Bureau Veritas UK Ltd

London Wide Environment Programme

Nitrogen Dioxide Diffusion Tube Survey Annual Report 2018

May 2019

Move Forward with Confidence

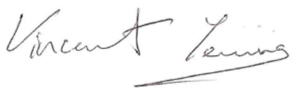
THIS PAGE IS LEFT BLANK INTENTIONALLY

Document Control Sheet

Identification	
Clients	London Borough of Croydon, City of London Corporation, Royal Borough of Greenwich, Royal Borough of Kensington and Chelsea, London Borough of Newham
Document Title	London Wide Environment Program NO_2 Diffusion Tube Survey Report 2018
Bureau Veritas Ref No.	6471611/AQ/V1

Contact Details	
Company Name	Bureau Veritas UK Limited
Contact Name	Vincent Yeung
Position	Consultant
Address	5th Floor 66 Prescot Street London E1 8HG
Telephone	0207 550 8938
e-mail	Vincent-ws.yeung@bureauveritas.com
Websites	www.bureauveritas.co.uk

Configuration				
Version	**Date**	**Author**	**Reason for Issue/Summary of Changes**	**Status**
01	17/05/2019	V Yeung	Draft for comment	Draft
02	29/05/2019	V Yeung		Draft
03	29/08/2019	V Yeung	Final draft for comment	Draft

	Name	Job Title	Signature
Prepared By	V Yeung	Consultant	
Approved By	P Bentley	Senior Consultant	

Disclaimer

This Report was completed by Bureau Veritas on the basis of a defined programme of work and terms and conditions agreed with the Client. Bureau Veritas confirms that in preparing this Report it has exercised all reasonable skill and care taking into account the project objectives, the agreed scope of works, prevailing site conditions and the degree of manpower and resources allocated to the project.
Bureau Veritas accepts no responsibility to any parties whatsoever, following the issue of the Report, for any matters arising outside the agreed scope of the works.
This Report is issued in confidence to the Client and Bureau Veritas has no responsibility to any third parties to whom this Report may be circulated, in part or in full, and any such parties rely on the contents of the report solely at their own risk.
Unless specifically assigned or transferred within the terms of the agreement, the consultant asserts and retains all Copyright, and other Intellectual Property Rights, in and over the Report and its contents.

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

Bureau Veritas UK Limited
5th Floor, 66 Prescot Street
London
E1 8HG

Telephone: +44 (0) 207 6610700
Fax: +44 (0) 207 6610741
Registered in England 1758622
www.bureauveritas.co.uk

Registered Office
Suite 206 Fort Dunlop
Fort Parkway
Birmingham B24 9FD

THIS PAGE IS LEFT BLANK INTENTIONALLY

Table of Contents

List of Tables

List of Figures

Executive Summary

Bureau Veritas (and its predecessors), have undertaken the London-Wide Environment Programme (LWEP) since 1986. The LWEP has previously consisted of the monitoring, analysis and reporting of key environmental indicators throughout the Greater London region. This report addresses one of the remaining indicators – nitrogen dioxide (NO_2) concentrations in ambient air.

NO_2 is one of the main pollutants within London that causes detrimental health effects for the population. Within London the main source of localised NO_2 concentrations is from vehicle emissions across the large network of roadways. The existing NO_2 monitoring networks operated by London local authorities remains a representative tool for reporting, prediction, and policy based decisions to be made upon.

The annual LWEP NO_2 report is principally provided as a service for London local authorities.

In 2018, diffusion tubes were located at 147 qualifying monitoring sites spread over five London Boroughs and the City of London. Annual average un-corrected for bias NO_2 concentrations (January to December) that were above the 40µg/m^3 annual mean Air Quality Strategy (AQS) objective were recorded at two urban background and ninety four roadside sites, resulting in 60.4% of monitoring locations exceeding the AQS objective.

When compared to the results for 2017 in which 58% of sites showed exceedance of the annual mean AQS objective, there has been an overall decrease of 0.9% in sites exceeding the AQS Objective in 2018.

Linear trend analysis has been completed between concentrations between 2017 and 2018, 2014 and 2018, and between the first year of monitoring for the current site and 2018. The comparison of annual mean between 2017 and 2018 shows that there is an increase in roadside annual mean concentration of 0.9%, whilst background concentrations has declined by -1.3%, the general trend can be seen across all 5 boroughs that have participated in 2018. Through long term trend analysis completed between when monitoring first started and 2018 for all monitoring sites which have more than six continuous years of monitoring data. The trend analysis indicates that concentrations of NO_2 are increasing at roadside sites, with the 2018 data set showing a positive trend of 17.5%. In comparison, background sites have shown a decrease of 10.5%. Whereas the five year comparison (2014 - 2018) linear trend shows that there is a decrease in both roadside and background concentrations by 10.5% and 6.6% respectively.

1 Introduction

1.1 Overview

Palmes-type nitrogen dioxide (NO_2) passive diffusion tubes are widely used across the UK for indicative measurements of ambient concentrations of NO_2. Diffusion tubes are useful tool for local authorities in screening and baseline surveys, particularly with regards to the Review and Assessment of NO_2 concentrations for the Local Air Quality Management (LAQM, Part IV of the Environment Act 1995).

The Greater London Authority (GLA) has an important role in air quality management, previously by virtue of the 2010 London Air Quality Strategy[1], which had to be taken into consideration by the London Boroughs and The City of London when carrying out their statutory duties. In May 2018, a new London Environment Strategy[2] was released, this is the first strategy to bring together every aspect of London's environment.

Air quality is a main focus of the strategy, with the overall aim for London to have the best air quality of any major world city by 2050, going beyond the legal requirements to protect human health and minimise inequalities. It outlines plans to pave the way for a zero waste, zero emission transport system and zero carbon new homes within London. The strategy focuses on four strategic approaches that have been designed to make the most of environmental opportunities now and in the future. These approaches are low carbon circular economy, smart digital city, green infrastructure and natural capital accounting, and the "Healthy Streets" approach.

In 2018, a total of five London Boroughs and the City of London participated in the NO_2 London Wide Environmental Programme (LWEP):

- City of London Corporation;
- London Borough of Croydon;
- Royal Borough of Greenwich;
- London Borough of Hammersmith and Fulham;
- Royal Borough of Kensington and Chelsea; and
- London Borough of Newham

1.2 Objectives

The aim of this report is to provide participating local authorities with an overview of the NO_2 concentrations (at both urban background and roadside monitoring sites) recorded as part of the LWEP NO_2 Diffusion Tube Survey in 2018, and to view these results in the broader context of regulatory requirements and to identify possible trends with previous NO_2 monitoring data. This aim is met by the following objectives.

- Outlining the reasons for undertaking the monitoring of ambient levels of NO_2;

[1] The Mayor's Air Quality Strategy December 2010, available at https://www.london.gov.uk/sites/default/files/Air_Quality_Strategy_v3.pdf

[2] Mayor of London, London Environment Strategy, available at https://www.london.gov.uk/what-we-do/environment/london-environment-strategy

- Outlining relevant existing and future legislative air quality requirements;

- Detailing the NO_2 sampling methods employed by Bureau Veritas 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 urban background and roadside sites;

- Assessing the long-term trends in NO_2 concentrations recorded as part of the LWEP NO_2 Diffusion Tube Survey, including comparisons from the earliest year of monitoring with 2018, over a 5-year period, and between 2017 and 2018 results to observe more recent trends;

- Reporting the annual mean NO_2 concentrations at each site for all participating boroughs in 2018, and to place these results in the context of results gathered since monitoring started at specific sites;

- Undertaking analysis of the results to assess trends in pollution at urban background and roadside sites for each participating borough;

- Identifying the elevation in NO_2 concentrations at roadside sites when compared to urban background levels; and

- Validation of NO_2 diffusion tube data through the analysis of results from tubes co-located with automatic analysers.

2 Formation, Sources and Effects of NO_2

2.1 Formation of Atmospheric NO_2

Nitrogen Dioxide occurs naturally within the troposphere mainly from thunderstorms due to the extreme heat of lightning, from forest fires and also through processes in soils and water bodies. In addition anthropogenic activities produce NO_2, generated from human activities such as road transport, power generation, and high temperature industrial processes. Anthropogenic emissions of NO_2 are normally generated through direct emission (primary NO_2) or formed through chemical reactions whilst NO is suspended in the air (secondary NO_2).

Further photochemical reaction between NO_2 and oxygen can form O_3, which is a transboundary air pollutant. Due to the nature and rate of formation, they are often in an inverse relationship to each other, where NO_x (mixture NO and NO_2) is at higher concentration within towns and local sources, and O_3 is at higher concentration in rural and suburban locations.

The concentration of NO_2 is highly influenced by a number of factors. These include the magnitude and proximity of emission sources, the rate of chemical reaction for the generation and destruction of NO_2, as well as the meteorological conditions of the local area as these will affect the dispersion or accumulation of pollutants.

The importance of existing and future pollutant concentrations can be assessed in relation to the national air quality standards and objectives established by Government. The Air Quality Strategy[3] (AQS) provides the over-arching strategic framework for air quality management in the UK and contains national air quality standards and objectives established by the UK Government and Devolved Administrations to protect human health. The air quality objectives incorporated in the AQS and the UK Legislation are derived from Limit Values prescribed in the EU Directives transposed into national legislation by Member States.

2.2 Emissions, Sources and Trends

Emissions inventories are an important means of quantifying emissions of NO_x from different sources at different times. The latest emissions inventory information released by the National Atmospheric Emissions Inventory (NAEI)[4] for 2016 states that, within England the majority of NO_x emissions continue to be generated from road transport emissions (54.7%) followed by industrial combustion (16.8%).

In terms of total emissions of NO_x, there has been a continual trend of decline over the past three years. Total emissions of NO_x from England within 2016 were estimated to be 643kt, this represents 72% of the total UK emissions in 2016. The 643kt for 2016 is a reduction when compared to the 676kt total and 708kt in 2015 and 2014 respectively.

NO_x emissions have declined since 1990 when total emissions were over 2,000kt. The decline is mainly due to changes within the transport sector such as tighter emission controls driving improvement in emissions abatement technology within vehicles. After an initial period of rapid reduction from 1990 the scale of reduction has decreased due to an increasing use of diesel vehicles (diesel vehicles emit higher NO_x relative to petrol vehicles) and deficiencies that have been identified in controlled condition emission tests for new vehicles. Though hybrid and electric vehicles have been popular and proved to reduce roadside NO_x emissions, the uptake of these vehicles are

[3] The Air Quality Strategy for England, Scotland, Wales and Northern Ireland (2007), Published by Defra in partnership with the Scottish Executive, Welsh Assembly Government and Department of the Environment Northern Ireland

[4] National Atmospheric Emissions Inventory, Air Quality Pollutant Inventories for England, Scotland, Wales and Northern Ireland: 1990-2016, prepared by Ricardo Energy & Environment, October 2018

around 0.4%[5] for the general car population, which have not provided any significant impact on the reduction on roadside emissions thus far. Further reductions can be seen in recent years, from emission reductions through accelerated phase out of coal-firing at power stations to natural gas, as well as the increasing share of renewable energy generation.

2.3 Health Effects of NO_2

Numerous studies describe that all types of air pollution, at high concentration, can affect the airways. Nevertheless, similar effects are also observed with long-term exposure to lower pollutant concentrations. Nitrogen dioxide (NO_2) is one of such air pollutant. At high-intensity, confined space exposure to NO_2 has caused adverse health effects to humans, from cardiovascular diseases to death. Ambient NO_2 exposure may increase the risk of respiratory tract infections through the pollutant's interaction with the immune system[6].

NO and NO_2, collectively known as NO_x, are produced during the high temperature combustion processes involving the oxidation of N. Initially, NO_x is mainly emitted as NO, which then undergoes further oxidation in the atmosphere, particularly with ozone (O_3), to produce secondary NO_2. Production of secondary NO_2 could also be favoured due to a class of compounds, VOCs, typically present in urban environments, and under certain meteorological conditions, such as hot sunny days and stagnant anti-cyclonic winter conditions.

Exposure to NO_2 can bring about symptoms such as nose and throat irritation, followed by bronchoconstriction and dyspnoea, especially in asthmatic individuals. It may also increase reactivity to natural allergens, and exposure to NO_2 puts children at increased risk of respiratory infection and may lead to reduced lung function in later life.

Air Quality in Europe (2018 report)[7] reported that within the UK in 2015 there were 9,600 premature deaths, and 6,400 years of lost life (154 years of life lost per 100,000 inhabitants) attributed to NO_2 exposure. For a total of forty one countries the totals for 2015 were estimated as 79,000 premature deaths and 193,800 years of life toast attributed to NO_2 exposure.

The effects of air pollution on health within the UK population put an additional burden on the National Health Service (NHS), costing £157 million in 2017[8]. With an increased number of hospital admissions and GP appointments taking place due to health detriments caused by air pollution the cost would only continue to grow.

Air pollution not only affects health, productivity can be used as a cost benefit factor within an impact assessment. It has been estimated by Defra[9] that poor air quality, in 2012 had a total cost of up to £2.7 billion through its impact on productivity.

[5] Electric vehicles, London Assembly Environment Committee available on: https://www.london.gov.uk/sites/default/files/environment_committee_-_ev_report.pdf

[6] Marilena Kampa and Elias Castanas, Human health effects of air pollution, June 2007

[7] European Environment Agency, Air Quality in Europe – 2017 Report, 13/2017

[8] RyanO'Hare, Air pollution in England could cost as much as £5.3 billion by 2035, May 2018

[9] Department for Environment, Food and Rural Affairs, Valuing the Impacts of Air Quality on Productivity, June 2014

3 Policy Framework

3.1 Standards and Objectives

Air quality standards relevant to NO_2 concentrations have undergone change, both nationally and on a European level. For Europe, the First Air Quality Daughter Directive (1999/30/EC) now incorporated into the Cleaner Air for Europe Directive (2008/50/EC), sets out limit values for annual mean and hourly mean NO_2 concentrations, to be achieved by 1st January 2010.

In 2007, the United Kingdom registered a notification of a postponement under Article 22(1) of Directive 2008/05/EC of the deadline for attaining the annual limit value for NO_2 in 24 air quality zones.

The Air Quality Directive 2008/50/EC contains provisions for additional time to meet the limit values for pollutants including NO_2. The extended deadline was 2015. In the UK, London and some other major urban centres are not currently meeting the limit values, as such Defra and the devolved administrations have published air quality actions demonstrating how the limit value for NO_2 will be achieved as soon as possible. These were submitted to the European Commission in 2011. In June 2012 the decision from the European Commission was issued.

In 2011, the European Commission began a review of EU air quality policy, which lead to the publication of new proposals on ambient air quality and emissions ceilings, the review was completed in 2013. The new EU policy package adopted in December 2013 contains a Clean Air Programme for Europe[10], which includes measures to help reduce air emissions with focus on air quality in cities, and sets out policy objectives up to 2030.

The UK Air Quality Plan[11] was released in July 2017 setting out the UK's plan for reducing roadside NO_2 concentrations. Within the revised plan additional measures to improve air quality are outlined at both a government and local authority level. The effort to reduce NO_2 concentrations is focussed on the sources that make the largest contribution to increased NO_2 concentrations. Vehicle emissions contribute approximately 80% of NO_2 concentrations at the roadside, with historic tax breaks introduced to diesel vehicles increasing the ownership of diesel vehicles that emit more NO_2 than petrol equivalent vehicles.

Following the release of the UK Air Quality Plan, on the 23rd of March 2018 the UK government initially legally directed the thirty-three local authorities identified within the Air Quality Plan to complete feasibility studies based upon exceedances of the NO_2 annual mean objective. A Supplement to the UK Plan[12] for tackling roadside NO_2 concentrations was published in October 2018, sets out measures that have been identified to bring forward compliance on identified road links which the UK government has direct local authorities to deliver.

In addition to the UK Air Quality Plan and Supplementary Document, during 2018 a draft Clean Air Strategy[13] was presented for consultation between the 22nd of May and the 14th of August, where the final strategy is set to be published in March 2019. The draft Strategy sets out the action that is required across all areas of government and society to meet to goals of tackling all sources of air pollution, making air healthier to breathe, protecting nature and boosting the economy. New legislation is promoted to create a stronger and more coherent framework for action to tackle air

---

[10] A Clean Air Programme for Europe, COM(2013 918 final, available at https://www.eea.europa.eu/policy-documents/a-clean-air-programme-for-europe

[11] UK Plan for tackling roadside nitrogen dioxide concentrations, published by Defra in partnership with the Scottish Government, Welsh Assembly Government, and Department of the Environment for Northern Ireland

[12] Supplement to the UK Plan for tackling roadside nitrogen dioxide concentrations, October 2018, available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/746100/air-quality-no2-plan-supplement.pdf

[13] Draft Clean Air Strategy 2018, available at https://consult.defra.gov.uk/environmental-quality/clean-air-strategy-consultation/user_uploads/clean-air-strategy-2018-consultation.pdf

pollution, this will be supplemented by new powers to control major sources of air pollution in line with the risk they pose to public health and the environment.

Table 3.1 – Air Quality Limit Values for Nitrogen Dioxide in CAFÉ Directive

	Concentrations	Measured As	Achievement Date
Hourly	200µg/m^3 not to be exceeded more than 18 times per year	1-hour mean	1st January 2010
Annual	40µg/m^3	Annual mean	1st January 2010

Air quality standards relevant to the UK are provided in The Air Quality Standards (AQS) 2010[14] for England. The air quality objectives applicable in England are set out in the Air Quality (England) Regulations 2000 (SI 928) and The Air Quality (England) (Amendment) Regulations 2002 (SI 3043). The regulations retain the annual and hourly NO_2 Air Quality Objectives (AQO) in line with those set in the European Directive, shown in Table 3.1.

Table 3.2 – Air Quality Objective for Nitrogen Dioxide in AQS 2010

	Concentration	Measured As	Achievement Date
Hourly	200µg/m^3 not to be exceeded more than 18 times per year	1-hour mean	31st December 2005
Annual	40µg/m^3	Annual mean	31st December 2005

The standards for the eight pollutants (PM_{10}, $PM_{2.5}$, O_3, Lead, Benzene, SO_2, CO, 1,3 Butadiene in addition to NO_2) covered by the strategy are underpinned by recommendations made by the Government's Expert Panel on Air Quality Standards (EPAQS). The objective levels are 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 when setting the final objective values.

The UK is required to report air quality data on an annual basis under two European Directives; The Council Directive on ambient air quality and cleaner air for Europe (2008/50/EC), and The Fourth Daughter Directive (2004/107/EC) under the Air Quality Framework Directive (1996/62/EC). In relation to NO_2, the 2017Air Pollution in the UK annual report[15] presented the following conclusions for the forty three separate geographical zones:

- Two zones had locations where the 1-hour limit value (200µg/m^3) was exceeded on more than the permitted 18 occasions during 2017: The Greater London Urban Area, and South Wales; and

- Thirty seven zones exceeded the limit value for annual mean NO_2 including the Greater London Urban Area, the exceedance values have decreased in comparison to 2016 exceedance 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 NO_2 diffusion tube monitoring network in London.

