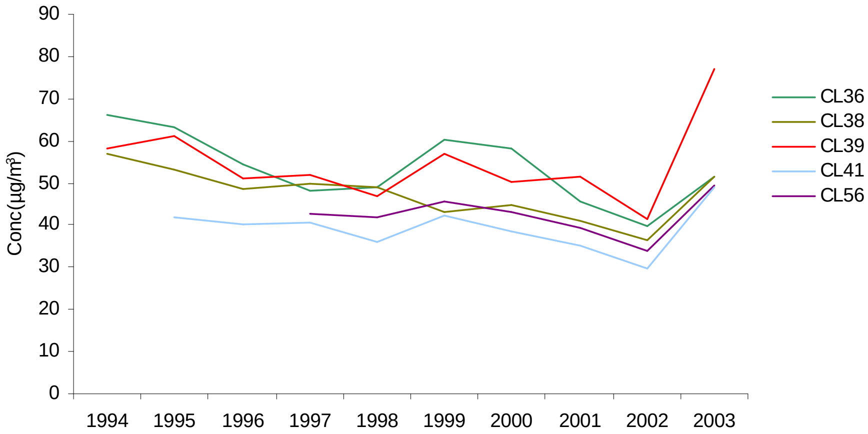
Site Time Series

Figure 19 Corporation of London Background Time Series, 1993-2003



Long-term background concentrations do not follow any particular trend. Between 2001 and 2002 NO_2 concentrations decrease at all background sites. However in 2003 annual mean concentration rise at all background sites in by approximately 33%.

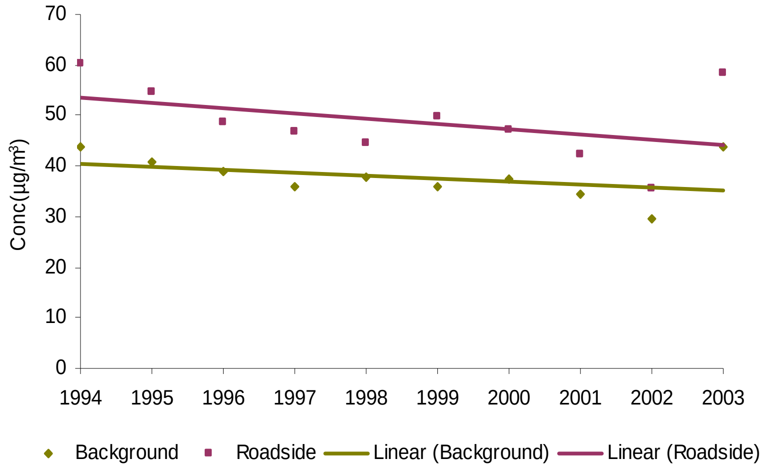
Figure 20 Corporation of London Roadside Time Series, 1993-2003



The long-term monitoring data reveal a peak in annual mean NO_2 concentration at all roadside sites in 1999, except CL38. A gradual reduction in NO_2 concentration is apparent at all sites from 2000 until 2002. A sharp increase in annual mean NO_2 concentration takes place at all roadside sites in 2003. Site CL39 experiences the greatest rise in NO_2 level; this doubles between 2002 and 2003. In 2003 sites CL39, CL56 and CL41 record the highest annual mean concentration since monitoring began in 1994.

Trend Analysis

Figure 21 Corporation of London Roadside Trend Analysis, 1993-2003



Background and roadside sites continue to display a downward trend in long term annual mean NO_2 concentrations.

Roadside Elevation

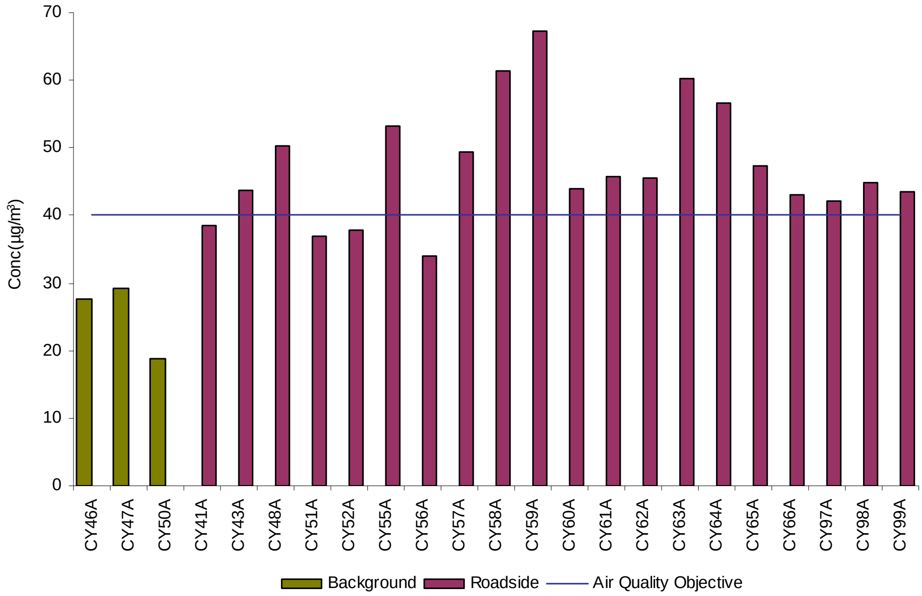
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Elevation above background (µg/m³)	16.7	13.9	9.8	10.6	6.8	13.9	9.5	8.0	5.7	14.3

A three-fold rise in the roadside elevation of NO_2 concentrations takes place in 2003. This is the largest contribution in roadside NO_2 concentration since 1999.

7.7 London Borough of Croydon

Annual Mean Values

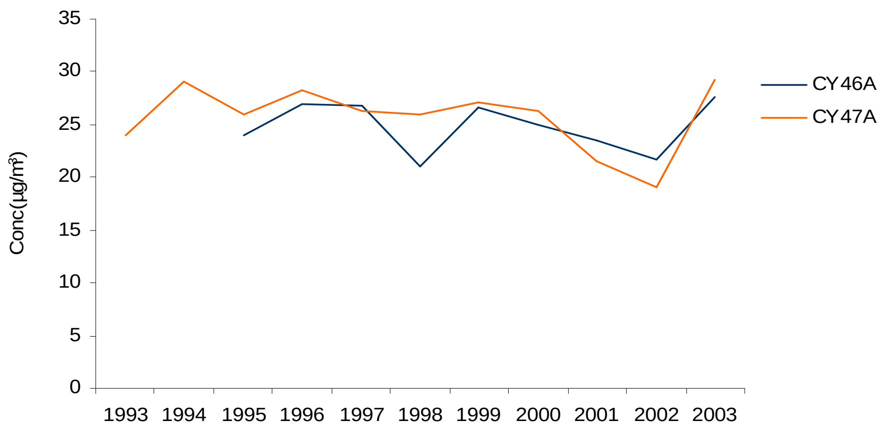
Figure 22 Croydon Background and Roadside Annual Mean NO_2 Concentrations, 2003



Croydon did not introduce any new monitoring site in 2003. Background NO_2 concentrations vary between 18.7 and 29.2 μg/m³. Roadside NO_2 concentrations range between 33.9 and 67.2 μg/m³. The 2005 air quality objective was exceeded at 70% of monitoring sites. This is significant increase since last year when only one site reached the 40 μg/m³ threshold.

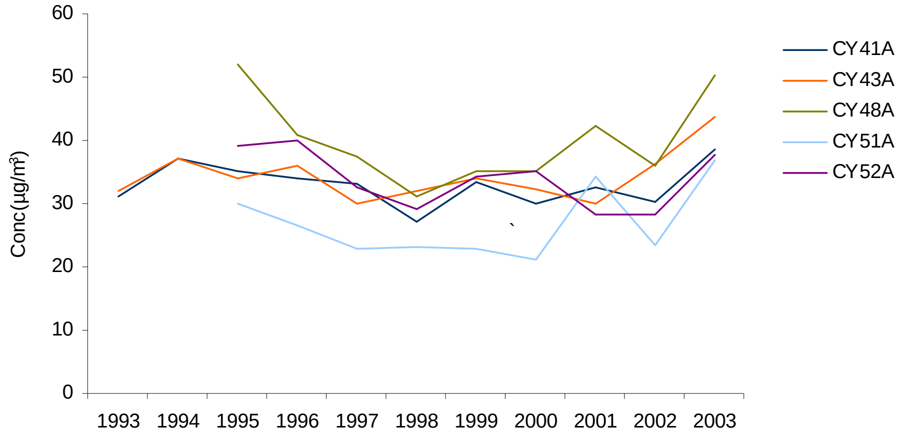
Site Time Series

Figure 23 Croydon Background Time Series, 1993-2003



Long-term background annual mean NO_2 concentrations at CY46A and CY47A do not display a distinct trend. From 1999 to 2002 the mean NO_2 concentration at both sites shows a steady decrease. In 2003 CY46A and CY47A experience a 28% increase in NO_2 concentrations.

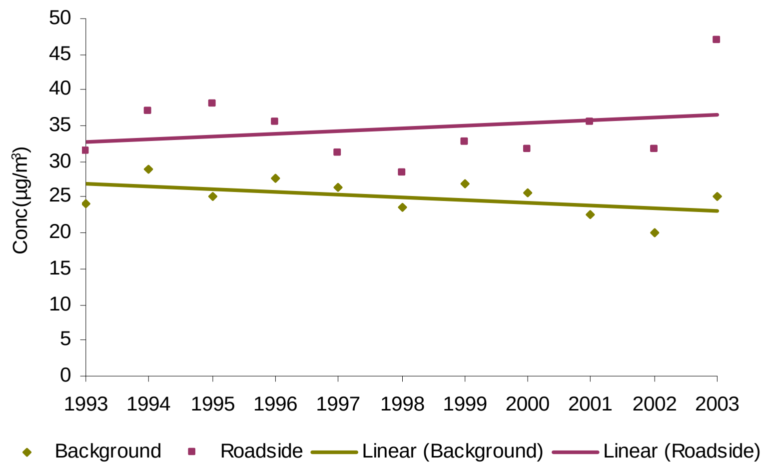
Figure 24 Croydon Roadside Time Series, 1993-2003



CY48A and CY51A follow an almost identical trend from 1995 to 2003. Sites CY41A, CY43A and CY52A display a similar rolling pattern. All roadside diffusion tube sites experience an apparent rise in NO_2 concentration in 2003. At the majority of roadside sites annual mean results recorded in 2003 represent the highest NO_2 concentrations.

Trend Analysis

Figure 25 Croydon Trend Analysis, 1993-2003



The trend in roadside NO_2 concentrations changes direction in 2003, and currently shows a positive trend. Backgrounds NO_2 concentrations conversely show a negative trend over time.