LAQM continues to be at the heart of the AQS, and local authorities are required to review current air quality and to assess whether the relevant AQO will be achieved. Those authorities that concluded that one or more of the objectives are unlikely to be achieved, are obliged to declare Air

[14] The Air Quality Standards Regulations (England) 2010, Statutory Instrument No 1001, The Stationary Office Limited

[15] Air Pollution in the UK 2017, Department for Environment, Food and Rural Affairs, available at https://uk-air.defra.gov.uk/library/annualreport/index

Quality Management Areas (AQMAs) and draw up an air quality action plan (AQAP) detailing how it is planned to reduce air pollution.

3.2 The Greater London Authority

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

As a result, the Mayor of London has significant decision-making abilities being charged with the responsibility for the London-wide environment and a duty to promote the health of the population of London. The Mayor of London 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 London Environment Strategy 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 31st May 2018[16] and Mayor's Transport Strategy was published in March 2018[12], in which they identify NO_2 alongside particulate matter (PM) as one of the main pollutants of concern within London.

Within 2018-19 the GLA have taken a number of actions in response to pollutant concentrations within London:

- The Ultra Low Emissions Zone (ULEZ)[17] has come into force on 8th April 2019, which will be replacing the pre-existing congestion charge. The ULEZ will be enforced within the area of the current Congestion Charging Zone (CCZ) and predictions have been made stating reductions of NO_x concentrations of 50% in central London, 40% in inner London, and 30% in outer London;

- Out of the twelve Low Emission Bus Zones proposed in 2016, three were delivered in 2018; Camberwell to New Cross, Wandsworth to St John's Hill and Haringey in August 2018, A12 Eastern Avenue from Homerton High Street in October 2018 and Edgware Road (Kilburn to Maida Vale) in November 2018. Buses operating within these routes are hybrid, electric or conform to the highest (Euro VI) emission standards, working to phase out the use of diesel only buses. The remaining ten routes are set to be delivered by 2020[16];

- An air quality audit of fifty London primary schools has been commissioned to investigate concentrations of NO_2 and to provide mitigation options to lower emissions and reduce exposure. With recommendation on moving school entrances and play areas away from busy roads, 'no engine idling' scheme for school run, reducing emissions from boilers, kitchens and other sources, improving local road layouts and restrict high polluting vehicles around schools and pedestrainisation of school entrances, encouraging students to walk or cycle to school[18];

- London taxis licensed after the 1st of January 2018 will have to be zero emission capable to reduce NO_x emissions from the taxi fleet. The network of rapid electric charging points is to expand during 2018 with points installed at taxi rank locations that will be dedicated

[16] Mayor of London, London Environment Strategy, available at https://www.london.gov.uk/what-we-do/environment/london-environment-strategy

[17] Mayor of London, Mayor Transport Strategy, available at https://www.london.gov.uk/sites/default/files/mayors-transport-strategy-2018.pdf

[18] Mayor of London, The Mayor's School Air Quality Audit Programme, May 2018, available at https://www.london.gov.uk/sites/default/files/20180523_saq_master_project_report_inc_append_-_final_v6.0_gla_frmt.pdf

exclusively to taxi use. Uptake on the new ZEC taxis have been fast, out of the 668 available, over 500[19] have already been taken up;

- The final Mayor's Transport Strategy was published in March 2018[20]. Which focuses on the reduce dependency on private car use and promote health benefits of walking and cycling are stated as an essential component of the strategy, with improving air quality a key factor for this, but also increase efficiencies and effectiveness of public transport and further development of borough traffic reduction strategies; and

- The Breathe London programme has been running since September 2018, where 100 low cost air quality monitoring sensors have been deployed across London, as well as Google Street View cars fitted with monitoring instruments measuring road emissions[21]. Although the monitors used within the programme are not accredited to CEN EU standards methods for monitoring the programme has been designed to illustrate how factors such as traffic, road layout and weather impact local air pollution patterns

[19] 500 LEVC TX electric taxis on London's streets. The green transformation of London's black cabs continues apace, October 2018 available at https://www.levc.com/corporate/news/500-electric-taxis-in-london/

[20] Mayor of London, Mayor's Transport Strategy, March 2018, available at https://tfl.gov.uk/corporate/about-tfl/how-we-work/planning-for-the-future/the-mayors-transport-strategy

[21] Breathe London project, available at https://www.breathelondon.org/

4 NO_2 Diffusion Tube Monitoring

4.1 Diffusion Tubes

Diffusion tubes are simple and inexpensive passive sampling devices that are widely used in the UK for measuring ambient NO_2 concentrations. The sampler is composed of an acrylic tube that can be sealed at both ends. One end of the tube contains two stainless steel mesh discs coated with triethanolamine (TEA) that adsorbs NO_2 to produce a nitrite salt that can be determined by colorimetry.

Once the inlet cap is removed, exposure begins, and a concentration gradient is established within the tube resulting in molecular diffusion taking place towards the TEA-coated grid. After exposure, the total quantity of gas transferred along the tube is determined by chemical analysis, commonly ultra-violet spectrometry.

There are a number of different diffusion tube preparation methods in use by laboratories in the UK. The difference relates to the way in which the metal grids are coated with TEA. The methods currently in use are 50% TEA in acetone, 50% TEA in water and 20% TEA in water. The methodologies of preparation, application and analysis have come under the review of the Defra Working Group on the Harmonisation of Diffusion Tubes[22].

4.2 Performance of Diffusion Tubes

NO_2 diffusion tubes are an indicative monitoring technique commonly used to investigate the temporal and spatial trends in NO_2 concentrations. These devices do not perform to the same accuracy as the automatic chemiluminescent analyser, which is identified by the EU as the reference method of measurement for nitrogen dioxide. It is stated within the NO_2 Diffusion Tube Practical Guidance[22] that the uncertainty of the measurements taken by NO_2 diffusion tubes should be recognised as ±25%.

Numerous studies have been undertaken to explore the factors affecting diffusion tube performance. These have focused on exposing diffusion tubes alongside chemiluminescence monitors. The results have observed that measurements by diffusion tubes over-estimate (positive bias) or underestimate (negative bias) the true ambient NO_2 concentrations. The various mechanisms[23] that have been proposed to explain the over, and under estimation of NO_2 concentrations by diffusion tubes include:

Over estimation of NO_2 concentrations:

- Higher wind speeds can generate turbulence at the entrance of the diffusion tube causing a shortening of the effective diffusion tube length;
- Reduced NO_2 photolysis in the tube by the blocking of UV light by the tube material;
- Interference effects of the secondary particulate compound peroxyacteyl nitrate (PAN); and
- Very high concentrations may occur due to sample contamination.

Under estimation of ambient NO_2 concentrations:

[22] Diffusion Tubes for Ambient NO_2 Monitoring : Practical Guide for Laboratories and Users, AEA Energy & Environment, 2008

[23] Nitrogen Dioxide in the United Kingdom, Air Quality Expert Group, 2004

- Insufficient extraction of nitrite from the grids;
- Incorrect standard solution used for calibration;
- Increased exposure time that is thought to cause the degradation of absorbed nitrite over time; and
- Very low concentrations may result from the grid disruption or loss, which are both outside the control of the analytical laboratory.

As detailed in the NO_2 Diffusion Tube Practical Guidance[22], the following factors have also been suggested to influence diffusion tube performance:

- The laboratory preparing and analysing the tubes;
- The diffusion tube preparation method;
- The exposure interval, weekly, 2-weekly or monthly;
- The time of year;
- The exposure setting, sheltered or more exposed;
- The exposure location, roadside or background; and
- The exposure concentration and NO_2/NO_x ratio.

4.3 Bias Adjustment Factors

Diffusion tube measurements exhibit a bias compared to the reference method that needs to be taken into consideration before results are compared to the air quality standards and objectives. Defra's London specific London Local Air Quality Management (LLAQM) Technical Guidance TG(16)[24] advises local authorities to examine the bias associated with their diffusion tubes and then apply an adjustment to the annual mean, if required. Co-location studies are recommended (for a minimum period of nine months) where diffusion tubes are exposed in triplicate concurrently with an automatic monitoring sites.

In circumstances where local authorities do not have the opportunity to carry out a co-location study, a default bias-adjustment factor should be applied. The National Physical Laboratory (NPL) distributes a spreadsheet (hosted on LAQM website) representing national bias-adjustment factors compiled from co-location studies carried out by local authorities at roadside and background sites throughout the UK[25]. The spreadsheet is released twice annually to allow for the inclusion of fully ratified automatic monitoring data. National bias-adjustment factors are available for the different tube preparation methods for a number of UK laboratories.

4.4 LWEP Monitoring Programme

A total of 153 NO_2 diffusion tube monitoring sites were active in the LWEP diffusion tube NO_2 monitoring programme during 2018, this is an increase of 6 sites from 2017. There is 1 additional

[24] Mayor of London (2016), London Local Air Quality Management Technical Guidance LLAQM.TG(16)

[25] National Diffusion Tube Bias Adjustment Factor Spreadsheet, NPL, most recent version available at https://laqm.defra.gov.uk/bias-adjustment-factors/national-bias.html

monitoring location located within the London Borough of Hammersmith and Fulham, and 5 additional locations located within London Borough of Kensington and Chelsea.

As per LLAQM.TG(16) guidance[24] 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 sites have been classified depending on the distance from the road as either roadside (0-20 m) or background (>20 m). The number of tubes exposed in each authority is at the discretion of each local authority involved in the monitoring programme. NO_2 concentrations in London, along with the rest of the UK, are mainly attributable to road transport, which results in a strong bias towards roadside as the choice of site compared to background sites. Background sites are chosen largely to represent relevant exposure to the public, such as residential properties.

4.4.1 Diffusion Tube Preparation and Analysis

The diffusion tubes employed in the LWEP are prepared and analysed by UKAS accredited Gradko International Ltd. Diffusion tubes are prepared using the 50% TEA with acetone method and analysed using UV spectrometry. The diffusion tubes are labelled, and kept refrigerated in plastic bags prior to and after exposure.

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 recommended exposure calendar[26]. Adherence to the changeover dates is important to enable as valid an inter-comparison as possible between the boroughs.

4.4.2 Quality Assurance and Quality Control

The Air Quality Directive 2008/50/EC sets data quality objectives for NO_2 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 calibre, strict performance criteria needs to be met through the execution of quality assurance and control procedures. As mentioned earlier, a number of factors have been identified as influencing the performance of diffusion tubes, including the laboratory preparing and analysing of the tubes, and the tube preparation method.

Quality assurance and therefore, control procedures are an integral feature of any monitoring programme, ensuring that uncertainties in the data are minimised and allowing the best estimate of true concentration. The Harmonisation Working Paper published its findings in February 2008 and this guidance provides a set of preparation and analytical procedures and guidelines for the deployment of diffusion tubes with the aim to standardise both. Gradko International was a member of the Working Party and were key partners in the standardisation of diffusion tubes.

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.

Laboratory Performance in AIR NO_2 Proficiency Testing (PT) Scheme

QA/QC of diffusion tube laboratories is provided by the AIR-PT Scheme, which is operated by LGC Standards and supported by the Health and Safety Laboratory. The AIR-PT scheme, commenced in April 2014 combines the two long running schemes of the HSL Workplace Analysis Scheme for

[26] 2018 Diffusion Tube Monitoring Calendar, Defra, available at https://laqm.defra.gov.uk/diffusion-tubes/data-entry.html

Proficiency (WASP) and the LGC Standards STACKS scheme. The scheme is designed to help laboratories meet the European Standard EN482[27].

Gradko International Ltd participates in the AIR-PT scheme and historically participated in the WASP scheme. Each quarter each laboratory receives tubes with known concentrations of nitrile for analysis. The tubes also include duplicates allowing for precision and accuracy to be assessed.

From 2011 onwards, a z-score system has been implemented to assess performance of laboratories. The key changes are the inclusion of all monthly performance scores (previously the lowest round out of 5 was dropped), the score is not based on a rolling performance indicator and all results from all UK participants are now reported.

A z-score is interpreted, and a deviation of less than 2 is a satisfactory result, deviation of equal to or more than 2 but less than 3 is a questionable laboratory result and deviation of more than 3 is deemed unsatisfactory.

The results are presented as the percentage of results where the z-score was between -2 and +2, which is deemed to be satisfactory. The 2018 AIR-PT[28] results Gradko are presented in

Table 4.1 – Laboratory Summary Performance for NO_2 AIR-PT Rounds

AIR PT AR024 Jan – Feb 2018	AIR PT AR025 Apr – May 2018	AIR PT AR027 July – Aug 2018	AIR PT AR028 Sept – Oct 2018
100%	100%	100%	100%
Note – AIR-PT Round 26 did not included NO_2 samples.			

Network Field Inter-Comparison Exercise

Gradko International Ltd also takes part in the NO_2 Network Field Inter-Comparison Exercise, operated by the National Physical Laboratory (NPL), which complements the AIR-PT 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 (AURN) site. These sites employ continuous chemiluminescent analysers to measure NO_2 concentrations.

The inter-comparison exercise is completed at the Marylebone AURN monitoring station. Of particular interest is the bias of the diffusion tube measurement relative to the automatic analyser that gives an indication of accuracy. Performance criterion have been established for participating laboratories in line with the Air Quality Directive 2008/50/EC requirement for indicative monitoring techniques, as the 95% confidence interval of the annual mean bias which should not exceed ±25%.

In conjunction with this, a measure of precision is determined by comparing the triplicate co-located tube measurements, commonly referred to as the coefficient of variation (CoV). This value is useful for assessing the uncertainty of results due to sampling and analytical techniques. The NPL performance criterion for precision is that the mean coefficient of variation for the full year should not exceed 10%, should this be achieved the precision is given a score of 'good'.

The Field Inter-Comparison Exercise initially generated the bias and precision results for each laboratory on an annual basis. This changed in 2004 to results being reported on a monthly basis. This enables a full year's inter-comparison against the NPL performance criteria to be carried out,

[27] 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

[28] Summary of Laboratory Performance in AIR NO_2 Proficiency Testing Scheme (April 2016 – February 2019), available at https://laqm.defra.gov.uk/diffusion-tubes/qa-qc-framework.html

as shown in Table 4.2. The results below indicate that Gradko International Ltd diffusion tubes are well within the performance targets.

Table 4.2 – Summary of NO_2 Network Field Inter-Comparison Results, 2018

Annual Mean Bias		Precision	
Performance Target	Gradko Annual Mean Bias	Performance Target	Gradko Precision
±25%	+ 6.5%	10%	Good

Gradko International Ltd performs blank exposures that serve as a quality control check on the tube preparation procedure.

Bureau Veritas conducts an 'in-house' co-location study to establish an LWEP bias-adjustment factor based on triplicate NO_2 diffusion tubes located with a continuous analysers across a number of the participating authorities. This is discussed in more detail in Section 8.

5 Overview of Results

5.1 Current Year Results

Table 5.1 presents summary statistics for the 147 qualifying diffusion tube sites operating in the 2018 LWEP Diffusion Tube Network. In 2017 there were 143 qualifying sites, the increase in qualifying sites is partly due to the additional twelve monitoring stations bought into the LWEP study within Hammersmith and Fulham.

Six monitoring sites were omitted from the 2018 results due to having a data capture below 75%, this is a slight increase in comparison to 2017 by one monitoring site. The overall data capture for 2018 from all valid monitoring sites was 97%.

The results for 2018 are summarised below, the concentrations in the following sections are uncorrected for bias:

- The maximum background annual mean concentration was 54.8µg/m³ recorded at the City of London Corporation site CL05;
- The maximum roadside annual mean concentration was 85.7µg/m³ recorded at the Kensington and Chelsea site KC33; and
- A total number of 96 sites exceeded the annual mean air quality objective, of which 98% were roadside monitoring sites.

It should be noted that due to the increase in sample size and changes in overall data capture, it is not possible to make direct comparisons between the 2017 and 2018 datasets. Where comparisons have been made these are provided as additional information points only and should be treated with caution:

- At background sites, the average annual mean NO_2 concentration showed a decrease in comparison to the 2017 concentration (-1.3µg/m³); and an increase in concentrations was observed at the roadside sites (0.9µg/m³); and
- The percentage of sites failing to meet the air quality objective increased by 2% between 2017 and 2018.

Table 5.1 – Summary Statistics for all Qualifying 2018 LWEP Diffusion Tube Monitoring Sites

Site Type	Number of Sites	Annual Mean Concentration Range (µg/m³)	Average Annual Mean Concentration Across all Sites (µg/m³)	Number of AQS Annual Mean Objective Exceedances
Background	34	16.1 – 54.8	31.7	2
Roadside	113	26.9 – 85.7	48.2	82

5.2 Geographical Spread of Nitrogen Dioxide Concentrations

Figure 5.1 and Figure 5.2 present the geographical spread of the annual mean concentrations (uncorrected for bias) for the NO_2 diffusion tube survey across London for 2018. The maps include data only from the local authorities that are part of the London Wide Environment Programme.

It can be seen, as expected, that roadside monitoring locations present higher concentrations of NO_2 compared to background locations across each local authority. Annual mean NO_2 concentrations at roadside sites are predominantly recorded in the 40-60µg/m^3 concentration range, with background concentrations typically under 45µg/m^3.

Figure 5.1 – 2018 Annual Mean Background NO_2 Concentrations (µg/m³)

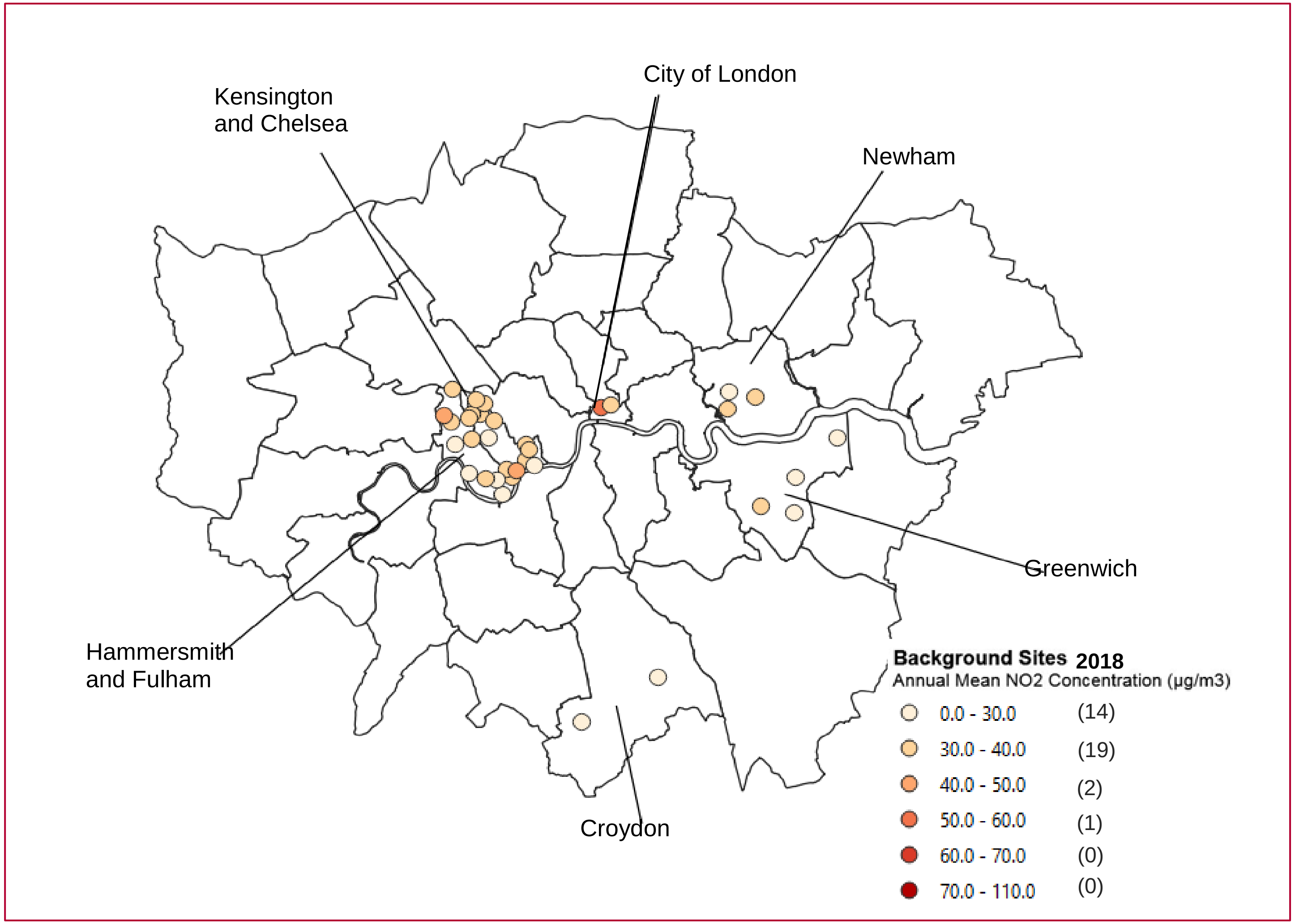
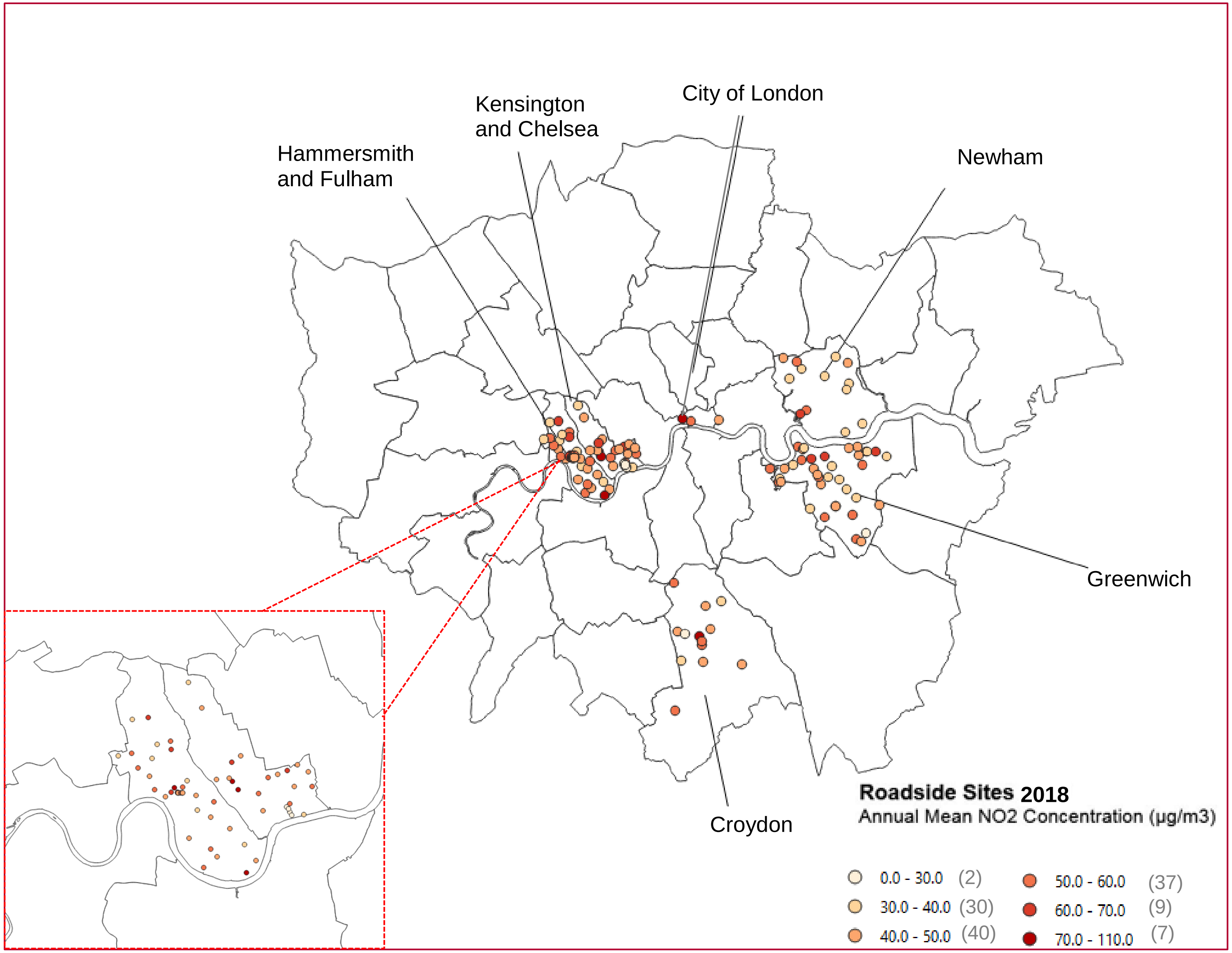


Figure 5.2 – 2018 Annual Mean Roadside NO_2 Concentrations ($\mu g/m^3$)

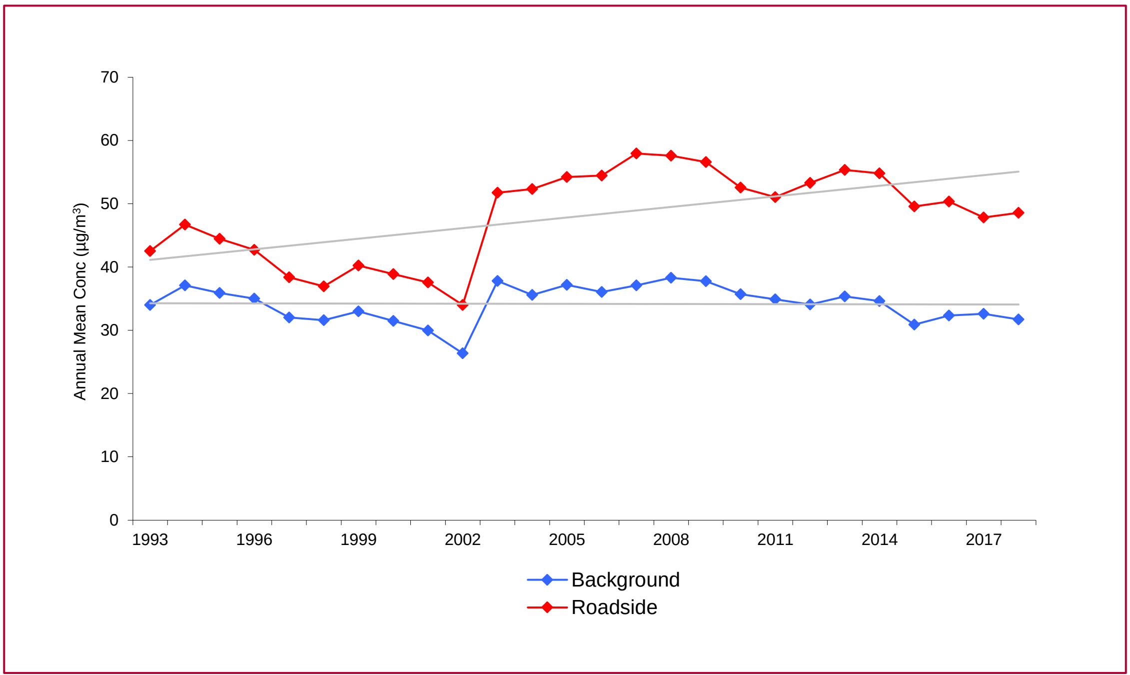


5.3 Long Term Trends

To establish long-term trends, annual mean NO_2 concentrations recorded at both background and roadside sites from 1993 to the 2018 have been utilised. The average of annual mean NO_2 concentrations measured at valid roadside and background sites have been used to analyse the long-term trend. The introduction of the UK Nitrogen Dioxide Diffusion Tube Survey in 1993 and the resultant increase in exposure time of the diffusion tubes from 2 to 4/5 weeks showed an apparent change in long-term concentrations. The extension in exposure period had the effect of decreasing the period average NO_2 concentrations.

In order to strengthen the comparability and representation of long-term trends, data have been collated from diffusion tube sites only from the start of monitoring at site to the present year. Sites were included if there were six or more years continuous data available. This subsequently provides a data set for 2018 comprising of a total of one hundred and fifty nine sites covering both roadside and background locations. Following the application of six years or more continuous data the long-term trend analysis sections are based on data from the ninety eight LWEP sites only.

Figure 5.3 – Long Term Annual Mean NO_2 Concentrations at Selected Background and Roadside Sites in London



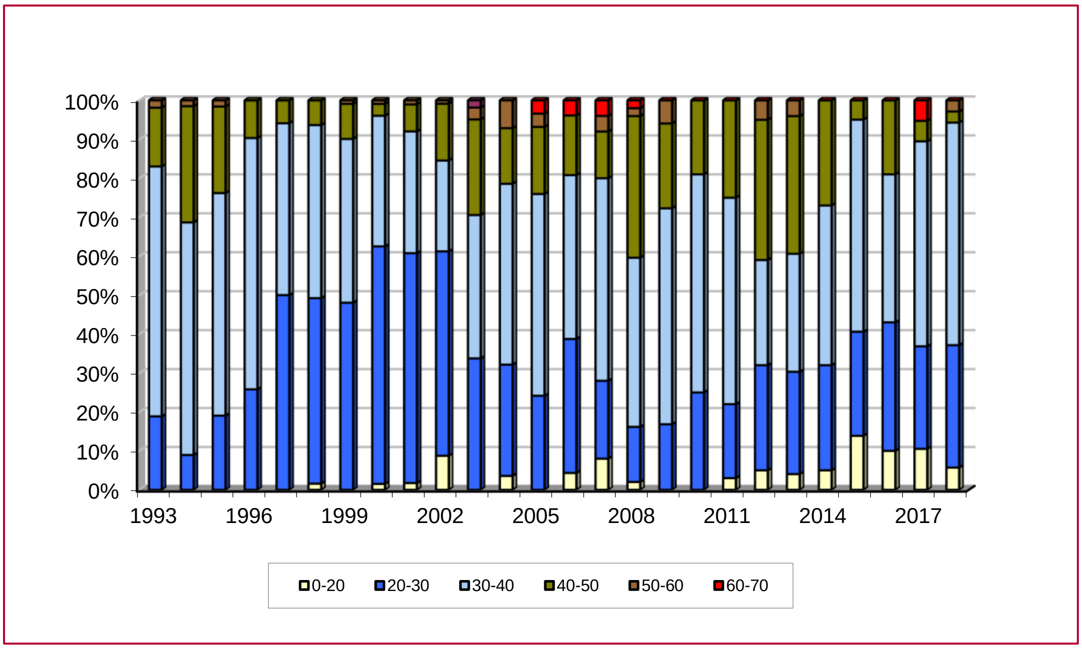
Long-term background and roadside sites follow very similar trends. The long-term trends indicate a gradual decline in annual mean NO_2 concentration between 1993 and 2002. In 2003 a distinct increase in annual NO_2 concentration is recorded at both site types, and was initially attributed to poor meteorological conditions; however, roadside concentrations continued to increase in all subsequent years up to 2007.

Concentrations at both site types have shown a steady decrease from 2007 through to 2011. Background concentrations showed an increase in 2013; however the 2014 and 2015 datasets show a gradual decrease from these concentrations. From 2011 to 2014 roadside sites have shown an increasing trend, with the 2015 concentration showing a decrease close to 2011 concentrations. Both roadside and background sites have shown an increase from 2015 through 2016, but only background increased to 2017 with the roadside reducing between 2016 and 2017. Background continued to decrease in 2018, but after a two year decrease the roadside is showing a slight increase over the past year. In general the concentrations are evenly stable across the past 3 years, but have shown a decline compared to 2011 concentration levels.

5.3.1 Frequency Distribution of Annual Mean NO_2 Concentrations

The frequency distribution of annual mean NO_2 concentrations at 2018 background and roadside sites is shown in Figure 5.4 and Figure 5.5 respectively, and is summarised below each figure.

Figure 5.4 – Frequency Distribution of Annual Mean Background NO_2 Concentrations, 1993-2018



- In the early part of the programme, 1993 to 1996, the largest percentage of annual mean NO_2 concentrations of background sites was observed in the 30-40µg/m³ banding with no sites recording concentrations above 60µg/m³;

- From 1997 to 2001 the largest percentage of annual mean concentrations was in the 20-30µg/m³ banding, with reductions of the 30-40µg/m³ banding during this period

- In 2002, lower NO_2 concentrations increased in frequency with the 0-20µg/m³ band recording its highest percentage since monitoring began in 1993. 2002 was the last year where there were no concentrations above 60µg/m³;

- In 2003 concentrations increased with 46% of sites being in the 30-40µg/m³ banding and the inclusion of a new band, 60-70µg/m³; Between 2004 and 2006 concentrations declined with increases in the 20-30µg/m³ banding;

- In 2007, 2008 and 2009 concentrations once again increased with growth in the higher bandings and concentrations in the 40-50µg/m³ banding were experienced;

- During 2010 and 2011, the percentage of sites in the upper banding of 40-50µg/m³ remained relatively stable. There was no re-occurrence of the 50-60µg/m³ banding and growth was seen in the 30-40µg/m³ banding;

- The results for 2012 and 2013 are very similar, with re-occurrence of the 50-60µg/m^3 banding. The number of sites in the bandings 20-30µg/m^3 , 30-40µg/m^3 and 40-50µg/m^3 have remained similar within these years;

- In 2014 the lower bandings 0-20µg/m^3 and 20-30µg/m^3 remain similar to the previous two years. The concentrations in the 30-40µg/m^3 banding increase, with no sites in the upper two bandings;

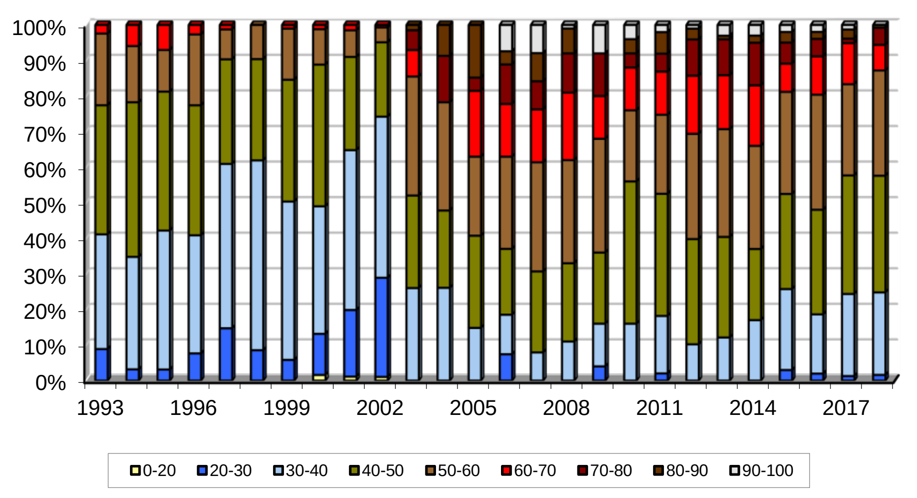
- The results for 2015 show an increase in the 0-20µg/m^3 and 30-40µg/m^3 bandings, the 20-30µg/m^3 banding remains similar and there is a reduction in the 40-50µg/m^3 banding. There were no sites within the upper two bandings;

- Compared to 2015 the 2016 distribution shows an increase in the 20-30µg/m^3 and 40-50µg/m^3 bandings, and a decrease in the 0-20µg/m^3 and 30-40µg/m^3 bandings. As per 2014 and 2015 there were no sites within the upper two bandings; and

- Within 2017, for the first time since 2008 there was a background site with a concentration above 60µg/m^3. When compared to 2016 there was an increase in the 0-20µg/m^3 and 30-40µg/m^3 bandings, and a decrease in the 20-30µg/m^3 and 40-50µg/m^3 bandings. Overall, for the first four concentration bandings, the 2017 concentrations are similar to concentrations in 2015.

- In 2018, the background results shows a similarity to recent years where a high majority of the results are within the lower bands of 20-30µg/m^3 and 30-40µg/m^3. There was a reduction in the number of results between 40-50µg/m^3 and 50-60µg/m^3 during 2018, and there were no concentrations in excess of 60µg/m^3.

Figure 5.5 – Frequency Distribution of Annual Mean Roadside NO_2 Concentrations, 1993-2018



- Between 1993 and 1996, the highest percentages of annual mean NO_2 concentrations at roadside sites were present in the 40-50µg/m^3 concentration banding. With similar percentages of sites in the 50-60µg/m^3 and 60-70µg/m^3 bandings;

- In 1997 through to 2000, the NO_2 concentration at all roadside sites was between 20µg/m^3 and 70µg/m^3, with around 50% of sites in the 30-40µg/m^3 band;

- A small percentage of sites recorded concentrations in the higher banding categories in 2001 and 2002, leading to a reduction in the percentage of sites in the 40-50µg/m³ banding The 2002 period saw the highest percentage of sites in the 20-30µg/m³ banding, the peak of an increasing trend since 2000;

- From 2003 through to 2007, the number of sites in the higher concentration banding continued to increase, with the 20-30µg/m³ and 30-40µg/m³ bandings decreasing. Also during this period the over 100µg/m³ banding first appeared and steadily increased in frequency to a peak in 2007 to 8% of sites;

- From 2007 onwards the percentage of sites in the higher bands (70µg/m³ and above) has remained relatively stable. The 50-60µg/m³ band has shown year on year reductions as the 40-50µg/m³ and 30-40µg/m³ bands have steadily increased in frequency;

- Concentrations from 2012 until 2014 were similar, with no sites in the lower two bands, the majority of sites between 40-60µg/m³ bandings and a small number of sites in the upper three bands;

- The results from 2015 compared to 2014 showed a decrease in three of the top four bandings, and an increase in the 20-30µg/m³, 30-40µg/m³ and 40-50µg/m³ bandings. The 50-60µg/m³ banding has remained relatively consistent for the past four years;

- In 2016 the 20-30µg/m³ and 30-40µg/m³ bandings have decreased, 40-50µg/m³ has remained constant and the 50-60µg/m³ banding has increased. Similar to 2015 20% of the values are within the top four bandings with a higher percentage within the 60-70µg/m³ during 2016; and

- Comparing 2017 with 2016 there was a reduction overall in the top three bands up to 100µg/m³. An increase was experienced in the 30-40µg/m³ and 40-50µg/m³ bands with a reduction in the 50-60µg/m³ band.