Roadside Elevation

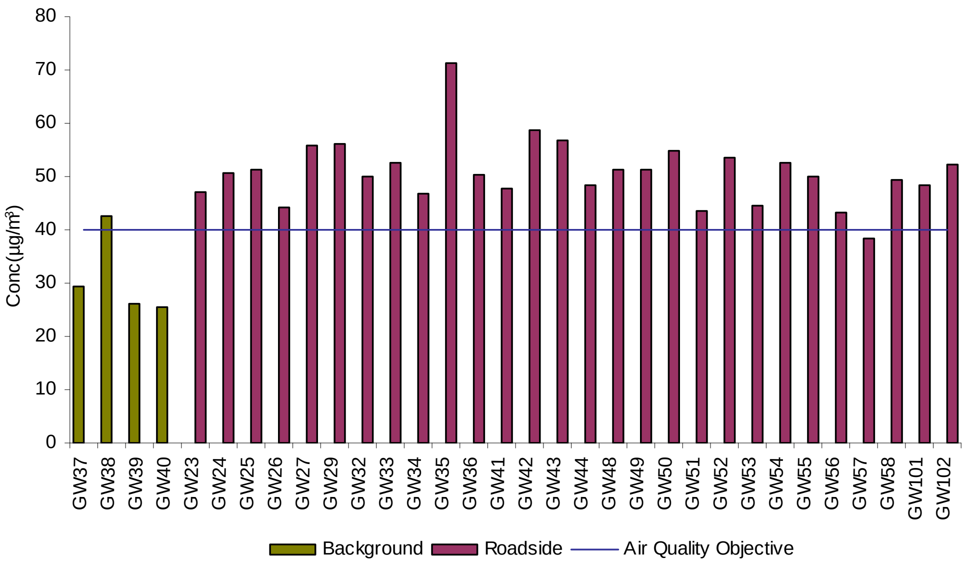
	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Elevation above background (µg/m³)	7.5	8.0	13.0	8.0	4.7	4.9	5.8	5.9	13.0	11.7	13.1

The elevation above background concentration peaks in 1995 and then reduces by over half over the next 5 years. From 2001 to 2003 the roadside elevation rises back up to 1995 levels.

7.8 London Borough of Greenwich

Annual Mean Value

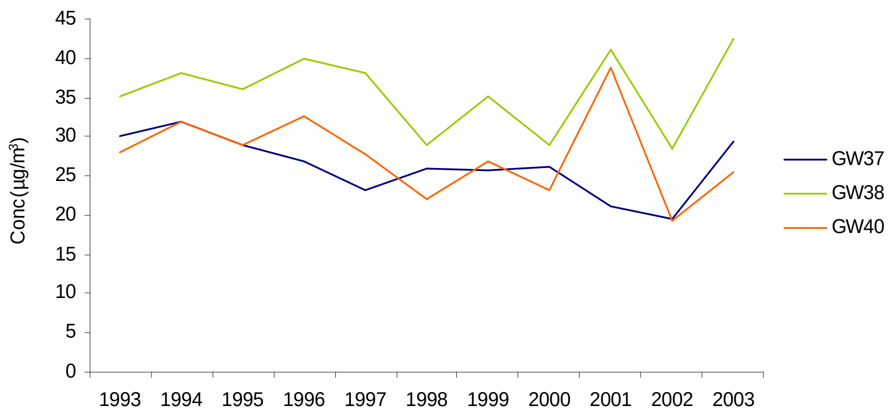
Figure 26 Greenwich Background and Roadside Annual Mean NO_2 Concentrations, 2003



Greenwich introduced four new roadside sites in 2003 GW39, GW55GW57 and GW58. Background concentrations vary between 25.4 to 42.5 µg/m^3. Roadside sites range between 38.3 to 71.4 µg/m^3. The 2005 air quality objective was exceeded at 88% of monitoring locations, predominantly roadside sites. This is a marked increase from 2002 when only site, GW43, recorded an annual mean NO_2 concentration in excess of the 40 µg/m^3.

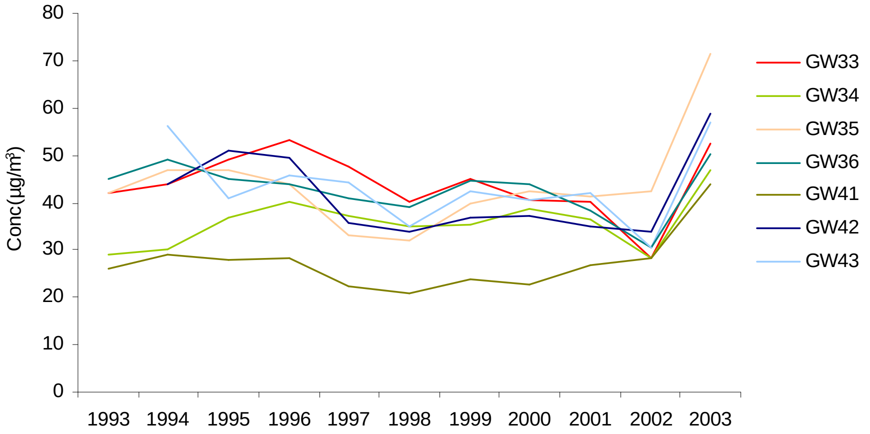
Site Time Series

Figure 27 Greenwich Background Time Series, 1993-2003



Between 1993 and 2003 GW38 and GW40 have followed an identical undulating trend. From 1994 to 1997 onwards GW37 shows a gradual decrease in NO_2 concentration. Over the next few year NO_2 concentrations increase by a few micrograms remaining relatively constant until 2001 when a sharp decline takes places. Background sites encounter a distinct reduction in annual mean NO_2 concentrations in 2002. In 2003 there is a marked increase in NO_2 concentrations at all background monitoring sites of approximately 33%.

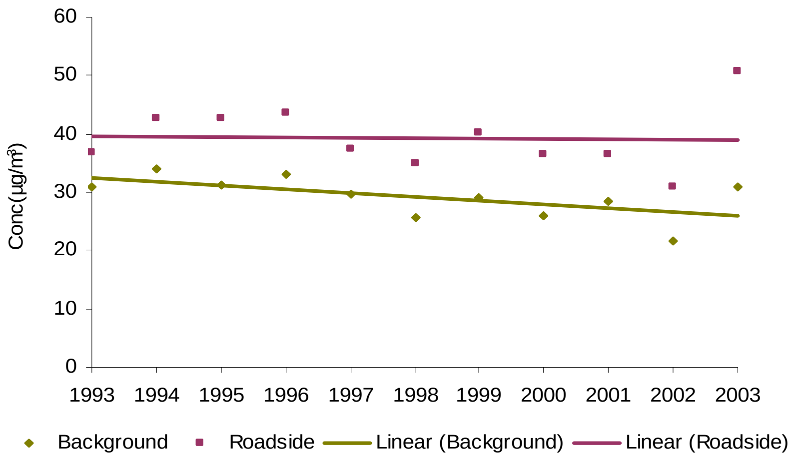
Figure 28 Greenwich Roadside Time Series, 1993-2003



NO_2 levels at roadside sites have fluctuated between 1993 and 2002. From 2001 to 2002 NO_2 concentrations at GW34, GW35 and GW41 have increased, with the remaining sites undergoing a decrease. In 2003 a significant increase in annual mean NO_2 concentration takes place at all roadside monitoring site with concentration reaching their highest levels over the eleven-year monitoring period.

Trend Analysis

Figure 29 Greenwich Trend Analysis, 1993-2003



The trend analysis continues to indicate a long-term decline in annual mean NO_2 concentration at background sites. The elevation in roadside NO_2 concentrations in 2003 has resulted in the previous year's negative trend being replaced by static trend line.

Roadside Elevation

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Elevation above background (µg/m³)	5.8	8.7	11.2	10.4	7.7	9.3	11.1	10.3	8.1	9.2	19.6

The roadside elevation records its lowest level in 1993 and after rising in 1994 fluctuates annually. In 2003 the roadside elevation concentration has increased by just over 50% reaching the highest figure since 1993.

7.9 London Borough of Hammersmith and Fulham

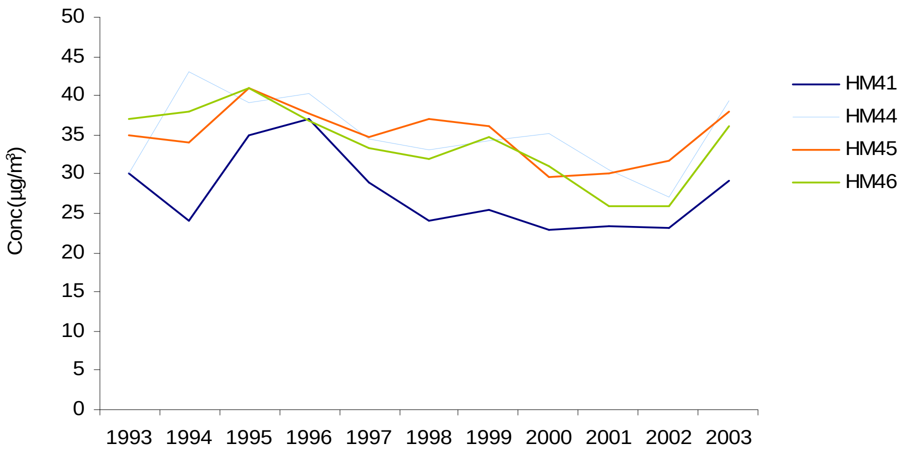
Annual Mean Values

Figure 30 Hammersmith and Fulham Background and Roadside Annual Mean NO_2 Concentration, 2003

Hammersmith and Fulham did not introduce any new monitoring sites in 2003. Background concentrations range between 29.1 and 51.2 µg/m^3. Roadside concentrations vary between 37.5 and 81.8 µg/m^3. The 2005 air quality objective was exceeded at 50% of monitoring sites. This is an increase from last year when only four sites recorded results over 40µg/m^3.

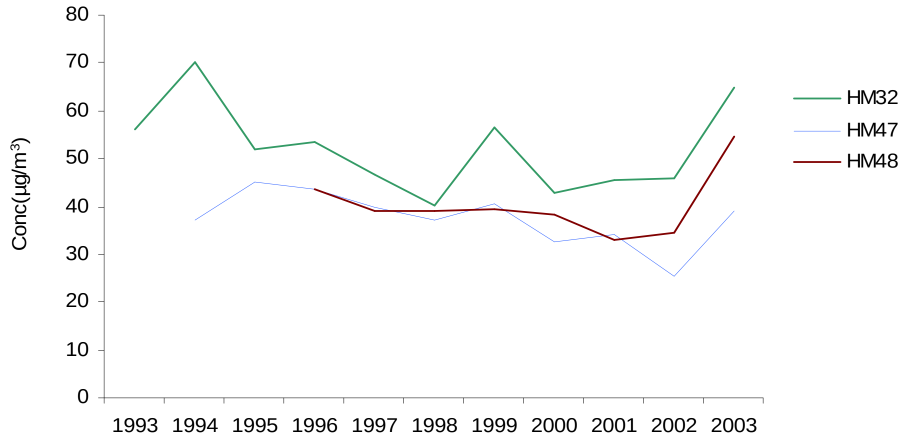
Site Time Series

Figure 31 Hammersmith and Fulham Background Time Series, 1993-2003



The long-term data show annual mean background NO_2 level to be lowest at HM41. After peaking in 1996 the mean concentration gradually decreases, remaining relatively constant from 2000 onwards. Annual mean NO_2 concentrations at HM44, HM45 and HM46 fluctuate over the ten-year monitoring period. Mean NO_2 levels decrease at HM44 and HM46 post 2000, whereas at HM45 a steady increase is evident. In 2003 all background diffusion tube sites experience a rise in annual mean NO_2 concentrations.

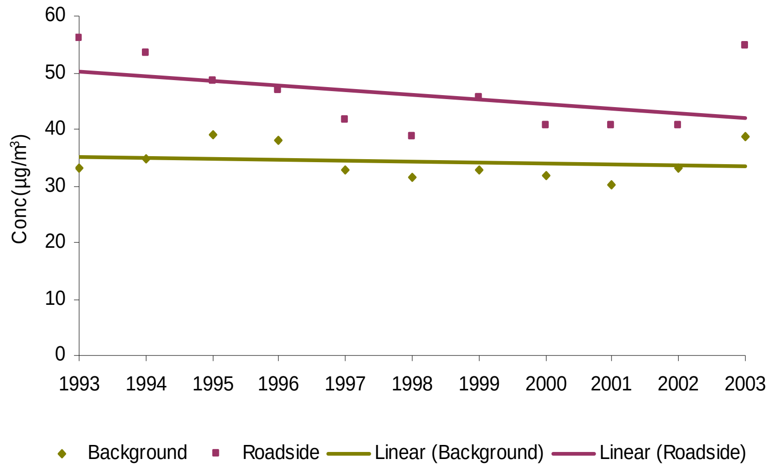
Figure 32 Hammersmith and Fulham Roadside Time Series, 1993-2003



HM32 records the highest roadside mean NO_2 concentration between 1993 and 2003, peaking in 1994, 1999 and 2003. The annual mean NO_2 concentration at HM48 remains fairly constant from 1997 to 1999. Between 2000 and 2001 a reduction in concentration takes place followed by a small rise in 2002. HM47 indicates a gradual decrease in NO_2 concentration between 1995 and 2002. HM32, HM47 and HM48 all record a marked increase in annual mean NO_2 concentration in 2003 of approximately 30%.