- During 2018 there is a slight reduction in the 60-70µg/m³ band with a subsequent slight increase in the 50-60µg/m³ band. Both the 30-40µg/m³ and 40-50µg/m³ continue to remain relatively constant in comparison to recent years.

6 Data Analysis

6.1 Introduction

Prior to analysing the results for 2018 for each borough, the entire year's data set, for each authority was validated for outliers and spurious results. Two screening procedures where adopted for this task:

- Monthly mean NO_2 concentrations recording under 5µg/m^3 were removed
- Any results where insects were found in the diffusion tubes were removed; and
- Only diffusion tube sites with at least nine months of validated monitoring data were then used for further analysis and reporting. To be considered valid, the exposure period must also follow the Suggested Exposure Period calendar dates[29].

The data reported in Section 7 for each participating local authority is uncorrected for bias.

6.2 Data Analysis

2018 Mean Values

Bar charts have been produced showing the 2018 annual mean NO_2 concentration recorded at each site included in the LWEP survey. The sites were classified by the local authorities based on distance from the nearest major road into background or roadside types.

Appendix A lists NO_2 concentration for all roadside and background sites in each local authority. Sites that have exceeded the 40µg/m^3 air quality objective have been highlighted. Data capture is calculated across all qualifying sites for each borough.

Site Time Series

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

Percentage change over the monitoring period has been calculated using the following method:

- Average annual mean from current year, minus the average annual mean from the comparison year. The answer is then divided by the average annual mean from the comparison year.

6.3 Further Analysis of Results

Trend Analysis by Site Class

Monitoring sites with a minimum of six 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 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 since 1997 within each borough.

Where there has been a percentage change over the 1997 to 2018 monitoring period, this has been calculated using the method as stated above. Where a percentage change has been calculated

[29] Diffusion tubes 2019 calendar, available at: https://laqm.defra.gov.uk/diffusion-tubes/data-entry.html

between 2017 and 2018 all sites with data capture above 75% have been included, regardless of them having six years continuous monitoring data.

Roadside Elevation

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

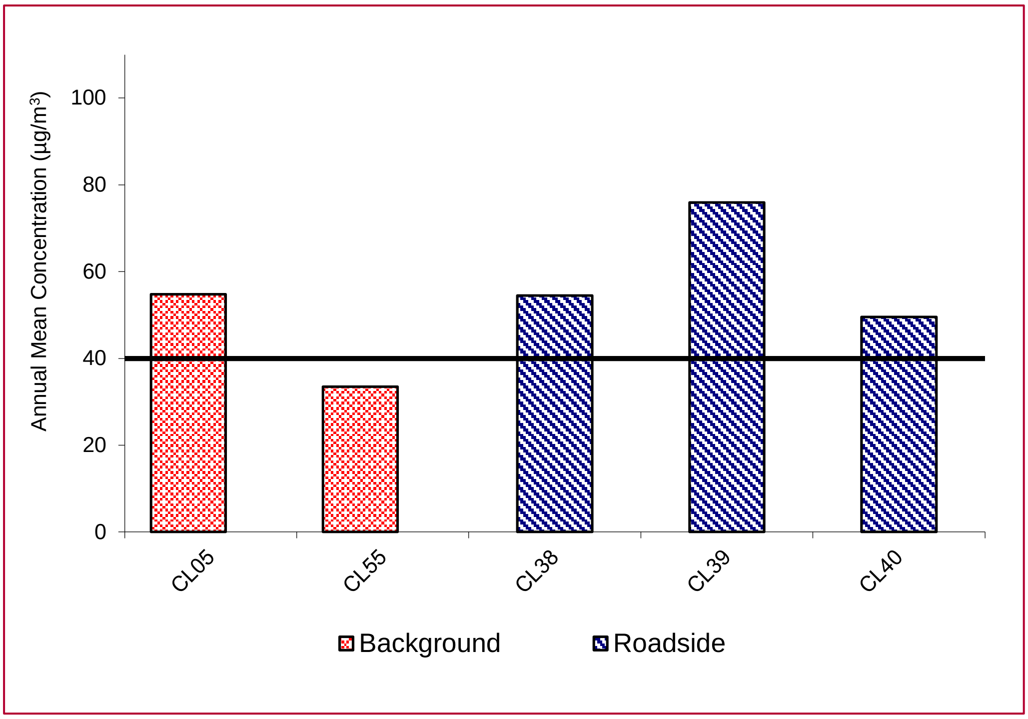
Diffusion tube sites were only included in the calculation of annual mean concentrations for each site class (roadside or background) if consistent and valid data was available. Sites with six or more valid years of data were used.

7 Reporting of Results – Participating Boroughs

7.1 City of London Corporation

Annual Mean Values

Figure 7.1 – City of London Corporation Background and Roadside Annual Mean NO_2 Concentrations, 2018



The City of London Corporation exposed diffusion tubes at five monitoring locations during 2018. Four out of the five sets have been monitoring since 1994/95, and the fifth site (CL40) was added in 2008. All five sites qualified for inclusion within the LWEP results, the overall data capture for 2018 was 95%, which was an increase from 2017 where only 92% of data was recorded.

In 2018 background concentrations were recorded as 54.8µg/m^3 (CL05) and 33.5µg/m^3 (CL55), the annual mean concentration recorded at site CL05 for 2018 has shown a slight decline compared to the 2017 concentration, but is the second highest recorded since monitoring began at this location. Roadside concentrations ranged between 49.6µg/m^3 (CL40) and 75.9µg/m^3 (CL39). The annual mean AQS objective was exceeded at four out the five monitoring locations, this is the same number of site exceedances as was experienced in 2016 and 2017.

Time Series

Figure 7.2 – City of London Corporation Background Time Series, 1997-2018

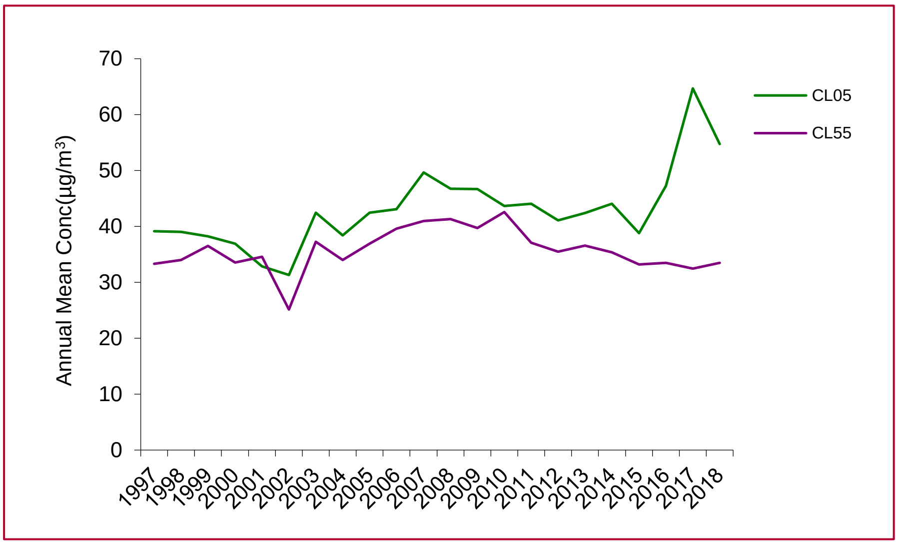


Figure 7.2 above presents the annual mean concentrations at the two background monitoring locations with six years of continuous data. Both sites show a similar trend between 1997 and 2015 albeit with CL05 consistently having a higher concentration. A large increase was experienced at CL05 from 2015 and there have been a number of differing trends throughout the monitoring period to date:

- 1997 to 2002 is a period of decline for both locations with the lowest annual mean concentrations for the entire monitoring period experienced in 2002;
- 2003 to 2007 is a period of increase for both locations where a plateau is reached in 2007; and
- 2008 to 2017 is slightly different for the two sites. CL55 has experienced a downward trend during this period, aside from an increased spike in 2010. CL05 experienced a downward trend between 2007 and 2015, but from 2015 to 2017 there has been a sharp rise in annual mean concentration with the 2017 value the highest recorded since the monitoring began.
- In 2018, CL55 continues to show a gradual decline in concentration, whilst CL05 is showing a decrease after experiencing the highest concentration record at the location in 2017. The concentration remains far higher than pre 2015 concentrations and continues to present a different trend to CL55.

A comparison between the annual mean concentrations monitored at the two background sites between 2017 and 2018 shows that there has been an average decrease in the NO_2 annual mean concentrations of 9.2%. As well as a 4.1% in the NO_2 annual mean concentration for roadside sites.

Figure 7.3 – City of London Corporation Roadside Time Series, 1997-2018

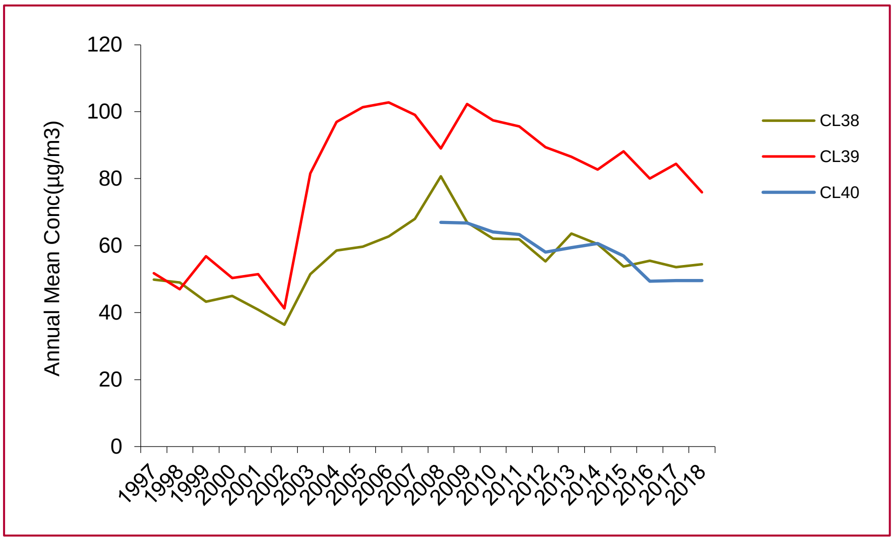


Figure 7.2 above presents the annual mean concentrations at the three roadside monitoring locations with six years of continuous data. Two of the monitoring sites, CL38 and CL39, have been collecting data since 1997, and CL40 has been collecting data since 2008. From the concentrations recorded in the initial years of monitoring, there have been significant changes throughout the monitoring period:

- 1997 to 2002 is a period of overall decline for both CL38 and CL39, but there are fluctuations of increases and decreases within this period. The lowest annual mean concentrations for the entire monitoring period are then experienced in 2002, much the same as for the background locations;

- 2003 to 2007 is a period of increase for both locations, with a steep increase experienced initially, and especially for CL39 which recorded its highest concentration throughout the monitoring period of 103µg/m^3 in 2006;

- 2008 to 2017 presents an overall downward trend for CL38 and CL39 but there are a number of increases and decreases during this period. In contrast, during 2008 CL38 recorded its highest concentration of the monitoring period (81µg/m^3) whilst CL39 experienced a sharp decrease followed by an increase in 2009; and

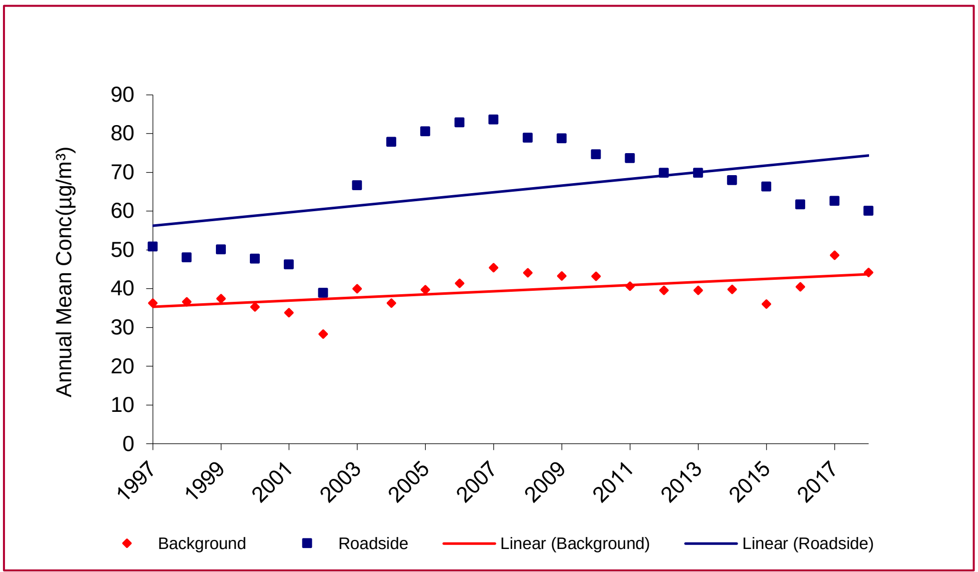
- Between 2008 and 2011, the concentration at CL40 remained relatively constant with a range of 3.7µg/m^3. Following this there was a decrease experienced between 2011 and 2012, after which there again was a period of consistency between 2012 and 2015. There was reduction in concentration between 2015 and 2016, and the concentrations in 2016 and 2017 have been very similar.

- The concentrations for CL39 and CL40 have remained comparable for the previous three years. CL38 is presents a fluctuation in trend year on year, but shows an overall decline in concentration compared to 2010 levels.

A comparison between the annual mean concentrations monitored at the three roadside sites between 2017 and 2018 shows that there has been an average decrease in the NO_2 annual mean concentrations of 4.1%.

Trend Analysis

Figure 7.4 – City of London Corporation Background and Roadside Trend Analysis, 1997-2018



Background annual mean NO_2 concentrations display an overall positive trend between 1997 and 2018 of 21.8%. This is a reduction in the positive trend presented in 2017 between 1996 and 2017, but still an increase compared to 2016 average, the high concentration recorded at CL05 during 2018 has influenced this increase in trend.

The roadside annual mean NO_2 concentrations also shows a positive trend relating to the same period of 18.1%, which is a decline from 23.0% in the 2017 report.

Roadside Elevation

Table 7.1 – City of London Corporation Roadside Elevation above Background NO_2 Concentration ($\mu g/m^3$)

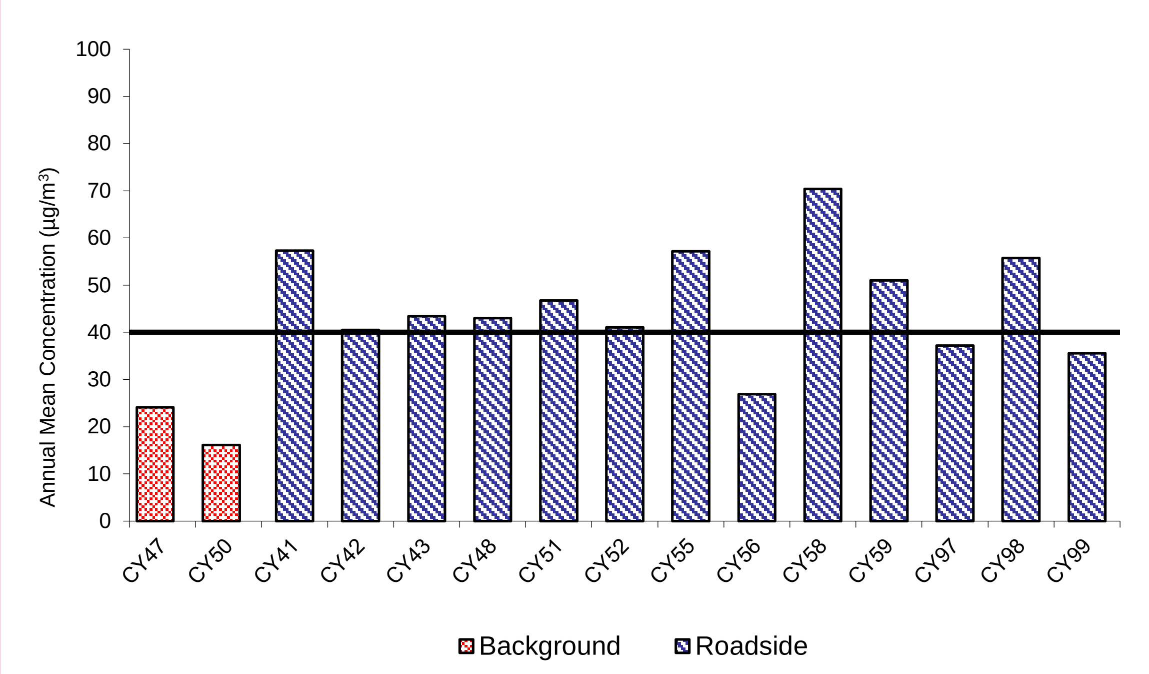
2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
26.7	41.5	40.8	41.4	38.2	34.8	35.4	31.4	33.0	30.3	30.4	28.2	30.3	21.2	13.9	15.9

The roadside elevation has fluctuated over the monitoring period, with the highest elevated observed between 2004 and 2007. Following this elevated period there has been an overall decrease in the roadside elevation between 2007 and 2014. There has been a sharp overall decrease experienced from 2015 to 2017 followed by an increase between 2017 and 2018, the 2018 elevation increased to 15.9 in comparison to 13.9 in 2017.

7.2 London Borough of Croydon

Annual Mean Values

Figure 7.5 – Croydon Background and Roadside Annual Mean NO_2 Concentrations, 2018



The London Borough of Croydon exposed diffusion tubes at sixteen locations during 2018, the same number as during 2017. One site (CY46) had a data capture of less than 75%, therefore this site was not included within the data analysis. All other sites had a data capture greater than 75%, and the overall data capture for the fifteen sites included within the data analysis in 2018 was 98%.

In 2018, background concentrations were recorded as 16.1µg/m³ (CY50) and 24.1µg/m³ (CY47). Roadside concentrations ranged between 29.6µg/m³ (CL56) and 70µg/m³ (CL58). The annual mean AQS objective was exceeded at ten out the fifteen qualifying monitoring locations, which is the same number of exceedance sites when compared to 2017.

Time Series

Figure 7.6 – Croydon Background Time Series, 1997-2018

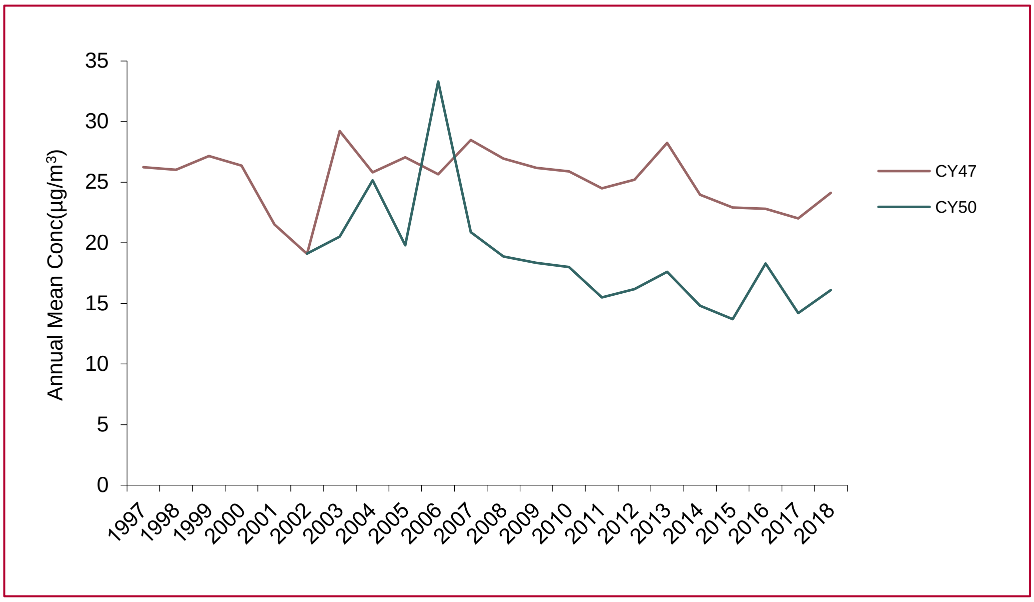


Figure 7.6 above presents the annual mean concentrations at the two qualifying background monitoring locations with at least six years of continuous data. Both sites show an overall downward trend since their inceptions, CY47 has reported a higher concentration in all years where both monitoring sites have been active apart from in 2006. There have been a number of differing trends throughout the monitoring period to date:

- From 1997 to 2001 only CY47 was monitoring, there was a large reduction in concentration experienced during this period;
- Monitoring commenced at CY50 in 2002. From 2002 to 2007 an overall increase in concentration was experienced at CY47 with the highest concentration of the monitoring period recorded in 2003 (29.3µg/m³). The concentration at CY50 is extremely varied within this period with many increases and decreases experienced, overall the concentration in 2002 (19.1µg/m³) is comparable to the concentration in 2007 (20.9µg/m³); and
- 2008 to 2017 presents an overall downward trend at both monitoring locations. There are a few peaks experienced within this period, at both sites in 2013 and at CY50 in 2016. The concentration for both locations is lower in 2017 than it was in the first year of completed monitoring.
- In 2018, an increase in concentrations were recorded at both background sites in comparison to 2017, but their concentrations are still well below the AQS annual mean objective of 40µg/m³.

A comparison between the annual mean concentrations monitored at the two background sites between 2017 and 2018 shows that there has been an average increase in the NO_2 annual mean concentration of 11.1%.

Figure 7.7 – Croydon Roadside Time Series, 1997-2018

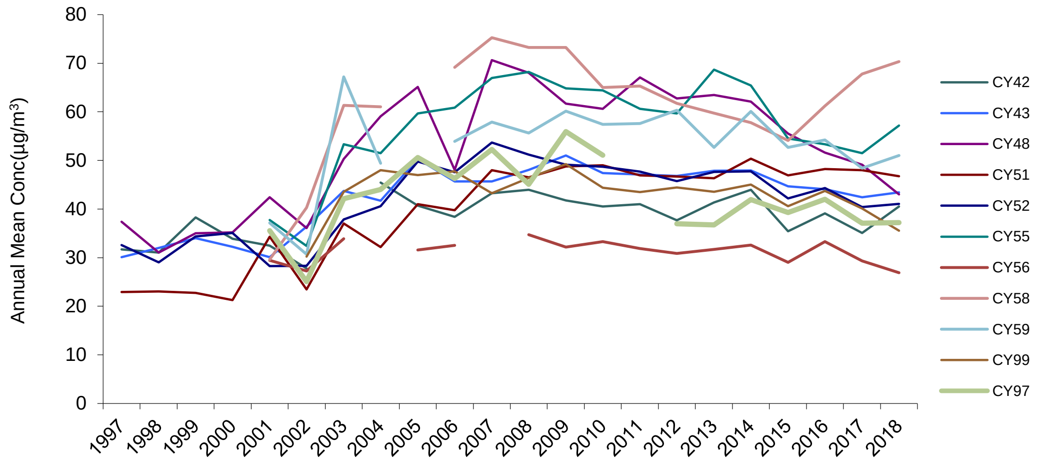


Figure 7.7 above presents the annual mean concentrations at the roadside monitoring locations with six years of continuous data. Five of the qualifying monitoring sites have been monitoring since 1997, and a further six of the qualifying monitoring sites began monitoring in 2001. From the initial concentrations recorded, to the 2018 monitored concentrations, there have been significant changes throughout the monitoring period:

- 1997 to 2001 is a period of overall slight decrease for all five locations that were monitoring from 1997;

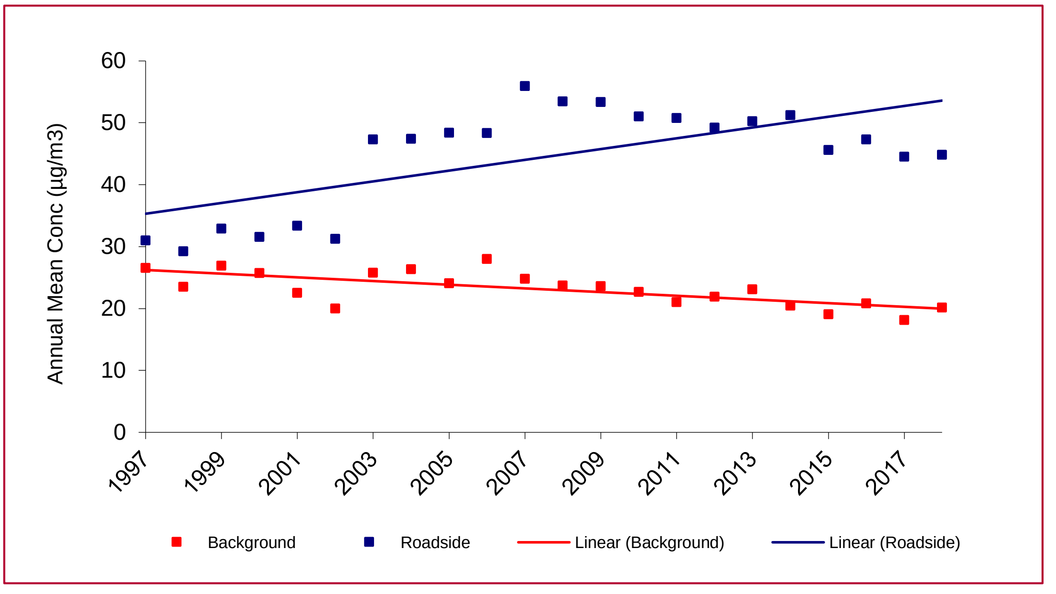
- 2002 to 2009 is a period of overall increase for all locations, with a number of the highest concentrations experienced for individual locations during 2008 and 2009. Within this period there is also a noticeable decrease in the concentrations during 2006 for a number of the locations. This decrease is only apparent during 2006 and concentrations increased again during 2007; and

- 2010 to 2018 presents an initial period of decrease between 2010 and 2015, this is followed by an increase between 2015 and 2018 for all of the sites except for CY41, CY42 and CY58 that have experienced an overall decrease.

A comparison between the annual mean concentrations monitored at the roadside sites between 2017 and 2018 shows that there has been an average increase in the NO_2 annual mean concentrations of 0.8%.

Trend Analysis

Figure 7.8 – Croydon Background and Roadside Trend Analysis, 1997-2018



Long-term background annual mean NO_2 concentrations display an overall negative trend from 1997 through to 2018, with the percentage decrease being 24.2%. Long-term roadside annual mean NO_2 concentrations display a high positive trend between 1997 and 2018 of 44.8%.

Roadside Elevation

Table 7.2 – Croydon Roadside Elevation above Background NO_2 Concentration (µg/m^3)

2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
21.5	21.1	24.3	20.4	31.1	29.8	29.7	28.3	29.7	27.3	27.1	30.8	26.5	26.5	27.1	24.7

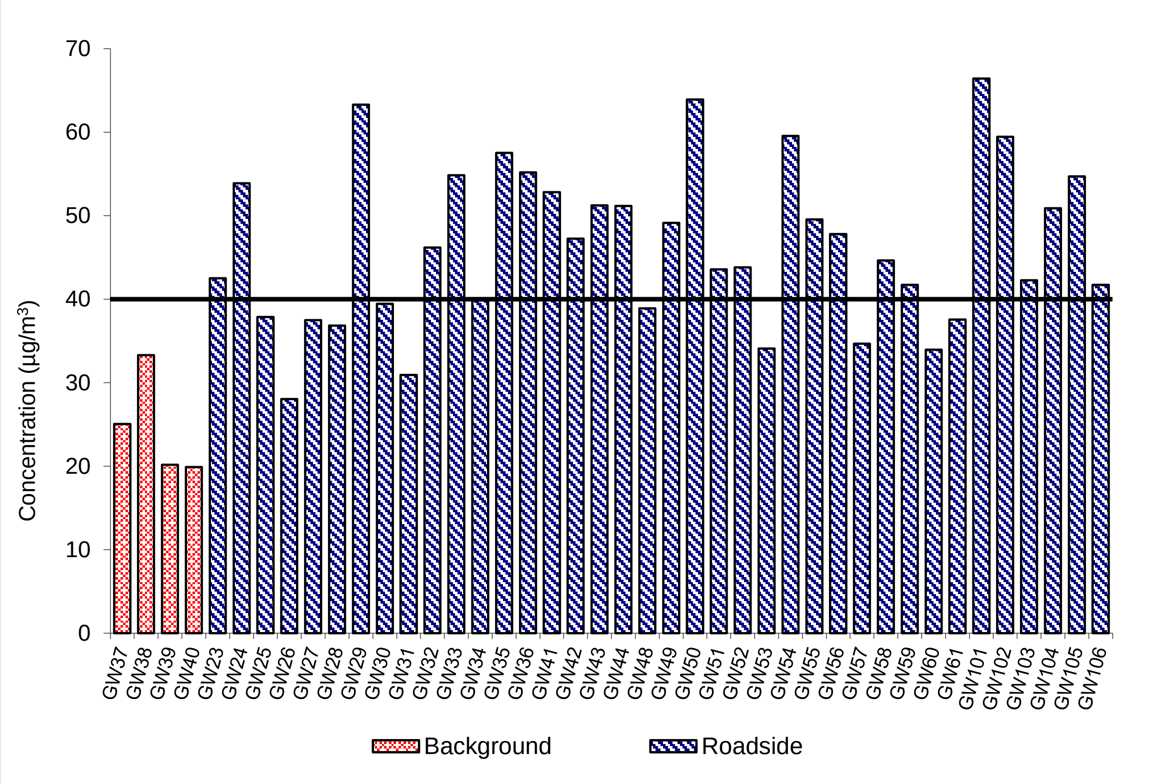
The roadside elevation above background concentrations has fluctuated between 2003 and 2018, with a minimum elevation of 21.1µg/m^3 in 2004 and a maximum elevation of 31.1µg/m^3 in 2007.The elevation was relatively stable between 2004 and 2006 followed by a significant increase between 2006 and 2007, after which the elevation remained relatively stable.

A reduction in the recorded elevation was experienced between 2012 and 2013 followed by an increase in 2014, this raised elevations similar to 2007 results. There was a reduction from 2014 to 2016 and then a slight increase experienced in 2017. In 2018 a reduction has been experienced and the value has fallen to its lowest since 2005.

7.3 Royal Borough of Greenwich

Annual Mean Values

Figure 7.9 – Greenwich Background and Roadside Annual Mean NO_2 Concentrations, 2018



The Royal Borough of Greenwich exposed diffusion tubes at forty two locations during 2018, the same number as during 2017. All monitoring sites had a data capture greater than 75% therefore met the quality criteria, and the overall data capture for the forty two sites was 98%.

In 2018, background concentrations ranged between 19.9µg/m³ (GW40) and 33.8µg/m³ (GW38). Roadside concentrations ranged between 28µg/m³ (GW26) and 66.4µg/m³ (GW101). The annual mean AQS objective was exceeded at twenty six out the forty two monitoring locations, these were all roadside monitoring sites. The twenty six exceedances is a reduction of one site when compared to 2017.

Time Series

Figure 7.10 – Greenwich Background Time Series, 1997-2018

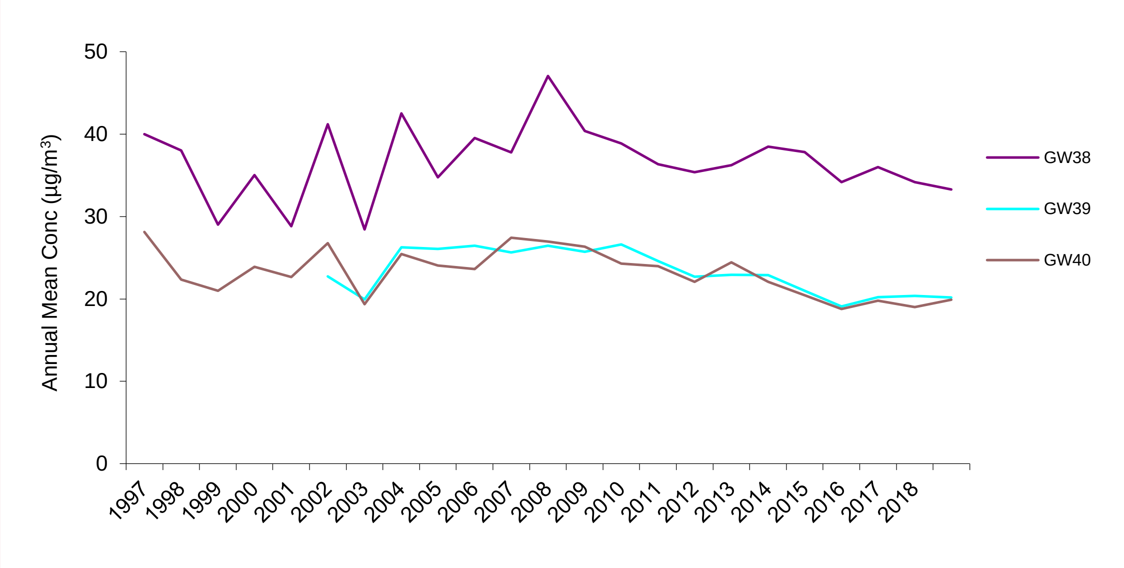


Figure 7.10 above presents the annual mean concentrations at the three background monitoring locations with six years of continuous data. GW38 and GW40 have monitoring data from 1997 whereas GW39 began monitoring in 2001. All sites show an overall downward trend since their inceptions. GW38 clearly shows higher concentrations when compared to GW39 and GW40 throughout the entire monitoring period. There have been a number of differing trends throughout the monitoring period to date:

- 1997 to 2001 presents a varied trend for both GW38 and GW40, there are distinct periods of increases and decreases in concentration;
- 2002 to 2007 again provided varied results for GW38 and a more gradual increase for both GW39 and GW40. The peak concentrations recorded for all three locations was recorded in either 2006 or 2007; and
- 2008 to 2018 presents an overall downward trend at all three monitoring locations. There are a few less prominent peaks experienced within this period, but an overall downward trend is apparent. The concentration for all three locations is lower in 2018 than it was in the first year of completed monitoring.

A comparison between the annual mean concentrations monitored at the background sites between 2017 and 2018 shows that there has been an average reduction in the NO_2 annual mean concentration of 0.3%.