Trend Analysis

Figure 33 Hammersmith and Fulham Trend Analysis, 1993-2003



The recent trend analysis indicates a faint positive long-term trend for background NO_2 concentrations. Roadside sites continue to display a downward trend.

Roadside Elevation

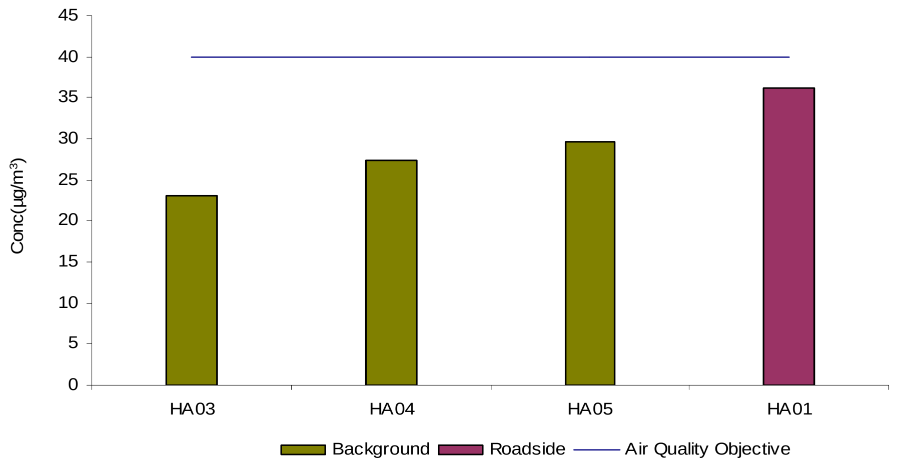
	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Elevation above background (µg/m³)	23.0	18.8	9.5	8.9	8.9	7.2	12.9	8.8	10.4	7.6	16.2

After experiencing a reduction in NO_2 concentration from 1995 onwards, the roadside elevation shows a 50% increase in 2003.

7.10 London Borough of Harrow

Annual Mean Values

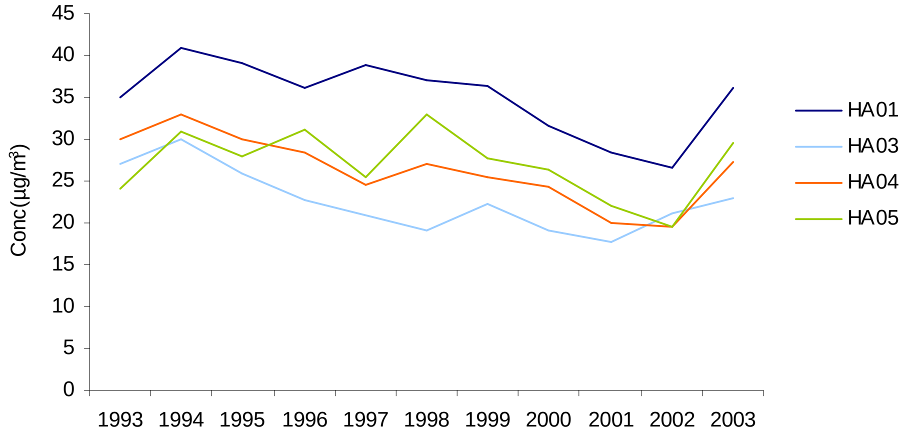
Figure 34 Harrow Background and Roadside Annual Mean NO_2 Concentrations, 2003



Harrow did not introduce any new sites during 2003.
Background concentrations vary only marginally between 23.1 and 29.6 µg/m^3. The NO_2 concentration at the single roadside site, HA01, is 36.2 µg/m^3. The 2005 air quality objective was not exceeded at any monitoring site.

Time Series

Figure 35 Harrow Background and Roadside Time Series, 1993-2003

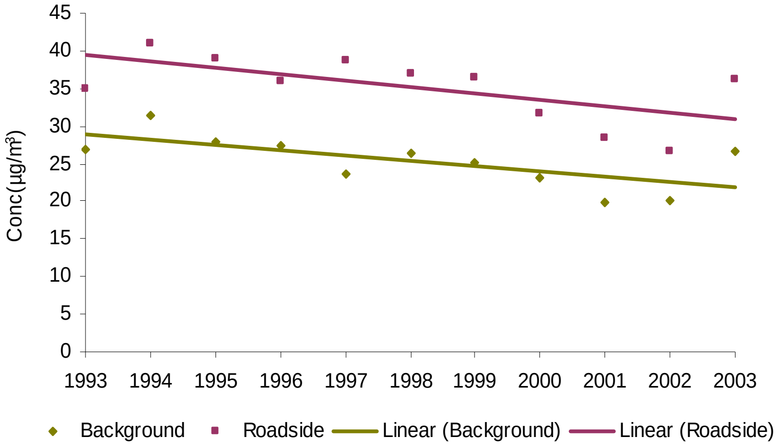


Background concentrations at HA03 and HA04 follow a similar pattern. HA05 displays a rolling trend with the mean NO_2 concentration showing a continual reduction from 1998 to 2002. In 2003 all background sites experience a rise in annual mean NO_2 concentration.

The roadside site, HA01, indicates a gradual decrease in NO_2 concentration after 1994 with this becoming more apparent from 1999 onwards. A sharp rise in annual mean NO_2 concentration takes place in 2003.

Trend Analysis

Figure 36 Harrow Trend Analysis, 1993-2003



Both background and roadside annual mean NO_2 concentrations have experienced a minor increase over the eleven years of monitoring. However the trend analysis continues to highlight a downward trend in NO_2 concentrations at both site types.

Roadside Elevation

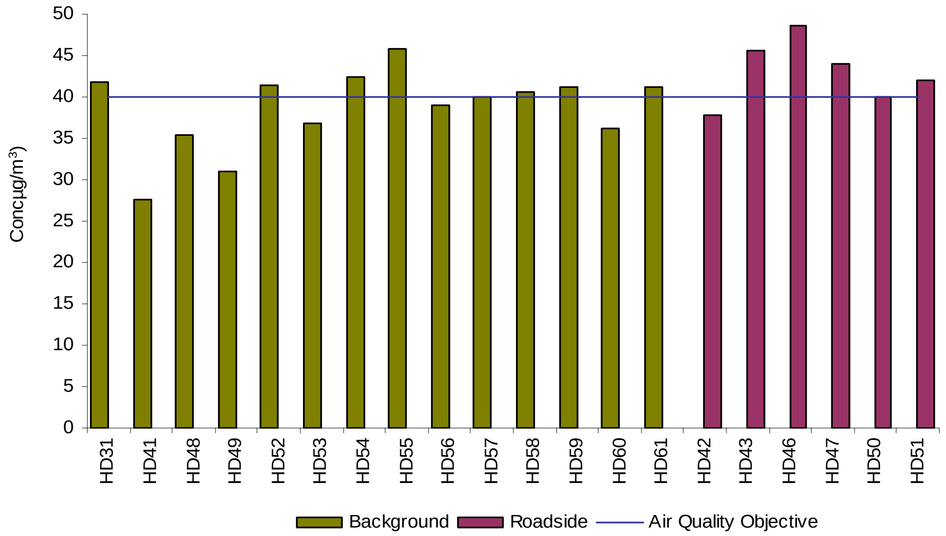
	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Elevation above background (µg/m³)	8.0	9.7	11.0	8.7	15.1	10.7	11.3	8.4	8.5	6.6	9.5

The roadside elevation fluctuates on an annual basis with the NO_2 contribution form road traffic peaking in 1997. There appears to be an overall reduction in roadside elevation from 1998 onwards, with a gradual decline taking place between 2000 and 2002. In 2003 NO_2 concentrations experience a minor increase in concentration.

7.11 London Borough of Hillingdon

Annual Mean Values

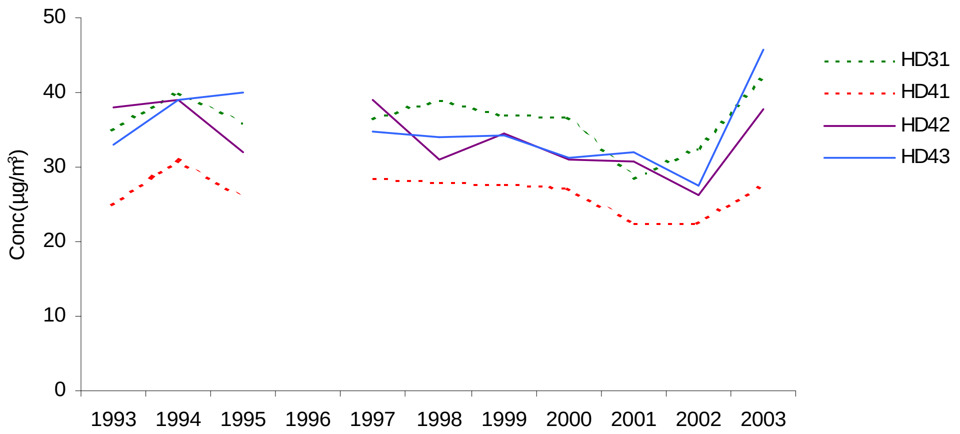
Figure 37 Hillingdon Background and Roadside Annual Mean NO_2 Concentration, 2003



Hillingdon did not introduce any new sites in 2003[14].
Background concentrations range between 27.5 and 45.8 µg/m^3. Roadside sites vary between 37.8 and 48.7 µg/m^3. The 2005 air quality objective has been exceeded at 60% of monitoring sites both background and roadside. This is an increase since last year when no breaches in the objective where encountered.

Site Time Series

Figure 38 Hillingdon Background Time Series, 1993-2003



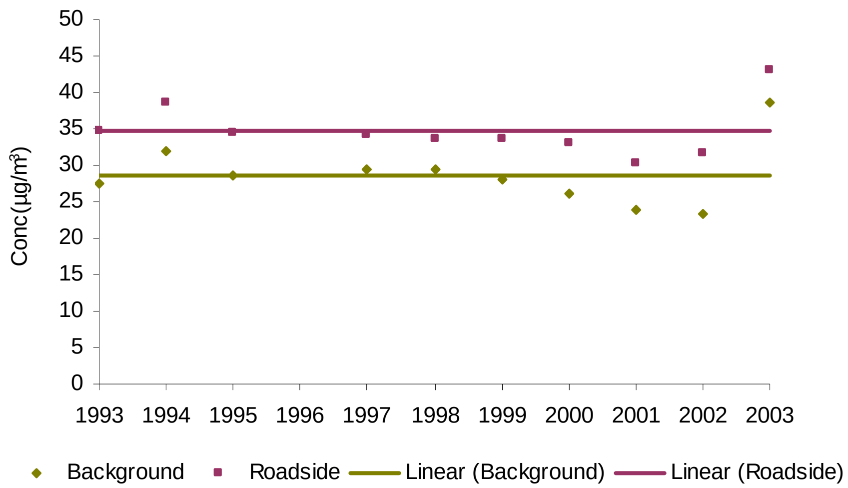
Background sites HD31 and HD41 to follow an identical pattern from 1993 to 2003. After peaking in 1994, annual mean NO_2 concentrations from these sites begin to decrease reaching their lowest levels in 2001. Over the next year concentrations begin to

[14] The background site HD32 became defunct in 2003.

rise. Roadside sites HD42 and HD43 show a very similar variation in annual mean NO_2 concentration. Between 1997 and 2002 NO_2 concentrations at HD42 and HD43 steadily declines but elevate sharply in 2003 by approximately 40%. HD31 and HD43 record the highest NO_2 concentrations during eleven-year monitoring period in 2003.

Trend Analysis

Figure 39 Hillingdon Trend Series, 1993-2003



Both background and roadside sites show an upward trend in annual mean NO_2 concentration compared to last year. Background sites have experienced a larger growth than roadside sites; showing an overall rise of 40% since 2002.

Roadside Elevation

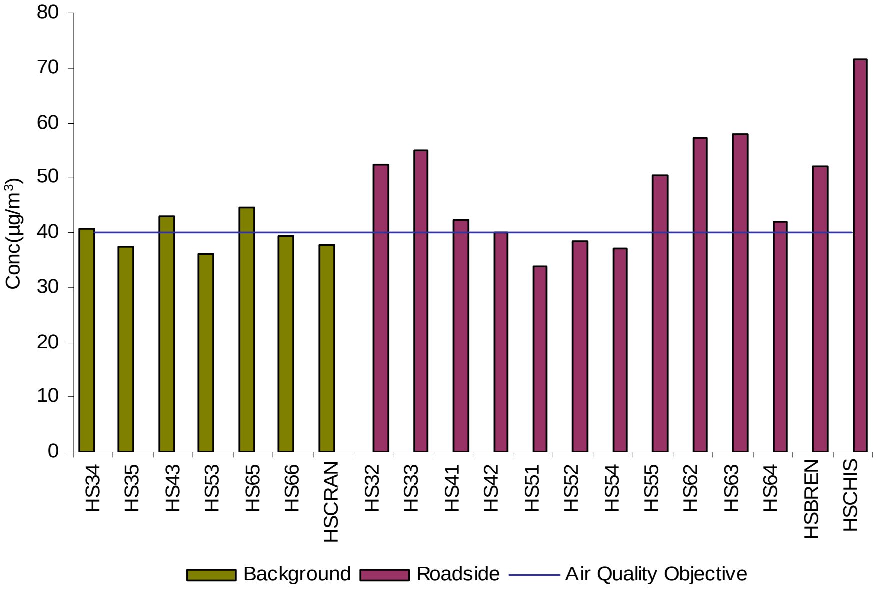
	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Elevation above background (µg/m³)	7.3	6.5	6.0		4.8	4.0	5.4	7.1	6.3	8.4	4.5

The increase in background NO_2 concentrations in 2003 has resulted in a decrease in the roadside elevation by approximately 50%.

7.12 London Borough of Hounslow

Annual Mean Values

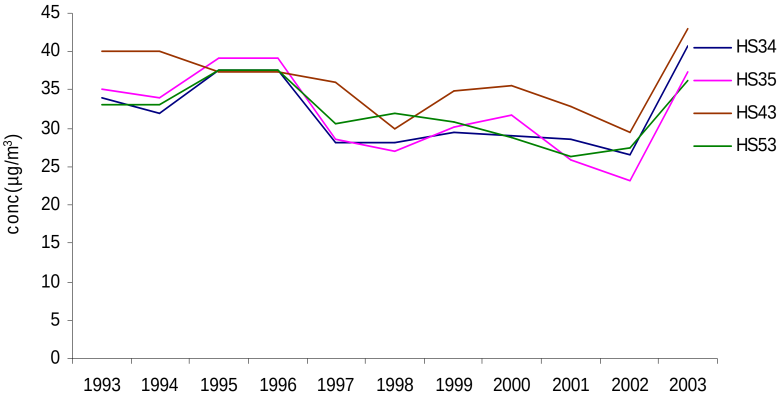
Figure 40 Hounslow Background and Roadside Annual Mean NO_2 Concentration, 2003



Hounslow did not introduce any new sites in 2003. Background NO_2 concentrations range from 36.1 and 44.6 µg/m^3. Roadside sites vary between 33.7 to 71.7 µg/m^3. The 2005 air quality objective has been exceeded at twelve of Hounslow's twenty monitoring sites. This is an increase since last year when only one site breached the objective.

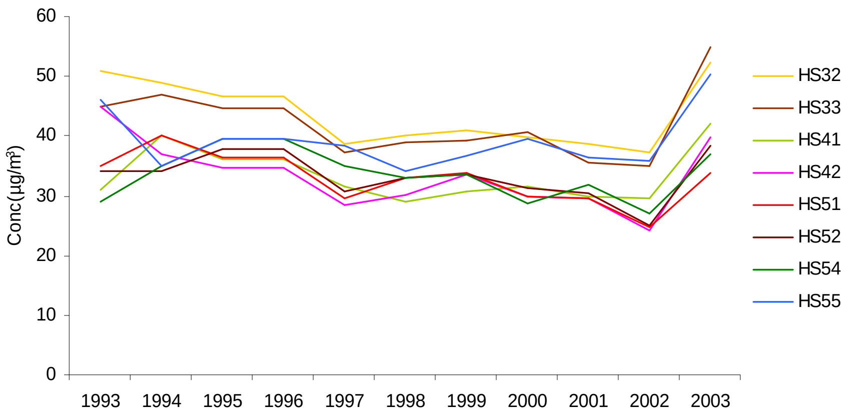
Site Time Series

Figure 41 Hounslow Background Time Series, 1993-2003



The time series reveals HS53, HS43 and HS34 to follow an identical trend from 1993 to 1997. Following a small peak in 1998, HS53 reflects a gradual decrease in NO_2 concentration until 2001, after which the concentration rises slightly. NO_2 concentration at HS34 rise between 1997 and 1999 but then begins to steadily decrease. HS35 shows a similar trend, with NO_2 concentrations falling earlier in 2000. The annual mean NO_2 concentration at HS43 shows a gradual decrease from 1993 to 1998. NO_2 concentrations at all sites show a minor rise from 1998 to 2000 and then begin to descend over the next two years. Between 2002 and 2003 a 34% increase in annual mean NO_2 concentrations at occurs at background monitoring locations.

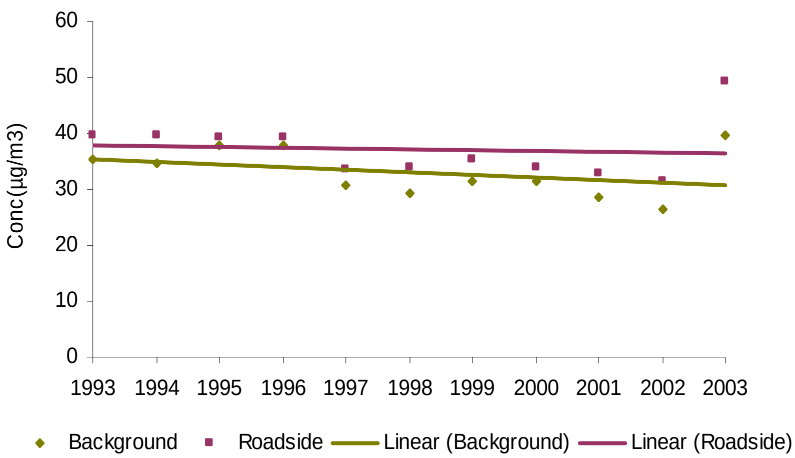
Figure 42 Hounslow Roadside Time Series, 1993-2003



HS32 and HS33 follow near identical trends with a gradual decrease in NO_2 concentrations between 1994 and 2002. With the exception of HS55, the remaining sites reflect a similar rolling pattern peaking in 1996 and 1999, then falling sharply in 1997 and 2002. In 2003 all roadside sites experience a sharp elevation in annual mean NO_2 concentration. 50% of sites recorded their highest long-term concentrations in 2003.

Trend Analysis

Figure 43 Hounslow Trend Analysis, 1993-2003



Background and roadside sites continue to indicate a downward trend on annual average NO_2 concentration over time; however this trend less pronounced compared to last year.

Roadside Elevation

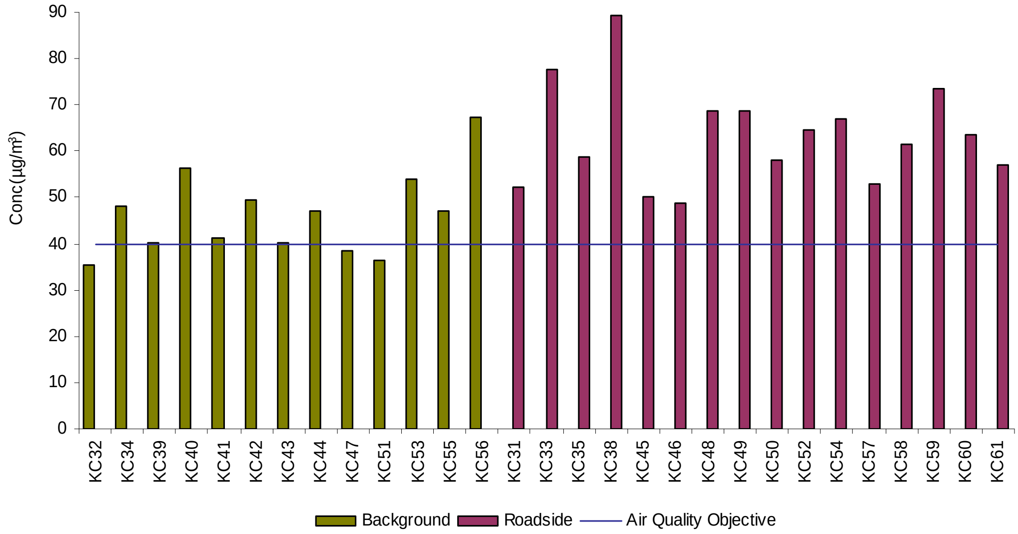
	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Elevation above background (µg/m³)	4.0	4.9	1.6	1.6	2.9	4.6	3.9	2.6	4.3	5.1	11.5

The elevation above background NO_2 concentration increased by over 50% in 2003 compared with all previous years. This is no doubt a consequence of the notable rise in roadside NO_2 concentrations recorded in this year.

7.13 London Borough of Kensington and Chelsea

Annual Mean Values

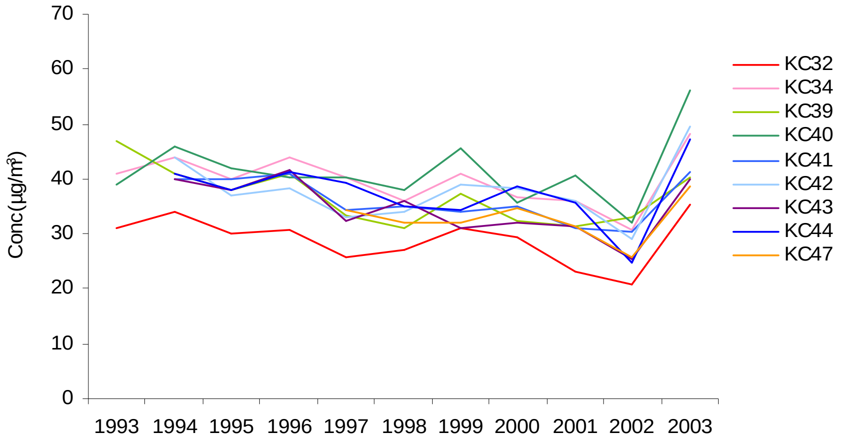
Figure 44 Kensington and Chelsea Background and Roadside Annual Mean NO_2 Concentration, 2003



Kensington and Chelsea did not introduce any new monitoring sites in 2003. Background concentrations record between 35.2 and 67.3 µg/m³. Roadside concentrations record between 48.9 and 89.2 µg/m³. The 2005 air quality objective is exceeded at 90% of monitoring sites both background and roadside. This compares with only six exceedences in 2002.