Figure 7.11 – Greenwich Roadside Time Series, 1997-2018

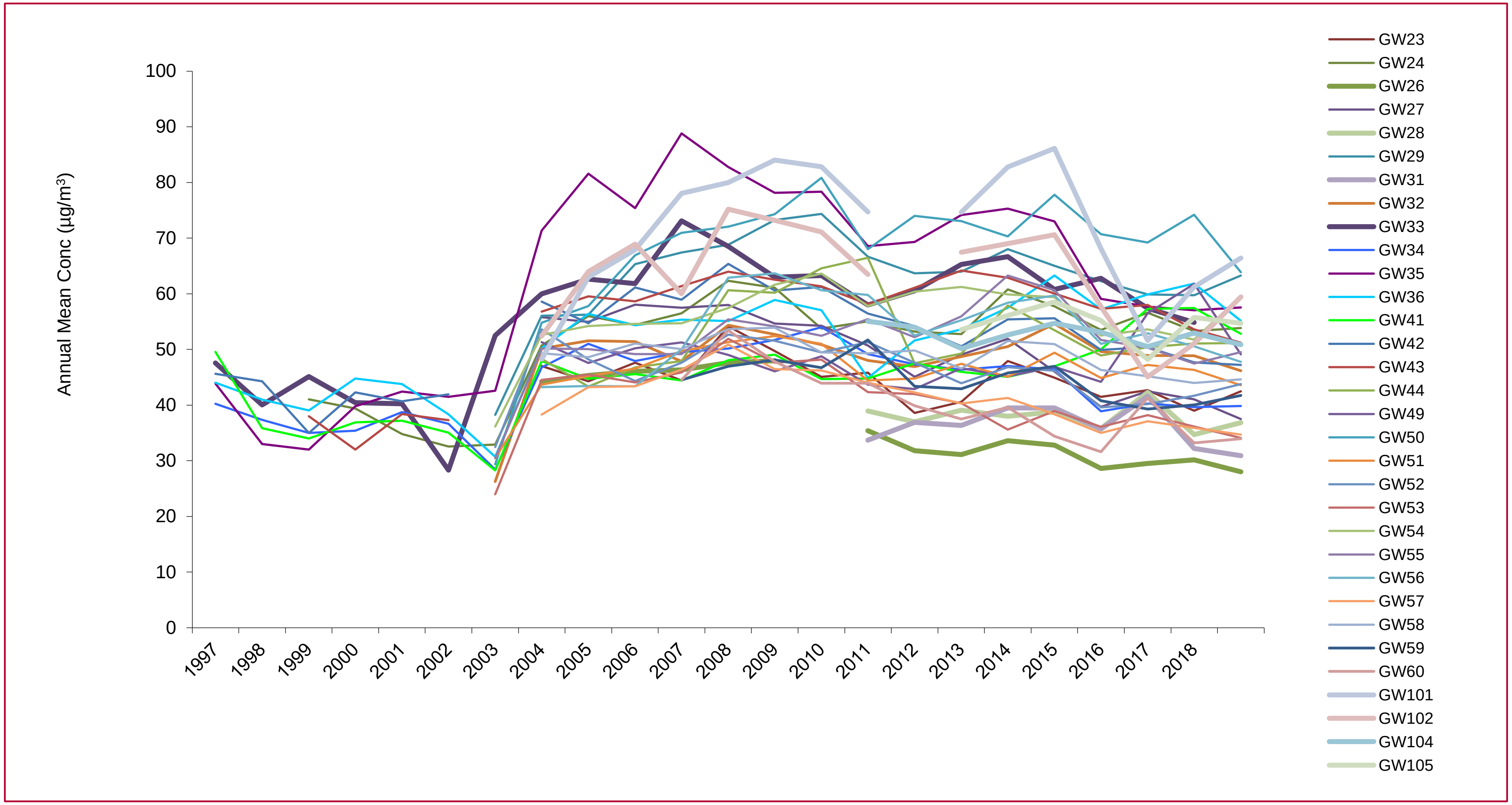


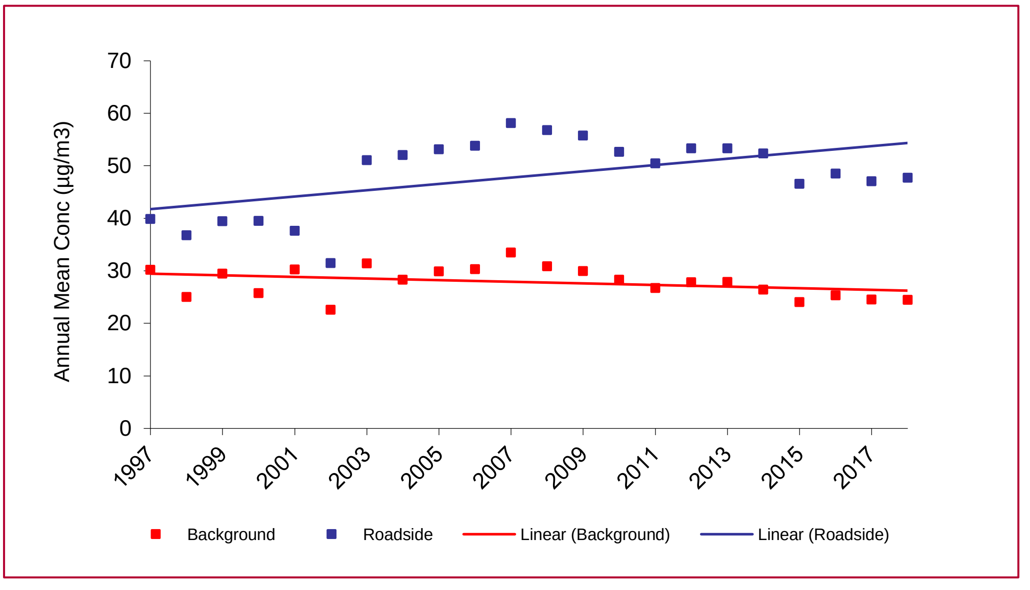
Figure 7.11 above presents the annual mean concentrations at the roadside monitoring locations with six years of continuous data. Six of the qualifying monitoring sites have been monitoring since 1997, one site began monitoring in 1998, eight further sites began monitoring in 2002, and five began monitoring in 2003. From the initial concentrations recorded, to the 2018 monitored concentrations, there have been significant changes throughout the monitoring period:

- 1997 to 2002 is a period of overall decrease for all monitoring locations that were in operation during this time, with the concentrations recorded in 2002 being the lowest for many of the monitoring sites across the entire monitoring period;
- 2003 to 2010 is a period of both increase and decrease, overall increase between 2003 and 2007 and followed by decrease between 2008 and 2010; and
- 2011 to 2018 presents an initial period of increase between 2011 and 2014, with a number of locations their highest concentration during the entire period in 2014. This is followed by a period of overall decrease between 2015 and 2018 across the majority of the locations.

A comparison between the annual mean concentrations monitored at the roadside sites between 2017 and 2018 shows that there has been an average increase in the NO_2 annual mean concentrations of 1.4%.

Trend Analysis

Figure 7.12 – Greenwich Background and Roadside Trend Analysis, 1997-2018



Long-term background annual mean NO_2 concentrations display an overall negative trend from 1997 through to 2018, with a percentage decrease of 19%. Conversely the long-term roadside annual mean NO_2 concentrations display a positive trend between 1997 and 2017 of 19.7%.

Roadside Elevation

Table 7.3 – Greenwich Roadside Elevation above Background NO_2 Concentration (µg/m^3)

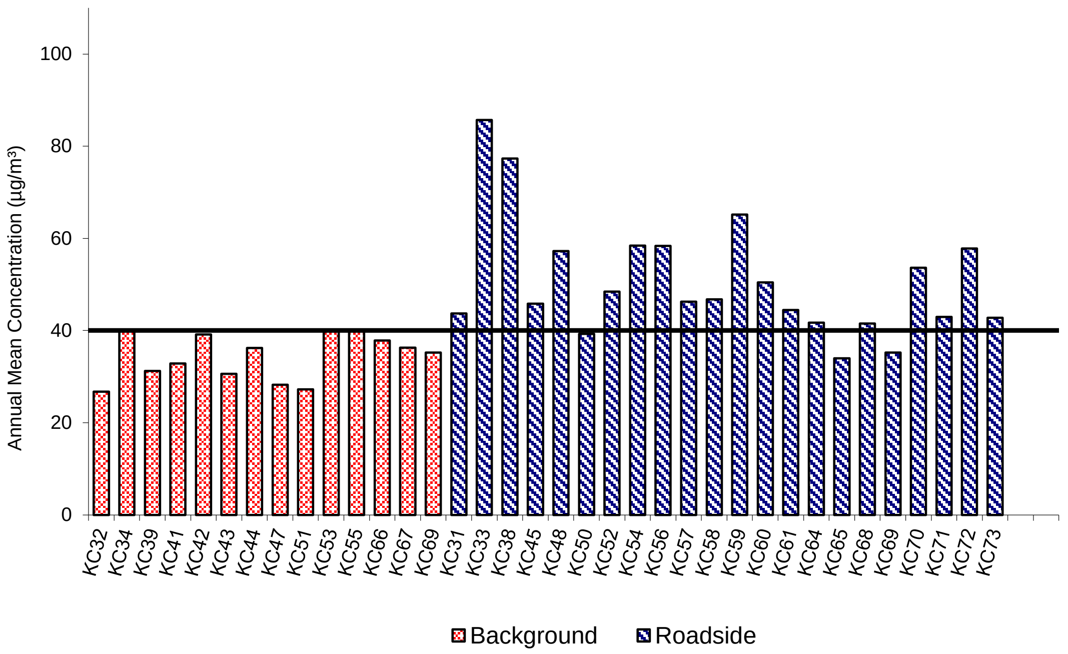
2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
19.6	23.8	23.3	23.5	24.6	26.0	27.2	23.3	23.7	23.0	25.5	25.9	22.5	23.2	22.5	23.3

The roadside elevation above background NO_2 concentration has not varied significantly between 2003 and 2018. The elevation has remained around 23µg/m^3 throughout the monitoring with the range between the highest and lowest value being 7.6µg/m^3 over the period.

7.4 Royal Borough of Kensington and Chelsea

Annual Mean Values

Figure 7.13 – Kensington and Chelsea Background and Roadside Annual Mean NO_2 Concentrations, 2018



The Royal Borough of Kensington and Chelsea exposed diffusion tubes at thirty eight locations during 2018, an increase of four monitoring sites compared to 2017. There were three sites (KC35, KC40 and KC49) that had a data capture of less than 75%, these sites were omitted from the data analysis. All other monitoring sites had a data capture greater than 75% therefore met the quality criteria, and the overall data capture for the thirty one sites was 97%.

In 2018, background concentrations ranged between 26.8µg/m³ (KC32) and 40µg/m³ (KC53). Roadside concentrations ranged between 34µg/m³ (KC65) and 85.7µg/m³ (KC33). The annual mean AQS objective was exceeded at five of the qualifying background monitoring sites and sixteen of the qualifying roadside sites. A total of twenty two monitoring locations exceeded the annual mean AQS objective, this is an increase of one site when compared to 2017.

Times Series

Figure 7.14 – Kensington and Chelsea Background Time Series, 1997-2018

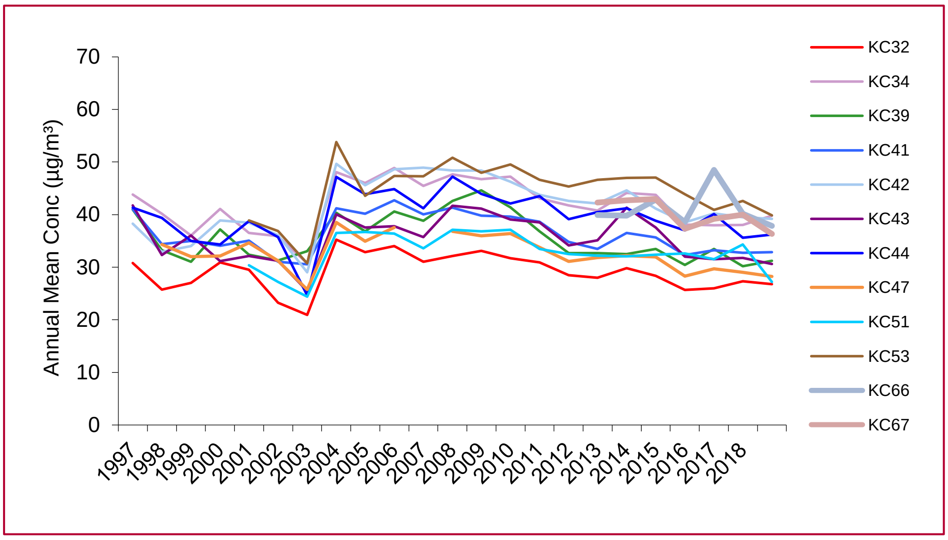


Figure 7.14 above presents the annual mean concentrations at the background monitoring locations with six years of continuous data. Eight sites have monitoring data from 1997, a further two sites were added in 2000 and another site in 2012. Throughout the entire monitoring period there have been a number of differing trends throughout the monitoring period to date:

- 1997 to 1999 presents a varied trend for the monitoring sites with both increases and decreases in concentration experienced across the different locations. Six locations were in exceedance of the AQS annual mean objective in 1996, this reduced to two sites in 1999;
- 2000 to 2005 again provided varied results with an overall decrease in concentrations between 2000 to 2004 followed by an increase in 2005 when a number of locations recorded their highest concentrations of the entire monitoring period;
- 2006 to 2011 produced a gradual decrease in concentrations at all monitoring sites except one (KC40). During this period there were a number of slight increases within certain years but the overall trend was a downward one; and
- The concentrations experienced between 2012 and 2018 remain relatively consistent for the tubes that have been monitoring previous to 2012. The two sites that began monitoring in 2012 remain relatively constant and both shows a decline over 2018.

A comparison between the annual mean concentrations monitored at the background sites between 2017 and 2018 shows that there has been a reduction in the NO_2 annual mean concentration of 2.9%.

Figure 7.15 – Kensington and Chelsea Roadside Time Series, 1997-2018

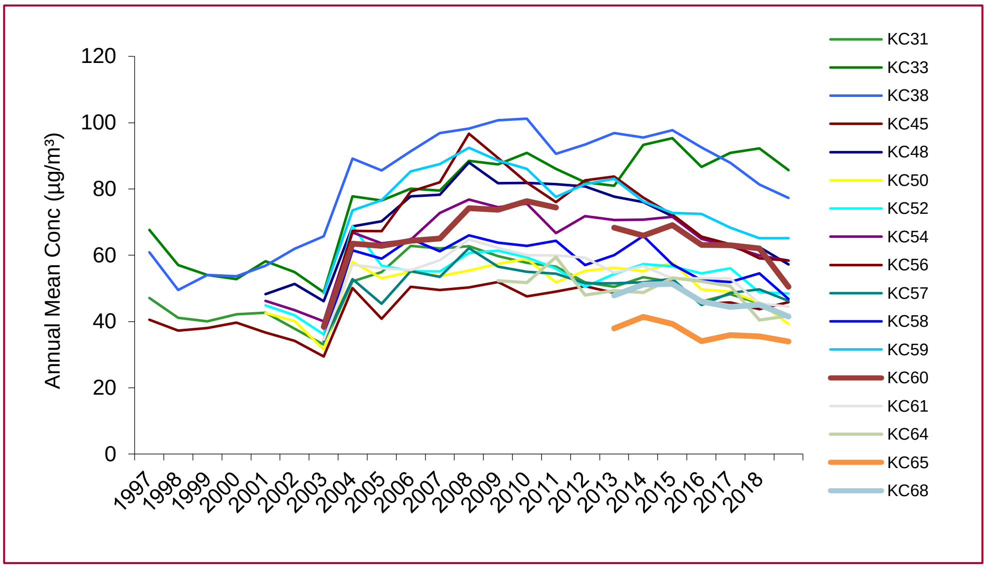


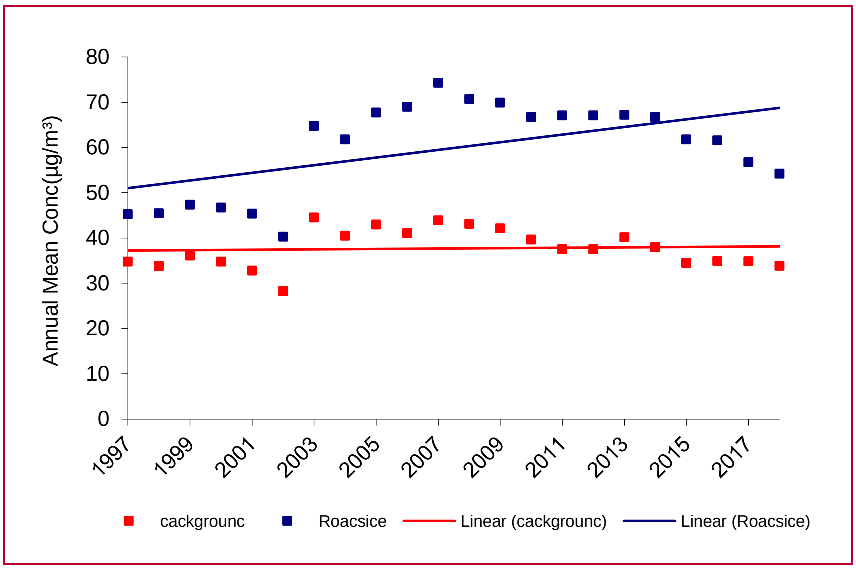
Figure 7.15 above presents the annual mean concentrations at the roadside monitoring locations with six years of continuous data. Five of the qualifying monitoring sites have been monitoring since 1997, four further sites began monitoring in 2000, six further sites began monitoring in 2002, one site began monitoring in 2008, and two began monitoring in 2012. From the initial concentrations recorded, to the 2018 monitored concentrations, there have been significant changes throughout the monitoring period:

- 1997 to 1999 is a period of overall decrease for all monitoring locations that were in operation during this time;
- 2000 to 2008 is a period of overall increase for all monitoring locations that were in operation during this time with many of the monitoring sites recording their highest values from the entire monitoring period within 2007 or 2008;
- 2009 to 2011 presents a period across all monitoring locations except for KC45 and KC59 where an slight increase in concentration was experienced; and
- 2012 to 2018 presents a varied trend across the monitoring locations. Thirteen locations experienced a decrease in concentration, but there was an increase in the number of annual mean exceedances from twenty to twenty-one sites.

A comparison between the annual mean concentrations monitored at the roadside sites between 2017 and 2018 shows that there has been a decrease in the NO_2 annual mean concentrations of 4.5%.

Trend Analysis

Figure 7.16 – Kensington and Chelsea Background and Roadside Trend Analysis, 1997-2018



Long-term background annual mean NO_2 concentrations display an overall slightly negative trend from 1997 through to 2017, with the percentage decrease being 2.7%. Long-term roadside annual mean NO_2 concentrations display a positive trend between 1997 and 2017 of 19.9%.

Roadside Elevation

Table 7.4 – Kensington and Chelsea Roadside Elevation above Background NO_2 Concentration (µg/m³)

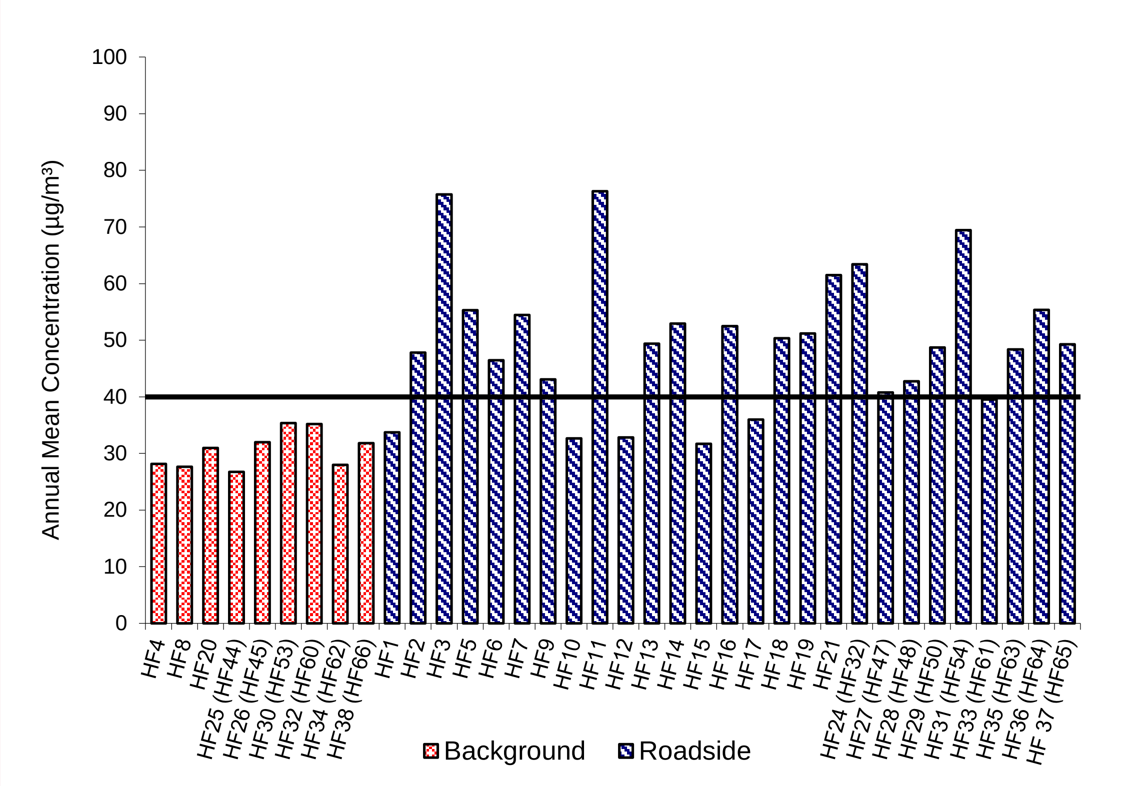
2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
20.3	21.3	24.8	28.0	30.4	27.6	27.8	27.1	28.4	29.5	27.1	28.7	27.2	26.7	21.9	20.4

From 2003 there has been a steady year on year increase to 2007, where roadside elevation peaked at 30.4µg/m³. Following this, the elevation decreased and remained relatively consistent in value up to 2015, but the elevation has been in decline since then.