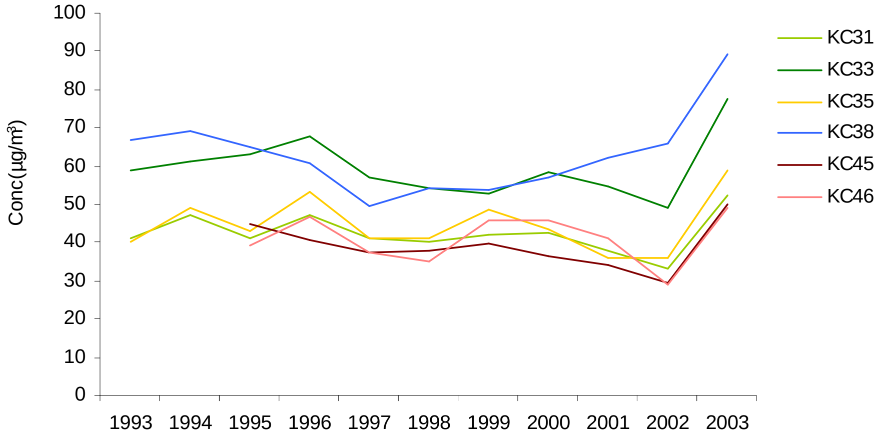
Site Time Series

Figure 45 Kensington and Chelsea Background Time Series, 1993-2003



All background sites appear to follow a similar rolling trend between 1993 and 2003. KC32 maintains the lowest annual mean NO_2 concentration over this monitoring period. From 2001 to 2002 all background sites except KC39 experience a decrease in annual mean NO_2 concentration. An abrupt rise in NO_2 concentration takes place at all sites in 2003 with KC32, KC34 and KC40 recording their highest concentrations over the eleven-year monitoring period. Background sites have experienced an obvious growth in NO_2 concentration in 2003.

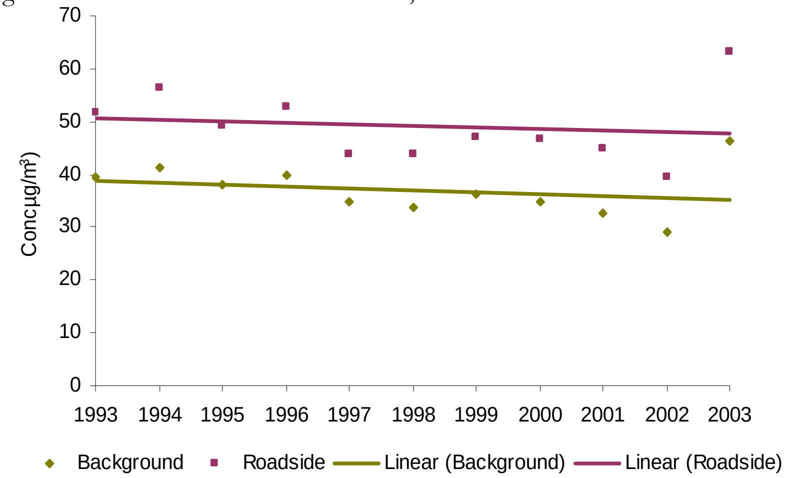
Figure 46 Kensington and Chelsea Roadside Time Series, 1993-2003



KC33 and KC38 clearly show the highest NO_2 concentrations between 1993 and 2003. KC38 is the only site to show a gradual increase in NO_2 concentration, taking place between 1997 and 2003. The NO_2 concentration at KC33 reveals a gradual reduction from 1997 to 2002. The NO_2 concentrations at the remaining sites fluctuate over the eleven-year monitoring period. Between 2002 and 2003 all roadside concentrations record an appreciable rise in NO_2 concentrations.

Trend Analysis

Figure 47 Kensington and Chelsea Roadside Time Series, 1993-2003



Background and roadside sites continue to reflect a downward trend in annual mean NO_2 concentrations. The trend is less distinct than last year due to NO_2 concentrations increasing by approximately 37% over the past year at both site categories.

Roadside Elevation

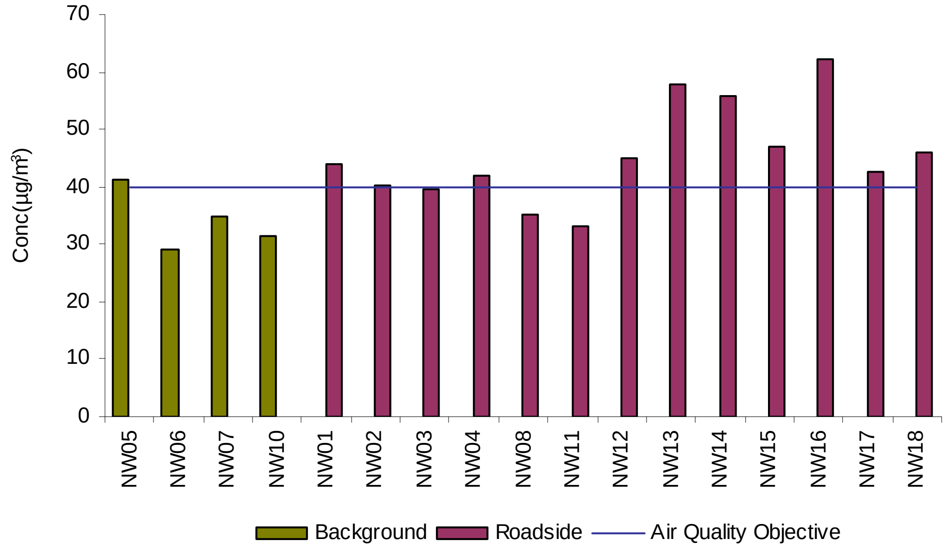
	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Elevation above background (µg/m³)	12.3	15.3	11.5	12.9	9.2	9.9	11.0	11.9	12.2	10.6	17.3

The elevation above background concentration fluctuates around 11 µg/m³ between 1993 and 2002. However in 2003 this increases by 7 µg/m³, reaching the highest long-term concentration.

7.14 London Borough of Newham

Annual Mean Values

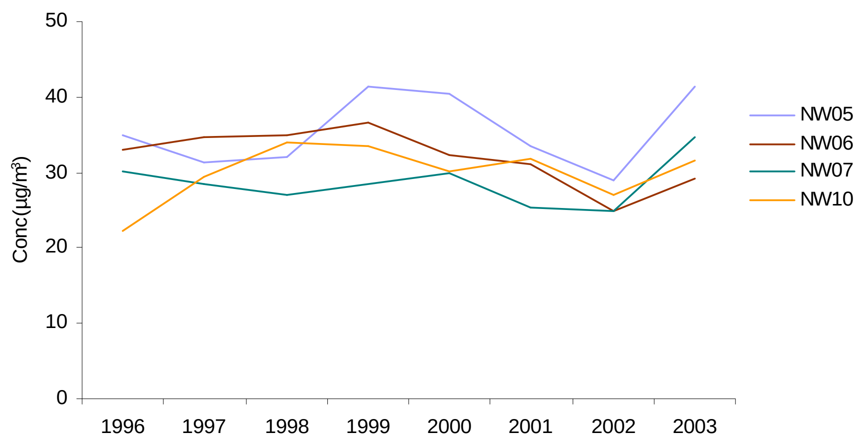
Figure 48 Newham Background and Roadside Annual Mean NO_2 Concentration, 2003



Newham introduced three new roadside sites in 2003, NH19 to NH21. The results have not been reported due to the sites late introduction during 2003. Background concentrations range between 29.2 and 41.4 µg/m³. Roadside concentrations vary between 31.6 and 62.1 µg/m³. The 2005 air quality objective is exceeded at 65% of monitoring sites, predominantly roadside sites. This is a distinct increase compared with the preceding year when no exceedences where recorded.

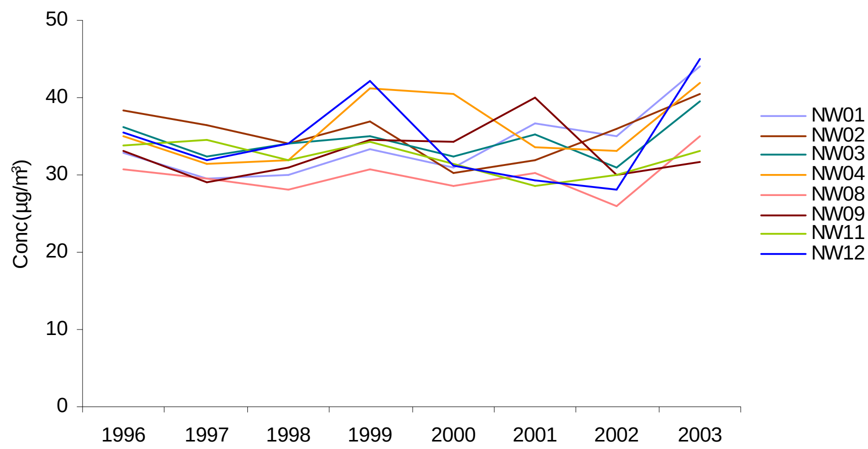
Site Time Series

Figure 49 Newham Background Time Series, 1993-2003



NW05 and NW07 follow similar patterns, with annual mean NO_2 concentrations progressively decreasing between 2000 and 2002. From 1999 onwards NW05 records the highest NO_2 concentrations. A noticeable increase in annual mean NO_2 concentration takes place in 2003 at sites NW05 and NW07. Sites NW06 and NW10 display a comparable trend from 1997 onwards. Annual mean concentrations at both sites fall sharply in 2000 and 2002, then increase slightly in 2003.

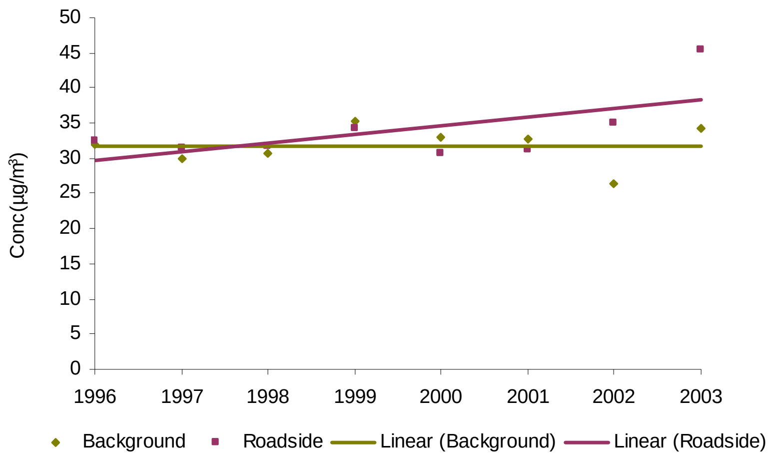
Figure 50 Newham Roadside Time Series, 1993-2003



Roadside site NO_2 concentrations appear to follow one another fairly closely. NO_2 levels appear to peak in 1999 and 2003. Annual mean concentrations show a distinct increase from 2002 to 2003 at all roadside sites. In 2003 the majority sites record their highest concentrations over the eight monitoring period, with NW12 experiencing the greatest increase in NO_2 concentration.

Trend Analysis

Figure 51 Newham Trend Analysis, 1993-2003



Long-term background concentrations maintain a static trend around 32 µg/m³. Roadside sites display a more accentuated upward trend in this year's analysis due to NO_2 concentrations increasing by 15% since 2002.

Roadside Elevation

	1996	1997	1998	1999	2000	2001	2002	2003
Elevation above background (μg/m^3)	0.5	1.3	0.9	-1.0	-2.3	-1.5	8.6	11.2

Between 1996 and 2001 the roadside elevation concentration is extremely low. Between 1999 and 2001 background concentrations elevate above roadside concentrations. This pattern changes from 2002 onwards with the roadside elevation significantly increasing.

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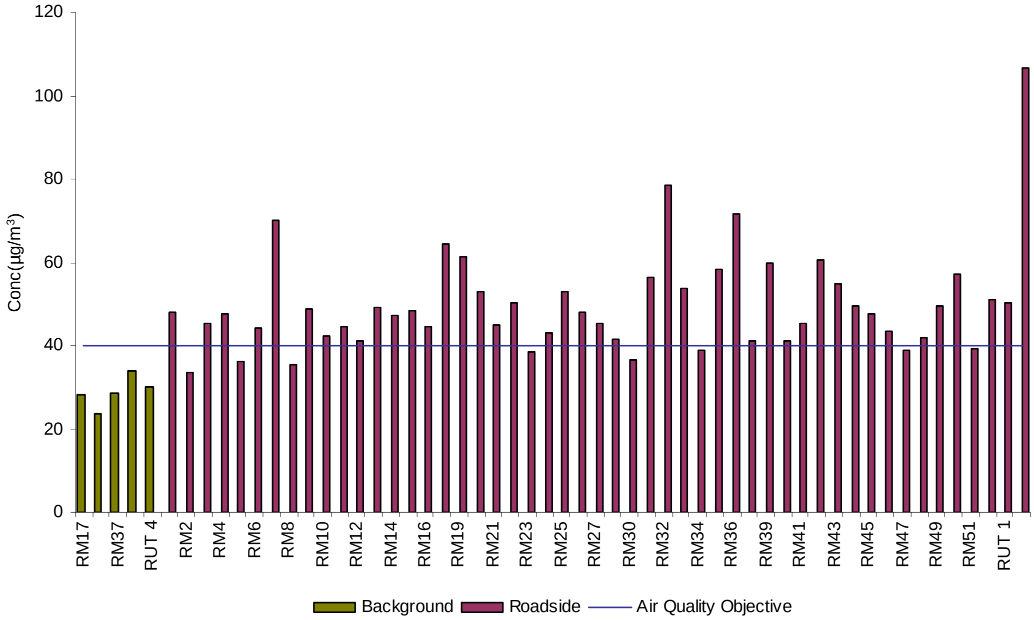
7.15 London Borough of Richmond Upon Thames

Annual Mean Values

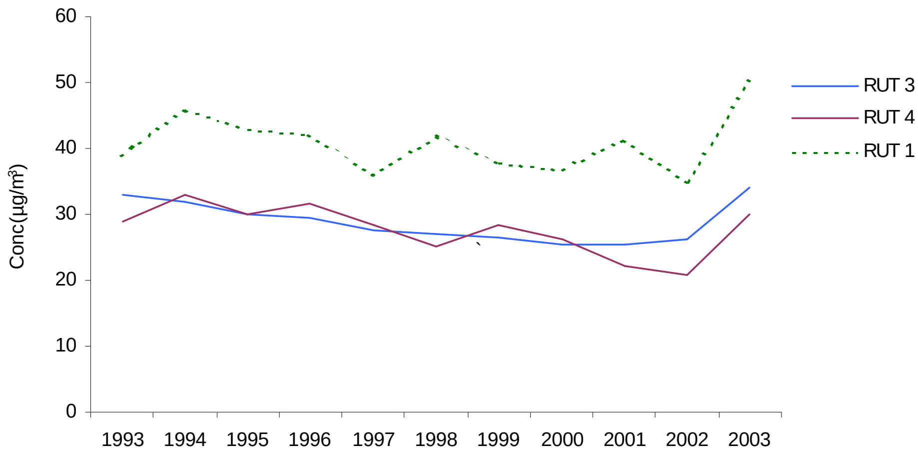
Figure 52 Richmond Upon Thames Background and Roadside Annual Mean NO_2 Concentration, 2003



Richmond Upon Thames introduced one new monitoring site in 2003, RM53. Background concentrations were recorded between 23.5 and 34.0 µg/m³. Roadside concentrations ranged between 33.4 and 106.5 µg/m³. The 2005 air quality objective was exceeded at 84% of roadside sites. This is a marked increase since last year when only nine roadside sites recorded levels over 40 µg/m³.

Time Series

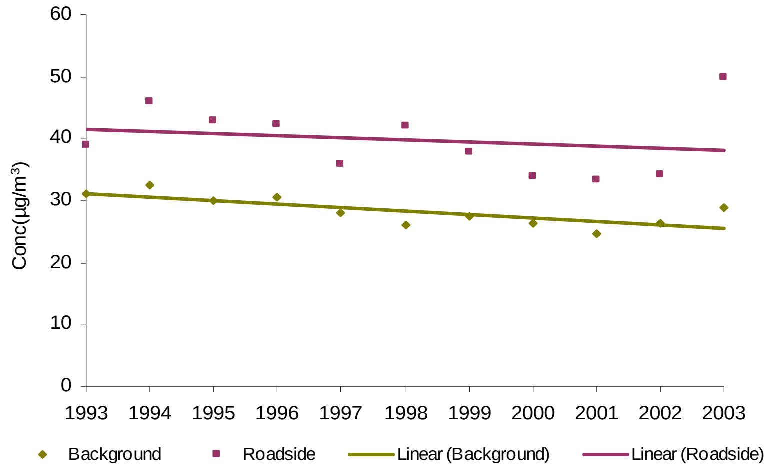
Figure 53 Richmond Upon Thames Background Times Series, 1993-2003



Background concentrations at RUT3 show a gradual reduction from 1993 to 2002. After a minor rise in 2002 NO_2 concentrations increase sharply in 2003. RUT4 shows gradual decrease in NO_2 concentration from 1996 to 2002. This trend is interrupted in 2003 by a distinct elevation in NO_2 concentration. Annual mean NO_2 concentrations at RUT1 decline from 1994 to 1996 and proceed to fluctuate slightly over the next seven years. A distinct increase in concentration takes place in 2003 with levels reaching 50.2 µg/m^3. Overall roadside NO_2 concentrations have risen by 31% in 2003.

Trend Analysis

Figure 54 Richmond Upon Thames Trend Analysis, 1993-2003



Both background and roadside sites continue to reflect a downward trend in long term NO_2 concentration. However this trend is less prominent in 2003 due to marked rise in NO_2 concentrations.

Roadside Elevation

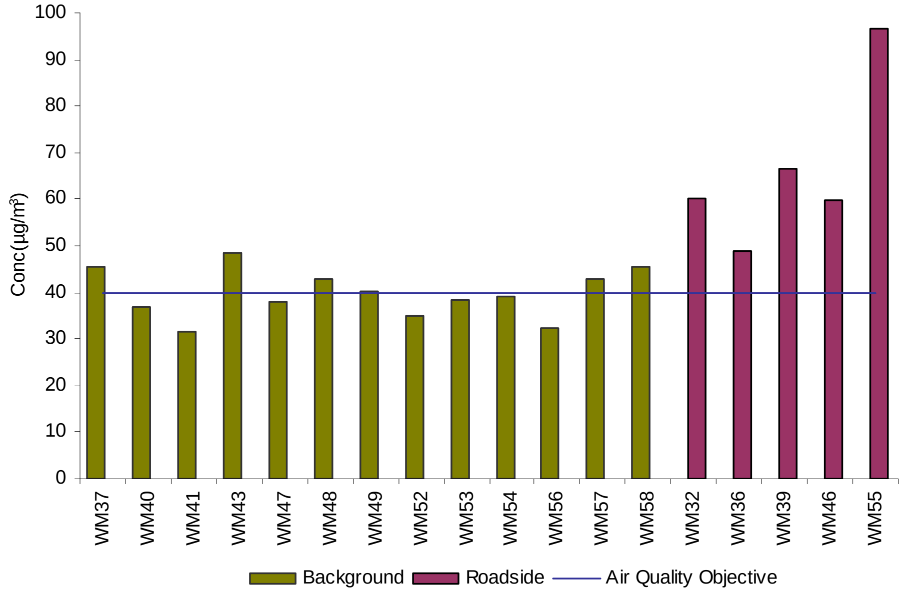
	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Elevation above background (µg/m^3)	8.0	13.5	13.0	11.7	7.9	16.0	10.4	7.7	8.8	7.8	21.0

The roadside elevation concentration fluctuates between 1993 and 2002, showing a sharp peak in 1998 at 16 µg/m^3 then falling sharply over the next four years. In 2003 there is an approximate three-fold increase in the NO_2 elevation above background concentration.

7.16 London Borough of Westminster

Annual Mean Values

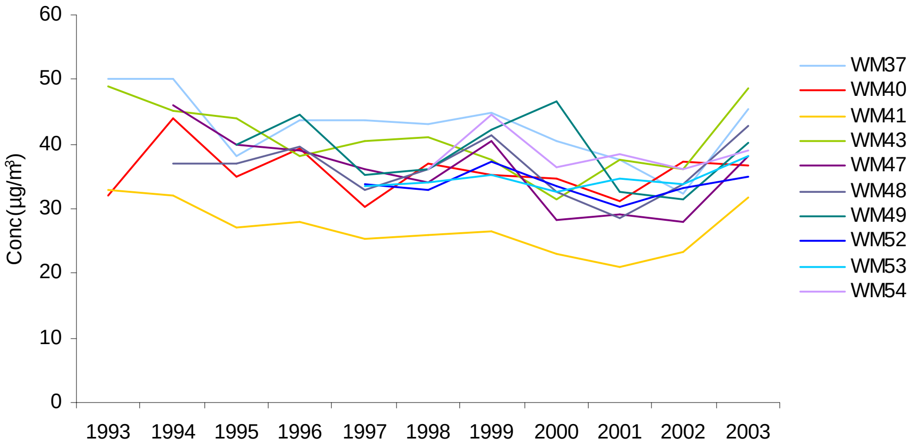
Figure 55 Westminster Background and Roadside Annual Mean NO_2 Concentration, 2003



Westminster did not introduce any new monitoring sites in 2003. Background concentrations range from 32.3 to 48.7 µg/m^3. Roadside concentrations vary between 48.7 and 96.8 µg/m^3. The 2005 air quality objective is exceeded at 60% of monitoring sites. This is an increase since last year when only 4 sites recorded over 40 µg/m^3.

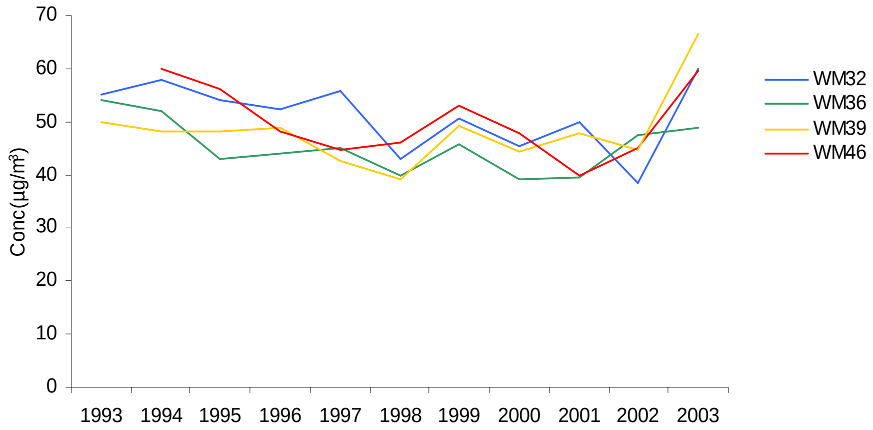
Time Series

Figure 56 Westminster Background Time Series 1993-2003



WM41 records the lowest annual mean NO_2 concentration over the eleven-year monitoring period. The NO_2 concentration at this site remains fairly uniform between 1996 and 1999. Over the next two years concentrations decrease but start to rise from 2001 onwards. A fluctuation in NO_2 concentration can be seen at the other background sites. All background locations, with the exception of WM40, experience a noticeable increase in annual mean NO_2 concentration in 2003.