7.5 London Borough of Hammersmith and Fulham

Annual Mean Values

Figure 7.17 – Hammersmith and Fulham Background and Roadside Annual Mean NO_2 Concentrations, 2018



The London Borough of Hammersmith and Fulham exposed diffusion tubes at thirty six locations during 2018, this is an increase of one site when compared to 2017. At this new location in 2018 there a triplicate set of diffusion tubes co-located with the HF4 Automatic Air Quality Monitoring Station located near Shepherds Bush Green. However, colocation data was not included in the report for bias adjustment due to poor data capture, which will decrease the precision of the bias adjustment factor. There were two sites (HF5 & HF21) that had a data capture of less than 75% and therefore was omitted from the data analysis. All other monitoring sites had a data capture greater than 75% therefore met the quality criteria, and the overall data capture for the thirty four sites was 97%.

In 2018, background concentrations ranged between 26.8µg/m^3 (HF25) and 35.3µg/m^3 (HF40). Roadside concentrations ranged between 31.7µg/m^3 (HF15) and 75.8µg/m^3 (HF3). The annual mean AQS objective was not exceeded at any of the qualifying background monitoring sites and was exceeded at thirty three of the qualifying roadside sites. This is an increase in exceedance of fifteen sites when compared to 2017 (an additional twelve monitoring sites qualified for analysis in 2018 compared to 2017).

A number of site code changes occurred during 2018, the site codes presented in brackets are the old site codes, and the codes outside or without brackets are the site code currently in use as provided by Hammersmith and Fulham. Despite the site code changes there are no changes to the any of the existing diffusion tubes locations, and these will be the site codes used moving forwards.

Times Series

Figure 7.18 – Hammersmith and Fulham Background Time Series, 2013-2018

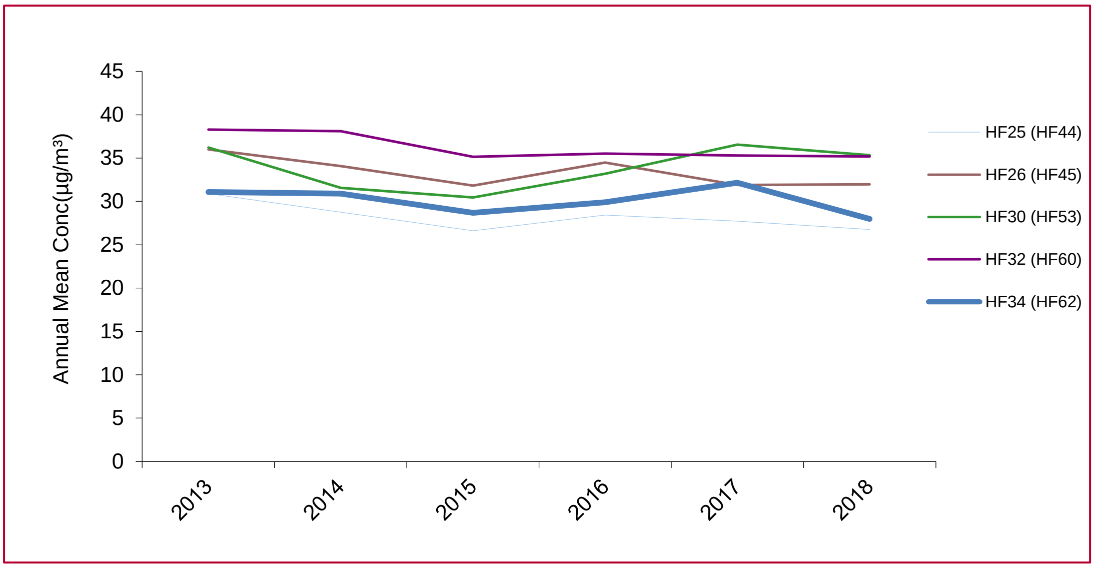


Figure 7.148 above presents the annual mean concentrations at the background monitoring locations with six years of continuous data. Five sites have monitoring data from 2013, which has been added within the 2018 report. Throughout the six years of monitoring presented the trends have remained relatively constant and are comparable:

- 2013 to 2018 shows that the concentrations for the five background sites are consistent in concentration and in trend, with HF34 showing a biggest decline from 2017 to 2018.

A comparison between the annual mean concentrations monitored at the background sites between 2017 and 2018 shows that there has been a reduction in the NO_2 annual mean concentration of 6.1%.

Figure 7.19 – Hammersmith and Fulham Roadside Time Series, 2013-2018

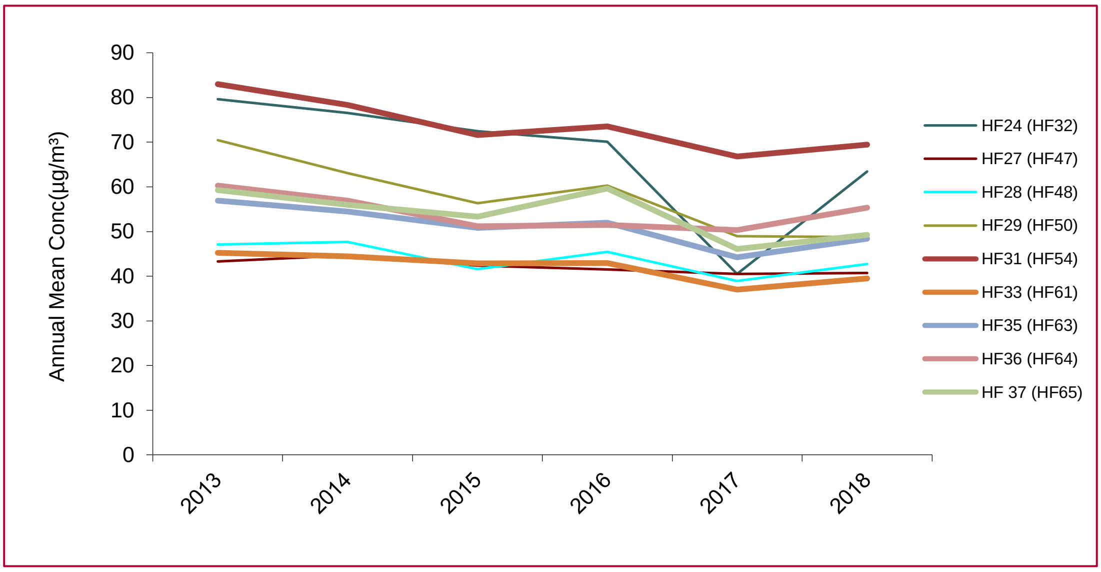


Figure 7.15 above presents the annual mean concentrations at the roadside monitoring locations with six years of continuous data. Nine sites have monitoring data from 2013, which has been added

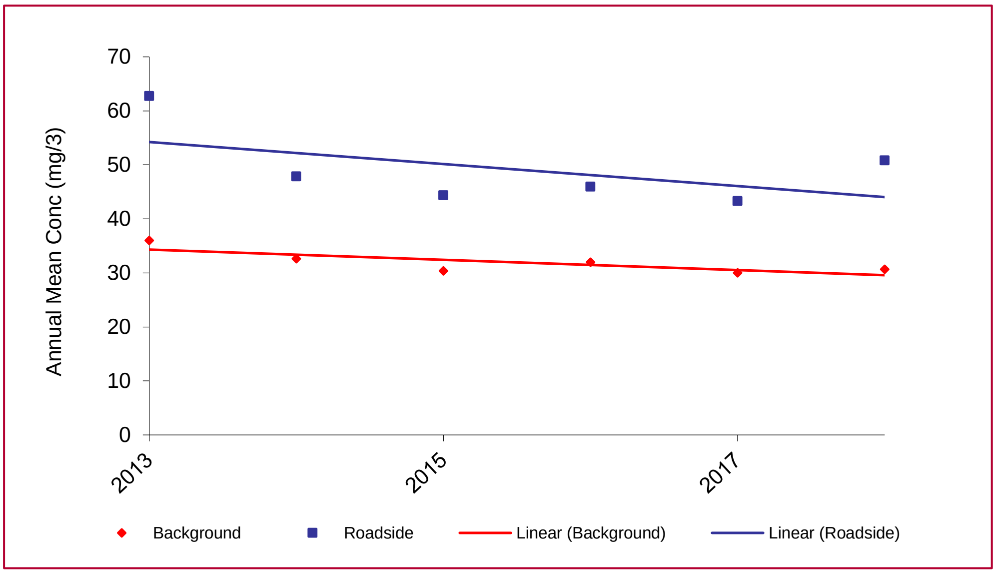
within the 2018 report. Throughout the six years of monitoring presented there have been a number of differing trends throughout the monitoring period to date:

- 2013 to 2018 shows a consistent concentration level across the majority of sites, with all sites presenting an overall decline since 2013. In 2017 all of the sites experienced a decline in concentration, the reduction was more pronounced for site HF24. All concentrations increased in 2018 with HF24 again showing the largest change in concentration.

A comparison between the annual mean concentrations monitored at the roadside sites between 2017 and 2018 shows that there has been a decrease in the NO_2 annual mean concentrations of 5.7%.

Trend Analysis

Figure 7.20 – Hammersmith and Fulham Background and Roadside Trend Analysis, 2013-2018



Both long-term background and roadside annual mean NO_2 concentrations display an overall negative trend from 2013 through to 2018, with the percentage decrease being 14.9% for background and 19% for roadside.

Roadside Elevation

Table 7.5 – Hammersmith and Fulham Roadside Elevation above Background NO_2 Concentration (µg/m^3)

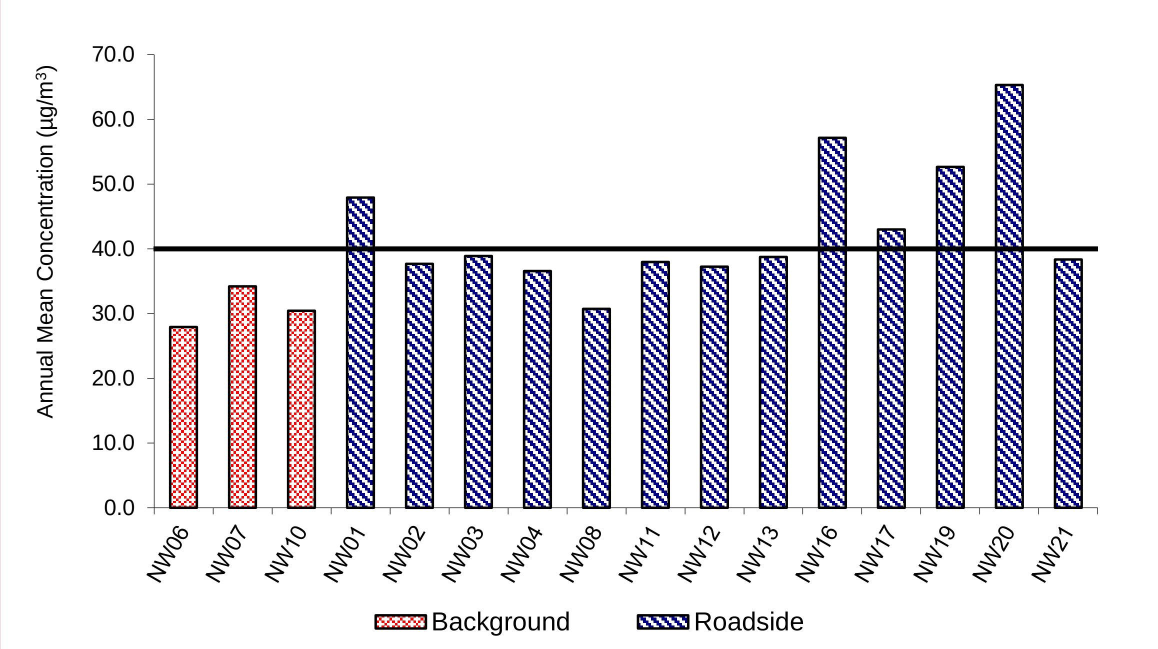
2013	2014	2015	2016	2017	2018
26.7	15.2	14.0	14.0	13.3	19.0

From 2013 there has been a year on year decrease experienced up to 2017. An increase has been experienced in 2018, this is mainly due to the sharp increase in concentration of roadside site HF24.

7.6 London Borough of Newham

Annual Mean Values

Figure 7.21 – Newham Background and Roadside Annual Mean NO_2 Concentrations, 2018



The London Borough of Newham exposed diffusion tubes at sixteen locations during 2018, the same number as during 2016. All monitoring sites had a data capture greater than 75% therefore met the quality criteria, and the overall data capture for the sixteen sites was 94%.

In 2018, background concentrations ranged between 27.9µg/m^3 (NW06) and 34.2µg/m^3 (NW07). Roadside concentrations ranged between 30.7µg/m^3 (NW08) and 65.3µg/m^3 (NW20). The annual mean AQS objective was not exceeded at any of the qualifying background monitoring sites and was exceeded at five of the qualifying roadside sites. This is an increase of one site when compared to 2017.

Time Series

Figure 7.22 – Newham Background Time Series, 1997-2018

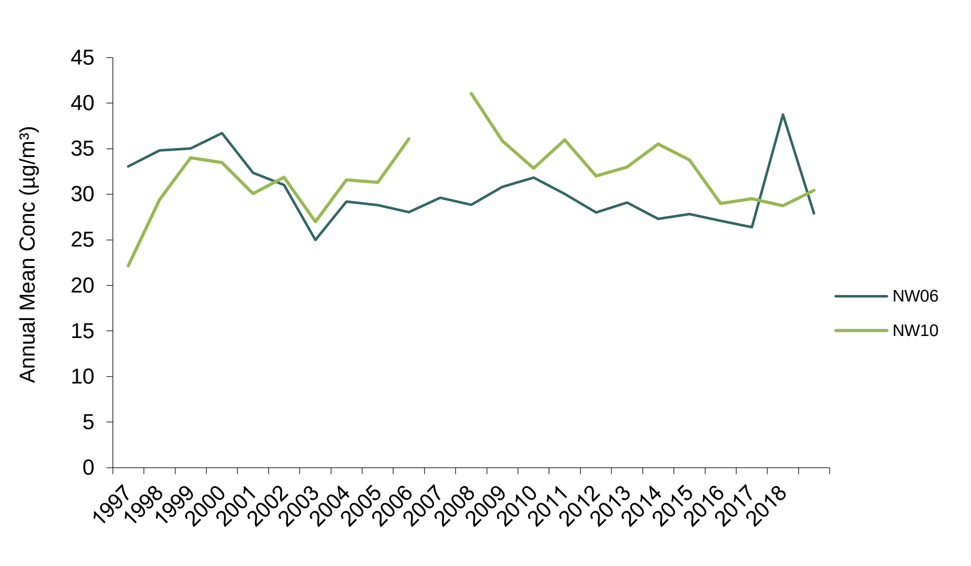


Figure 7.22 above presents the annual mean concentrations at the background monitoring locations with six years of continuous data. Only two monitoring sites currently have six years of continuous data, NW06 and NW10. Throughout the entire monitoring period there have been a number of differing trends throughout the monitoring period to date:

- 1997 to 2002 presents an increase in concentrations for both sites between 1996 and 1999 followed by a period of reduction between 2000 and 2002. In 2002 both sites experienced a sharp drop in concentrations with NW06 recording its lowest concentration for the entire monitoring period;

- 2003 to 2010 presented an overall increase in concentrations, with more variability in the yearly concentrations experienced at NW10. During this period the highest concentration from the entire monitoring period was experienced at NW10, 41.1µg/m^3 in 2007; and

- 2011 to 2017 produced a gradual decrease in concentrations at both monitoring sites aside from NW06 in 2017 where there was a sharp increase in concentration and the site recorded its highest recorded concentration for the entire monitoring period of 38.7µg/m^3.

- In 2018, the concentration at NW06 reduced from the high concentration experienced in 2017 to the concentration levels that were experienced between 2013 and 2015. There was a slight increase experienced at NW10, but the concentration has remained relatively constant since 2016.

A comparison between the annual mean concentrations monitored at the background sites between 2017 and 2018 shows that there has been a decrease in the NO_2 annual mean concentration of 9.7%, this reduction can be attributed to the high annual concentration recorded for NW06 in 2017.