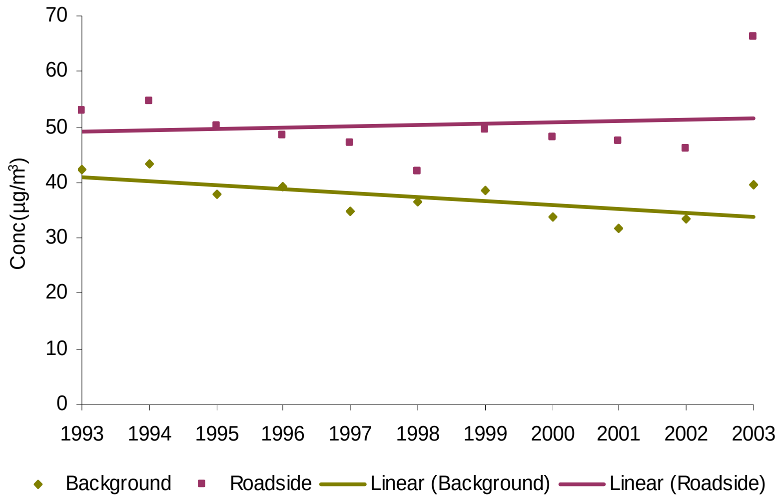
Figure 57 Westminster Roadside Time Series, 1993-2003



All roadside sites display a rolling trend in annual mean NO_2 concentration. Between 2002 and 2003 the NO_2 concentration rises by 52% at WM32, WM36 and WM39. WM36 records a minor rise in NO_2 concentration.

Trend Analysis

Figure 58 Westminster Trend Analysis, 1993-2003



Long-term background annual mean NO_2 concentrations continue to exhibit a downward trend. The trend for roadside sites has altered this year to an upward trend no doubt due to the marked increase in NO_2 concentrations.

Roadside Elevation

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Elevation above background (µg/m³)	10.6	11.2	12.3	9.1	12.4	5.6	10.8	14.2	15.8	12.8	26.6

The elevation above background NO_2 concentration fluctuates between 1993 and 2002 around 10µg/m³. The lowest concentration is recorded in 1998 where a drop of just over 50% takes place. In 2003 there is a two-fold increase in roadside elevation concentration.

9 Diffusion tube co-location study

9.1 Introduction

The NO_2 diffusion tube sampling technique is a low-cost monitoring option allowing large spatial coverage, which other sampling techniques may not be able to provide at similar cost. Though being widely used across the UK, particularly with regards to the review and assessment process and baseline surveys, its accuracy is however limited. There is therefore a need to establish the bias compared to more accurate sampling methods such as continuous analysers.

This chapter examines results from triplicate exposures of diffusion tubes that have been co-located with continuous analysers at four London authorities who participate in the LWEP nitrogen dioxide monitoring network. The mean bias correction factor derived from this study is intended to aid those local authorities that do not have the facilities to allow the calculation of their own correction factor. The study additionally aims to show compliance with EU Daughter Directive data quality objectives.

9.2 Methodology

The diffusion tubes have been dispatched on a monthly basis to the local site operators for exposure on the dates determined by the UK NO_2 diffusion tube network. Triplicate tubes have been exposed for 4-5 week periods within 0.5 m distances from continuous analysers that are part of the Automatic Urban and Rural Network (AURN) or London Air Quality Network (LAQN). These sites are operated on behalf of DEFRA by Central Management and Coordination Units (CMCU) which are either Kings ERG (responsible for LAQN) or Casella Stanger (responsible for AURN). The sites are summarised in Table 8. Recognised QA/QC procedures for calibration and data ratification of the continuous monitoring data are performed by NETCEN.

Table 5 Site details of the continuous monitors included in the diffusion tube collocation study

Site Location	Network	CMCU	Site Classification
Hillingdon	AURN	Casella Stanger	Suburban
North Kensington	LAQN	Kings ERG	Urban Background
Brent	AURN	Casella Stanger	Urban Background
Bloomsbury	AURN	Casella Stanger	Urban Centre

The triplicate tube results were averaged and compared to the period equivalent concentrations measured by continuous analyser. Period averages containing less than 90% data capture by continuous analysers over the tube exposure periods have been omitted to ensure a comparative and robust data set.

Calculation

The diffusion tube bias adjustment factor, A, has been calculated for each month as follows:

$$A = C_m/D_m$$

The percentage diffusion tube bias, B, has been calculated for each month as follows:

$$B = (D_m/C_m)/C_m * 100$$

N.B. The bias should always be expressed relative to the continuous analyser.

Further details of calculations and the methodology used to derive the bias and bias adjustment factor can be found in LAQM.TG (03)

9.4 Results

Details of calculations used to produce the % bias and adjustment factor can be found in the LAQM.TG(03)[15].

The study shows that the level of bias varies between – 4 and –16% giving a mean bias relative to the continuous monitor of –10% across the sites (Table 6). The mean precision across all sites in 2003 was 7.4 $\mu g/m^3$.

Although there is no requirement for this value in LAQM.TG (03), it may be useful for local authorities to consider such variation where NO_2 concentrations are close to the national air quality standard.

The bias adjustment factors range from 1.04 at Brent to 1.19 at Hillingdon. The mean correction factor is 1.11. The influence of specific site characteristics upon the NO_2 diffusion tube efficiency is unknown and has not been quantified within this report, but may account for some of the inter-site variation and will invariably reflect the individual NO_x/NO_2 ratios for each site.

When the mean bias adjustment factor of 1.11 is applied to the raw diffusion tube results reported in this report, the number of sites showing exceedences is further increased. NO_2 concentrations above 36 $\mu g/m^3$ will exceed the 2005 AQO; monitoring sites over this concentration are highlighted in Appendix 1.

[15] Source: DEFRA (2003) Technical Guidance, LAQM.TG (03)

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Table 6 Co-location data for 4 continuous monitoring sites

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Mean Conc. (µg/m³)	Mean Site Precision (µg/m³)	% Bias based on continuous monitor (B)	Correction Factor (A)
Hillingdon																
Mean diffusion tube (HD31)	33.6	50.9	41.2	39.2	41.6	30.3	36.4	39.0	52.8	41.8	52.2	42.50	41.8			
Mean continuous analyser	42.9	62.9	50.9	53.9	*	*	*	48.2	67.3	46.3	48.9	44.8	51.8	7.0	-16	1.19
Mean precision	-22	-19	-19	-27				-19	-22	-10	7	-5	-16			
North Kensington																
Mean diffusion tube (KC47)	32.7	49.9	40.0	34.8	31.7	38.7	27.2	37.8	44.7	39.6	46.6	38.2	38.5			
Mean continuous analyser	43.2	57.8	50.5	43.0	28.7	*	28.1	40.2	51.7	48.4	50.0	49.8	44.7	5.0	-14	1.16
Mean precision	-24	-14	-21	-19	11		-3	-6	-13	-18	-7	-23	-14			
Brent																
Mean diffusion tube (BR51)	33.1	57.2	28.7	35.1	19.2	20.5	23.6	26.8	43.5	37.1	*	43.7	33.5			
Mean continuous analyser	38.5	49.7	42.1	35.8	23.0	13.8	19.3	24.1	44.2	46.3	*	46	34.5	7.2	-4	1.04
Mean precision	-16	13	-46	-2	-19	33	18	10	-1	-25		-5	-4			
Bloomsbury																
Mean diffusion tube (CA28)	44.4	53.3	48.8	46.5	29.1	50.8	50.0	*	55.4	61.9	45.2	59.3	49.5			
Mean continuous analyser	*	*	*	*	45.3	44.4	43.4	*	64.1	43.0	60.8	66.2	52.5	10.4	-6	1.06
Mean precision					-36	14	15		-14	44	-26	-10	-6			
													Overall Mean Precision	**7.4**		
													Overall % Bias		**-10**	
													Mean Bias Adjustment Factor			**1.11**

* no data recorded

As can be seen in Table 7 the mean % bias and bias adjustment factor results for 2003 are clearly lower than those calculated in the preceding years. In order to validate this change and ensure that a potential systematic error associated with the preparation or analysis of the diffusion tubes had not occurred, Gradko Internationally Ltd where contacted. The laboratory has guaranteed that no modifications have taken place with any of their preparation or analytical procedures during this year[16].

Table 7 Mean correction factor and %bias of Gradko International Ltd tubes prepared with 50% TEA v/v in acetone from LWEP Studies 2001-2003.

	Mean correction factor (A)	Mean % bias (B)
2001	1.37	-26
2002	1.35	-26
2003	1.11	-10

16 Personal communication Gerry Stutchbury, Technical Manager, Gradko International Ltd, May 2004

10 Conclusion

In 2003, annual mean NO_2 concentration at both background and roadside monitoring sites experienced a marked rise compared to the previous year. On average, background site NO_2 concentrations increased by 27% and roadside sites by 33%. Background sites were mainly recording within the concentration range of 30-40 $\mu g/m^3$. For roadside sites NO_2 results where predominantly recorded in the 50-60 $\mu g/m^3$ concentration ranges.

A total of 215 of the 326 monitoring sites exceeded the 2005 Air Quality Objective of 40 $\mu g/m^3$; of these 48 where background sites and 116 were roadside sites. This is a distinct increase compared to 2002 where 57 monitoring sites exceeded to air quality objective. This rise in annual mean NO_2 concentrations is not unique to the LWEP programme, and has been noted at both automatic and non-automatic NO_2 networks nationwide. Meteorological conditions during 2003 have been accepted as the source of this is sharp rise in NO_2 concentrations.

Long-term trend analysis continue to indicate a general decrease in concentrations of NO_2 over time at both site classes irrespective of this year's rise in NO_2 results.

Analysis of the roadside elevation is intended to provide an indication of the contribution of road traffic to total NO_2 concentrations. Contribution from road traffic to annual average NO_2 concentrations has increased in thirteen Boroughs, contrary to preceding years where a general decrease in roadside concentrations was evident. The meteorological conditions experienced during 2003 may have been influential in enhancing the roadside elevation concentration.

The LWEP co-location study, where triplicate diffusion tubes are concurrently situated with automatic analysers at four sites in London, showed that the diffusion tubes used in this air quality programme under-read by 10%. This is well within the criterion of $\pm$25% set by the NETCEN inter-comparison exercise. Overall mean precision was calculated to at 7.4, which additionally meets the performance criterion of $\pm$ 10%, specified by NETCEN. This provides a high level of confidence in the accuracy of NO_2 results obtained from using the preparation and analytical procedures of Gradko International Ltd.

The mean bias adjustment factor derived from the LWEP collocation study for 2003 was calculated as 1.11. This is a notable decrease compared to last two years suggesting an improved comparability between diffusion tube and automatic monitor results. If the LWEP bias adjustment factor is applied to the raw diffusion tube results reported in this report, the number of sites showing exceedences further increases.

11 Disclaimer

Casella Stanger completed this report on the basis of a defined programme of works and within the terms and conditions agreed with the Client. This report was compiled with all reasonable skill and care, bearing in mind the project objectives, the agreed scope of works, prevailing site conditions and degree of manpower and resources allocated to the project as agreed.

Casella Stanger cannot accept responsibility to any parties whatsoever, following issue of this report, for any matters arising, which may be considered outside the agreed scope of works.

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Any questions or matters arising from this report may be addressed in the first instance to the Project Manager.

Appendix 1

Annual mean NO_2 concentration results background and roadside sites, 2003

Site Codes = Existing site exceeding 2005 AQO
Site Codes = New site exceeding 2005 AQO
Site Code = Site likely to exceed the 2005 AQO if the 1.11 bias adjustment factor is applied

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London Borough of Barking and Dagenham

Total Number of Sites: **10** Data Capture: **60%**

Site Code	Site Type	NO_2 Conc. (µg/m³)
BD32	B	32.1
BD35	B	65.3
BD38	B	30.6
BD39	B	62.8
BD40	R	35.9
BD41	R	26.7
BD42	R	32.7 *
BD43	R	34.6 *
BD44	B	24.7 *
BD45	B	23.5 *

London Borough of Bexley

Total Number of Sites: **7** Data Capture: **72%**

Site Code	Site Type	NO_2 Conc. (µg/m³)
BX31	B	31.2
BX32	B	30.4
BX33	B	26.8
BX34	R	41.7
BX35	R	40.9
BX36	R	32.6
BX37	B	34.3

London Borough of Brent

Total Number of Sites: **12** Data Capture: **92%**

Site Code	Site Type	NO_2 Conc. (µg/m³)	Site Code	Site Type	NO_2 Conc. (µg/m³)
BR31	B	66.1	BR53	R	79.4
BR41	B	32.3	BR54	R	55.0
BR51	B	33.5	BR55	R	76.4
BR42	R	46.1	BR56	R	55.5
BR43	R	69.2	BR57	R	67.0
BR52	R	47.2	BR58	R	57.6

London Borough of Camden

Total Number of Sites: **25** Data Capture: **80%**

Site Code	Site Type	NO_2 Conc. (µg/m³)	Site Code	Site Type	NO_2 Conc. (µg/m³)
CA01	B	41.1	CA19	R	60.4
CA06	B	42.5	CA21	R	43.7
CA07	B	31.3	CA23	R	52.7
CA22	B	36.7	CA24	R	48.4
CA25	B	46.4	CA27	R	53.6
CA26	R	65.8 *	CA28	R	60.9
CA29	B	49.5	CA30	R	44.2
CA03	R	62.3	CA31	R	60.9 *
CA04	R	60.0	CA32	R	49.1
CA05	R	57.3	CA33	R	41.7 *
CA10	R	46.2	CA35	R	38.0 *
CA11	R	56.5	CA36	R	52.6 *
CA15	R	65.4			

Corporation of London

Total Number of Sites: **11** Data Capture: **100%**

Site Code	Site Type	NO_2 Conc. (µg/m³)	Site Code	Site Type	NO_2 Conc. (µg/m³)
CL02	B	47.4	CL36	R	55.1
CL03	B	43.9	CL38	R	51.5
CL05	B	42.5	CL39	R	81.6
CL51	B	50.1	CL41	R	52.1
CL55	B	37.3	CL56	R	52.3
CL62	B	43.5			

London Borough of Croydon

Total Number of Sites: **24** Data Capture: **96%**

Site Code	Site Type	NO_2 Conc. (µg/m³)	Site Code	Site Type	NO_2 Conc. (µg/m³)
CY46A	B	27.6	CY58A	R	61.3
CY47A	B	29.2	CY59A	R	67.2
CY50A	B	20.5	CY60A	R	44.0
CY41A	R	38.6	CY61A	R	45.8
CY42A	R	60.4 *	CY62A	R	45.4
CY43A	R	43.7	CY63A	R	60.2
CY48A	R	50.3	CY64A	R	56.6
CY51A	R	37.0	CY65A	R	47.4
CY52A	R	37.8	CY66A	R	43.1
CY55A	R	53.3	CY97A	R	42.1
CY56A	R	33.9	CY98A	R	44.9
CY57A	R	49.4	CY99A	R	43.5

London Borough of Greenwich

Total Number of Sites: **32** Data Capture: **100%**

Site Code	Site Type	NO_2 Conc. (µg/m³)	Site Code	Site Type	NO_2 Conc. (µg/m³)
GW37	B	29.3	GW41	R	47.9
GW38	B	42.5	GW42	R	58.6
GW39	B	26.3	GW43	R	56.8
GW40	B	25.4	GW44	R	48.3
GW23	R	47.0	GW48	R	51.2
GW24	R	50.7	GW49	R	51.3
GW25	R	51.1	GW50	R	54.8
GW26	R	44.2	GW51	R	43.7
GW27	R	55.8	GW52	R	53.6
GW29	R	56.1	GW53	R	44.5
GW32	R	50.1	GW54	R	52.6
GW33	R	52.5	GW55	R	50.2
GW34	R	46.8	GW56	R	43.2
GW35	R	71.4	GW57	R	38.3
GW36	R	50.2	GW58	R	49.3

London Borough of Hammersmith and Fulham

Total Number of Sites: **20** Data Capture: **100%**

Site Code	Site Type	NO_2 Conc. (µg/m³)	Site Code	Site Type	NO_2 Conc. (µg/m³)
HM41	B	29.1	HM32	R	64.7
HM44	B	39.3	HM47	R	39.0
HM45	B	37.9	HM48	R	54.7
HM46	B	36.0	HM50	R	73.1
HM51	B	46.8	HM52	R	81.8
HM53	B	39.2	HM54	R	62.8
HM60	B	38.5	HM61	R	43.1
HM63	B	51.2	HM62	R	37.5
HM66	B	34.3	HM64	R	50.5
HM67	B	34.8	HM65	R	41.9

London Borough of Harrow

Total Number of Sites: **4** Data Capture: **100%**

Site Code	Site Type	NO_2 Conc. (µg/m³)
HA01	R	36.2
HA03	B	23.1
HA04	B	27.3
HA05	B	29.6

London Borough of Hillingdon

Total Number of Sites: **20** Data Capture: **98%**

Site Code	Site Type	NO_2 Conc. (µg/m³)	Site Code	Site Type	NO_2 Conc. (µg/m³)
HD31	B	41.8	HD58	B	40.5
HD41	B	27.5	HD59	B	41.2
HD48	B	35.4	HD60	B	36.2
HD49	B	31.1	HD61	B	41.2
HD52	B	41.5	HD42	R	37.8
HD53	B	36.8	HD43	R	45.7
HD54	B	42.4 *	HD46	R	48.7
HD55	B	45.8	HD47	R	44.1
HD56	B	38.9	HD50	R	40.1
HD57	B	40.0	HD51	R	42.0

London Borough of Hounslow

Total Number of Sites: **21** Data Capture: **98%**

Site Code	Site Type	NO_2 Conc. (µg/m³)	Site Code	Site Type	NO_2 Conc. (µg/m³)
HS34	B	40.6	HS51	R	33.7
HS35	B	37.4	HS52	R	38.3
HS43	B	42.9	HS54	R	37.0
HS53	B	36.1	HS55	R	50.5
HS65	B	44.6	HS61	R	76.1 *
HS66	B	39.4	HS62	R	57.2
HSCRAN	B	37.6	HS63	R	57.8
HS32	R	52.3	HS64	R	41.9
HS33	R	54.8	HSBREN	R	52.0
HS41	R	42.2	HSCHIS	R	71.7
HS42	R	39.9			

Royal Borough of Kensington and Chelsea

Total Number of Sites: **29** Data Capture: **100%**

Site Code	Site Type	NO_2 Conc. (µg/m³)	Site Code	Site Type	NO_2 Conc. (µg/m³)
KC32	B	35.2	KC35	R	58.6
KC34	B	48.1	KC38	R	89.2
KC39	B	40.3	KC45	R	50.1
KC40	B	56.3	KC46	R	48.9
KC41	B	41.2	KC48	R	68.7
KC42	B	49.6	KC49	R	68.7
KC43	B	40.0	KC50	R	58.0
KC44	B	47.1	KC52	R	68.7
KC47	B	38.5	KC54	R	66.9
KC51	B	36.5	KC57	R	52.8
KC53	B	53.8	KC58	R	61.5
KC55	B	47.1	KC59	R	73.5
KC56	B	67.3	KC60	R	63.5
KC31	R	52.1	KC61	R	57.1
KC33	R	77.8			

London Borough of Newham

Total Number of Sites: **20** Data Capture: **85%**

Site Code	Site Type	NO_2 Conc. (µg/m³)	Site Code	Site Type	NO_2 Conc. (µg/m³)
NW05	B	41.4	NW12	R	45.0
NW06	B	29.2	NW13	R	57.8
NW07	B	34.7	NW14	R	55.7
NW10	B	31.6	NW15	R	47.1
NW01	R	44.1	NW16	R	62.1
NW02	R	40.4	NW17	R	42.6
NW03	R	39.4	NW18	R	46.0
NW04	R	41.8	NW19	R	48.1 *
NW08	R	35.1	NW20	R	62.0 *
NW09	R	31.6	NW21	R	47.7 *
NW11	R	33.1			

London Borough of Richmond Upton Thames

Total Number of Sites: **56** Data Capture: **98%**

Site Code	Site Type	NO_2 Conc. (µg/m³)	Site Code	Site Type	NO_2 Conc. (µg/m³)	Site Code	Site Type	NO_2 Conc. (µg/m³)
RM1	R	47.9	RM23	R	38.5	RM45	R	47.5
RM2	R	33.4	RM24	R	43.0	RM46	R	43.4
RM3	R	45.5	RM25	R	52.9	RM47	R	38.9
RM4	R	47.6	RM26	R	47.8	RM48	R	41.9
RM5	R	36.2	RM27	B	45.5	RM49	R	49.6
RM6	B	44.1	RM28	R	23.5	RM50	R	57.0
RM7	R	70.3	RM29	B	41.5	RM51	R	39.3
RM8	R	35.6	RM30	R	36.6	RM52	R	51.2
RM9	R	48.7	RM31	R	56.3	RM53	R	47.1 *
RM10	B	42.4	RM32	R	78.4	RUT 1	R	50.1
RM11	R	44.6	RM33	R	53.5	RUT 2	B	106.5
RM12	R	41.1	RM34	R	39.0	RUT 3	B	34.0
RM13	R	49.0	RM35	R	58.4	RUT 4	B	29.9
RM14	R	47.4	RM36	B	71.7			
RM15	R	48.3	RM37	R	28.4			
RM16	B	44.6	RM38	R	41.2			
RM17	R	28.1	RM39	R	60.0			
RM18	R	64.3	RM40	R	41.0			
RM19	R	61.4	RM41	R	45.3			
RM20	R	53.0	RM42	R	60.5			

RM21	R	45.1	RM43	R	54.7
RM22	R	50.3	RM44	R	49.5

London Borough of Westminster

Site Code	Site Type	NO_2 Conc. (µg/m³)	Site Code	Site Type	NO_2 Conc. (µg/m³)
WM37	B	45.5	WM54	B	39.2
WM40	B	36.8	WM56	B	32.3
WM41	B	31.7	WM57	B	42.9
WM43	B	48.7	WM58	B	45.5
WM47	B	38.1	WM32	R	60.1
WM48	B	42.7	WM36	R	48.7
WM49	B	40.2	WM39	R	66.4
WM52	B	34.9	WM46	R	59.7
WM53	B	38.3	WM55	R	96.8

Total Number of Sites: **18**
Data Capture: **100%**