Figure 7.23 – Newham Roadside Time Series, 1997-2018

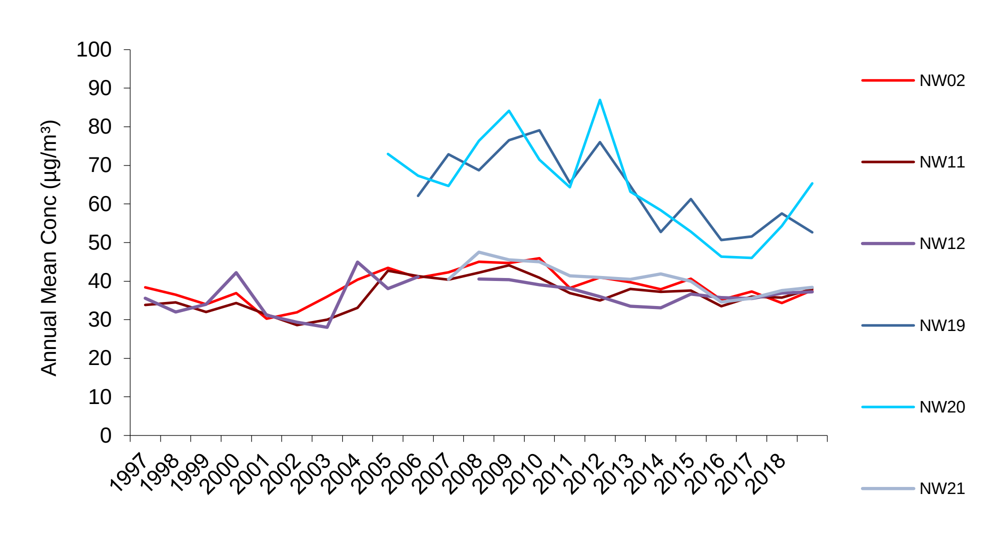


Figure 7.23 above presents the annual mean concentrations at the roadside monitoring locations with six years of continuous data. Three of the qualifying monitoring sites have been monitoring since 1997, two further sites began monitoring in 2004, and one began monitoring in 2005. From the initial concentrations recorded, to the 2018 monitored concentrations, there have been significant changes throughout the monitoring period:

- 1997 to 2003 is a period of overall increase for NW02 and NW12, and NW11 has remained relatively consistent. For NW02 and NW12 concentrations initially decreased between 1996 and 1998 but then have gradually increased since 1998;

- NW19 and NW20 began monitoring in 2004 and 2005 and are report noticeably higher concentrations than the other monitoring locations. These two sites have reduced in concentrations since their inceptions but have seen many increases and decreases up to 2017; and

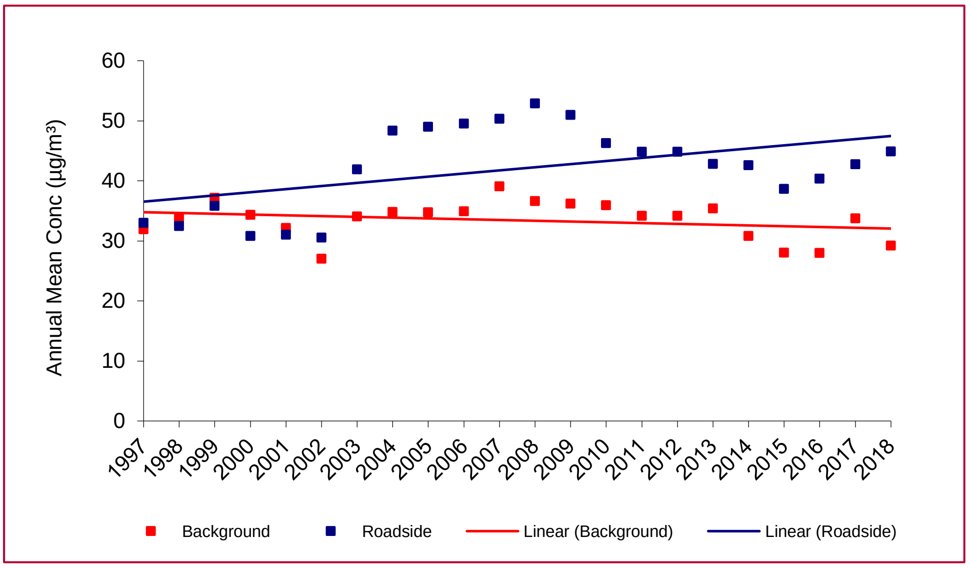
- NW02, NW12 and NW21 have remained relatively consistent between 2004 and 2018, overall there has been a gradual reduction. Also the range of concentrations is quite low as there have not been any peaks or distinctive lows in concentrations.

- NW20 presents a continual sharp increase in concentration from 2017. Aside from NW12 the other monitoring sites experience an increase in concentration between 2017 and 2018, but not to the same magnitude as NW20..

A comparison between the annual mean concentrations monitored at the roadside sites between 2017 and 2018 shows that there has been an increase in the NO_2 annual mean concentrations of 4.9%.

Trend Analysis

Figure 7.24 – Newham Background and Roadside Trend Analysis, 1997-2018



Long-term background annual mean NO_2 concentrations display an overall positive trend from 1997 through to 2018, with the percentage decrease being 8.5%. Long-term roadside annual mean NO_2 concentrations also display a positive trend between 1997 and 2017 of 36%.

Roadside Elevation

Table 7.6 – Newham Roadside Elevation above Background NO_2 Concentration (µg/m³)

2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
7.8	13.6	14.2	14.6	11.3	16.3	14.8	10.4	14.8	10.7	7.4	11.8	10.6	12.4	9.0	15.7

After an initial increase in the roadside elevation between 2003 and 2004 the value remain relatively constant through to 2007 where there was a sharp decrease. This was followed by a large increase in 2008 to where the highest roadside elevation was experienced (16.3). Since 2008 the elevation has both increase and decreased, with a trend lasting no longer than a maximum of two years. The elevation in 2016 was the highest since 2011, then fell to a low value of 9.0 in 2017. The value has increased to 15.7 in 2018 which is the highest value recorded since 2008. This increase corresponds to the sharp increase in NW20 annual concentration.

8 Diffusion Tube Co-Location Study

This section examines the results of triplicate diffusion tubes that have been co-located with a continuous NO_x analyser operated by three of the London authorities who participate in the LWEP NO_2 monitoring network. The mean bias-adjustment 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 the AQS objectives.

8.1 Co-location Monitoring Sites

Fourteen monitoring sites have been selected for this co-location study, all of which operate as part of the Automatic Urban and Rural Network (AURN) or London Air Quality Network (LAQN).

The fourteen sites are operated on behalf of the Environment Agency by Central Management and Coordination Units (CMCU), which are Kings ERG or Ricardo (responsible for LAQN) and Bureau Veritas (responsible for AURN). The sites are summarised in Table 8.1. Recognised QA/QC procedures for calibration and data ratification of the continuous monitoring data are performed by Ricardo Energy and Environment.

Triplicate diffusion tube NO_2 results associated with each monitoring site were averaged, and the annual mean NO_2 concentration compared to the equivalent concentration measured by the co-located continuous NO_x analyser over the twelve-month period. Monthly continuous NO_2 data for each monitoring site was retrieved from the LAQN website[30].

Monitoring sites have been omitted from the overall calculation where their data quality check has resulted in poor precision or poor data capture results. Surveys are considered of poor precision when:

- Monthly Coefficient of Variations (CVs) are often above 20% (maybe 4-5 months out of 12); or
- The average CV for the whole survey is above 10%.

Surveys are considered to be of poor data capture when the automatic monitoring site has an annual data capture of below 90%.

In 2018, twelve out of fourteen sites were accepted into the bias adjustment factor.

The bias-adjustment results for the eleven qualifying sites are summarised in Table 8.2.

[30] Continuous monitoring data from London Air Quality Network (LAQN) website, available at: https://www.londonair.org.uk/LondonAir/Default.aspx

Table 8.1 – Co-Location Monitoring Site Details

Monitoring Site Name	Network	CMCU	Site Classification
Kensington North Kensington	LAQN	Kings ERG	Urban Background
Kensington Cromwell road	LAQN	Kings ERG	Roadside
LWEP Bloomsbury	AURN / LAQN	Bureau Veritas	Urban Background
Croydon Park Lane	LAQN	Kings ERG	Roadside
Croydon London Road	LAQN	Ricardo	Kerbside
Greenwich Eltham	LAQN	Kings ERG	Suburban
Greenwich Blackheath	LAQN	Kings ERG	Roadside
Greenwich Westthorne Avenue	LAQN	Kings ERG	Roadside
Greenwich Burrage	LAQN	Kings ERG	Roadside
Greenwich John Harrison Way*	LAQN	Kings ERG	Roadside
Greenwich Woolwich Flyover	LAQN	Kings ERG	Roadside
Greenwich Bexley Falconwood	LAQN	Kings ERG	Roadside
Newham Cam Road	LAQN	Ricardo	Roadside
Hammersmith, Shepherd's Bush Green**	LAQN	Ricardo	Roadside

*****Greenwich John Harrison Way continuous monitoring site was not included in the bias adjustment due to low data capture over 2018 (42.2%).

******Hammersmith, Shepherd's Bush Green continuous monitoring site was not included in the bias adjustment due to lack of full triplicate sets over 2018, leading poor precision in bias adjustment.

8.2 Results

The bias-adjustment factors are shown in Table 8.2. The bias-adjustment factors (A) range between 0.74 and 1.18 for the fourteen monitoring sites which met the qualifying criteria for the LWEP co-location study.

The final 2018 LWEP mean bias adjustment factor is calculated at 0.85. This is lower than the 0.97 identified by the latest National Physical Laboratory National Diffusion Tube Bias Adjustment Factor Spreadsheet (v03/18)[31] for Gradko diffusion tubes prepared with the 50% TEA in acetone method for 2018. The overall percentage bias (B) for 2018 is 17.5%, indicating that the diffusion tubes are providing an over-estimation of the concentration.

The calculation of bias adjustment factors has been completed using fully ratified data for all of the individual continuous monitoring stations for 2018, except for Kensington North Kensington, Kensington Cromwell Road, LWEP Bloomsbury, Hammersmith Shepherd's Bush Green and Newham Cam Road, to compare with the co-located triplicate sets of diffusion tubes.

Greenwich John Harrison Way continuous monitoring station has only been active in the latter half of 2018, with a data capture of 42.2% over 2018. Whilst Hammersmith Shepherd's Bush had poor precision, due to lack of full triplicate months and data over 2018. Therefore both diffusion tubes

[31] National Physics Laboratory, National Diffusion Tube Bias Adjustment Factor Spreadsheet version 03/18 available at https://laqm.defra.gov.uk/bias-adjustment-factors/national-bias.html

and continuous monitoring results have not been taken into account for the bias adjustment factor and percentage bias comparison for both of these sites.

The calculations for averaging the individual bias factors have been completed in line with the procedure given in paragraph 4.194 in LLAQM TG(16)[24].

Table 8.2 – Bias Adjustment Factor and % Bias of LWEP Co-Location Study 2018

	Diffusion Tube Annual Mean Concentration (µg/m³)	Continuous Analyser Annual Mean Concentration (µg/m³)	Correction Factor (A)	% Bias based on Continuous Monitor (B)
Kensington North Kensington	28.2	27.6	0.99	1
Kensington Cromwell Road	58.4	47.5	0.83	20
LWEP Bloomsbury	40.5	36.6	0.90	11
Croydon Park Lane	55.8	41.3	0.74	35
Croydon London Road	57.2	49.0	0.87	15
Greenwich Eltham	20.4	17.6	0.87	16
Greenwich Blackheath	44.6	35.8	0.80	25
Greenwich Westhorne Av	41.7	38.7	0.92	9
Greenwich Burrage	34.8	35.1	0.98	2
Greenwich Woolwich Flyover	63.9	56.7	0.89	13
Greenwich Bexley Falconwood	49.5	39.1	0.79	27
Newham Cam Road	38.4	29.1	0.76	32
Overall % Bias				**17.17**
Overall Bias Adjustment Factor			**0.85**	

When the bias adjustment factor of 0.85 is applied to the raw 2018 diffusion tube NO_2 measurements the number of qualifying sites showing an exceedance of the AQS annual mean objective of 40µg/m^3 is sixty six sites. The monitoring sites that have an exceedance of the AQS annual mean objective after bias adjustment are highlighted in Appendix A.

The variation in the overall bias adjustment factors over the past seventeen years is Table 8.3.

Table 8.3 – Overall Correction Factor and % Bias from LWEP Studies, 2001 – 2018

Year	Overall Bias Adjustment Factors	Mean % Bias
2001	1.37	-26
2002	1.35	-26
2003	1.11	-10
2004	1.10	-9
2005	1.03	-3
2006	1.06	-4
2007	1.01	-1.06
2008	0.98	3.92
2009	0.97	3.79
2010	1.06	-4.78
2011	1.02	-0.91
2012	1.04	-3
2013	0.96	2.13
2014	0.95	6.22
2015	0.98	2.10
2016	0.97	3.33
2017	0.93	7.18
2018	0.85	17.5

9 Summary and Conclusions

In 2018 there were 147 qualifying diffusion tube monitoring sites in operation across the six participating LWEP boroughs. When compared with the results from 2017 there was an increase in the annual mean concentrations of both background and roadside concentrations[32]. In relation to the AQS annual mean objective, a total of 84 qualifying monitoring sites exceeded the 40µg/m^3 objective (uncorrected for bias), this represents 57.1% of the total qualifying diffusion tube monitoring sites.

There was an increase in the number of diffusion tube monitoring sites included within the LWEP report due to the incorporation of an additional sixteen locations within the London Borough of Hammersmith and Fulham. Out of the qualifying tubes from this additional sixteen locations, ten exceeded the NO_2 annual mean AQS objective.

A long term trend analysis has been completed comparing the year that monitoring started with the 2018 monitoring results for all monitoring sites that were in operation in 2018. The trend analysis indicates that concentrations of NO_2 are increasing at roadside sites, with the 2018 data set showing a positive trend of 17.5%. In comparison, background sites shown a decrease of 10.5%. The large changes are due to a reduction in number of sites that have been running continuously for 6 years or more; 80 roadside sites and 27 background sites.

A 5-year trend analysis has been completed 2014 monitoring results for all monitoring sites that were in operation in 2018. The trend analysis indicates that concentrations of NO_2 are increasing at roadside sites, with the 2018 data set showing a decline in both roadside and background annual mean concentration of 10.5% and 6.6% respectively.

A comparison between concentrations in 2017 and 2018 shows a decrease at background locations (1.3%), and an increase at roadside locations (0.9%).

A summary of the 2018 results for both background and roadside sites is as follows:

- The annual mean background NO_2 concentration averaged across all qualifying background sites in 2018 was 31.7µg/m^3; site concentrations were predominantly recorded in the 30-40µg/m^3 concentration range;

- Six qualifying background sites exceeded the NO_2 annual mean AQS objective. This is a decrease of one site in comparison to 2017;

- The annual mean roadside NO_2 concentration averaged across all qualifying roadside sites in 2018 was 48.2µg/m^3, site concentrations were predominantly recorded in the concentration range 40-50µg/m^3; and

- Eighty two qualifying roadside sites exceeded the NO_2 annual mean AQS objective. This is an increase in the number of sites that exceeded in 2017 (76).

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 reduced within five of the participating boroughs and increased in one borough (Croydon) when comparing the 2017 and 2018 elevation levels.

A number of co-location studies have been completed during 2018, results from fourteen monitoring locations across five local authorities and the LWEP reference sites (London Bloomsbury). These

[32] Note that due to the changes in sample size and data capture – where comparisons have been made these are provided as additional information points only and should be treated with caution

co-location studies have had triplicate diffusion tubes concurrently situated with an automatic NO_x analyser.

The results showed that the diffusion tubes used in this air quality programme over-read by 17.5%. The overall bias adjustment factor derived from the LWEP co-location study for 2018 was calculated as 0.85. If the LWEP bias adjustment factor is applied to the raw diffusion tube results, the total number of sites showing an exceedance is seventy locations.

Appendices

Appendix A – Monthly and Annual Mean NO_2 Concentrations: All Sites, 2018

Site Code = Site exceeding Air Quality Objective (no correction applied)

Site Code = Site likely to exceed the Air Quality Objective if the 0.85 bias adjustment factor is applied

Annual Mean = Value not reported due to data capture <9 months

- = No monitoring data

Borough	Site Code	Class	X	Y	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Mean NO_2 Concentration
City of London Corporation	CL 38	R	531851	180962	54.57	59.39	54.01	54.81	64.76	55.89	57.35	46.95	54.53	52.92	50.97	47.61	54.5
	CL 39	R	531235	181155	71.86	92.08	81.66	76.96	91.76	77.46	80.26	79.04	72.21	60.75	59.75	67.54	75.9
	CL 40	R	533796	181020	52.34	-	51.08	52.86	43.15	37.68	48.39	48.54	53.89	52.35	53.75	51.07	49.6
	CL 5	B	531901	181571	77.56	-	52.45	45.40	-	35.30	49.18	57.56	65.55	57.30	54.88	52.42	54.8
	CL 55	B	532482	181799	42.88	34.65	37.28	32.18	29.97	24.68	24.19	26.31	33.69	36.64	39.07	40.38	33.5
London Borough of Croydon	CY 41	R	530705	160815	50.19	60.84	65.13	63.94	69.71	20.86	64.17	57.68	58.81	59.55	52.78	63.73	57.3
	CY 42	R	530881	166312	38.44	44.02	49.31	35.61	47.33	42.34	40.33	31.85	32.96	43.02	41.57	39.55	40.5
	CY 43	R	533170	166470	37.61	51.93	59.40	46.72	54.17	48.53	43.40	35.61	28.09	44.25	31.07	40.35	43.4
	CY 46	B	529749	159641	-	-	-	23.64	24.84	59.73	23.21	22.46	23.93	25.83	-	25.57	28.7
	CY 47	B	530663	160813	22.67	30.36	30.11	23.13	24.45	22.31	23.84	18.56	21.61	27.08	20.31	25.09	24.1
	CY 48	R	532808	168102	40.08	43.64	48.61	45.56	47.32	37.12	50.27	-	41.50	41.37	35.89	41.78	43.0
	CY 50	B	535470	163782	16.44	20.82	19.64	13.45	16.58	16.74	11.23	10.80	12.40	19.40	18.41	17.24	16.1
	CY 51	R	535415	163976	41.49	52.56	49.34	47.12	54.23	44.76	48.65	39.79	46.99	45.59	41.34	49.02	46.7
	CY 52	R	532683	164196	37.66	46.11	52.50	44.02	48.82	36.64	38.01	33.86	39.91	38.81	37.19	39.21	41.1
	CY 55	R	530637	169696	45.14	68.29	70.59	59.57	75.30	64.14	57.70	45.04	45.58	54.63	51.43	48.54	57.2
	CY 56	R	531373	166098	14.87	32.72	25.30	27.68	30.77	25.20	-	13.35	29.34	36.01	28.43	32.34	26.9
	CY 58	R	532383	165981	44.21	94.47	81.04	66.06	-	65.65	77.72	71.50	71.44	70.75	67.88	63.24	70.4
	CY 59	R	532553	165384	44.29	52.36	61.68	52.36	59.68	47.93	51.47	45.83	51.93	45.85	46.94	51.82	51.0
	CY 97	R	531151	164258	15.61	40.94	40.51	37.54	43.24	35.01	43.19	35.14	37.23	45.78	32.13	39.94	37.2
	CY 98	R	532583	165637	50.53	55.43	63.20	58.62	62.80	55.99	60.87	53.20	51.88	55.25	53.93	47.46	55.8

Borough	Site Code	Class	X	Y	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Mean NO_2 Concentration
	CY 99	R	533940	168390	18.25	40.57	45.67	38.91	36.41	33.27	37.69	35.34	37.46	29.57	32.50	40.86	35.5
Royal Borough of Greenwich	GW 101	R	544727	178884	57.65	84.82	68.90	73.02	72.59	-	71.97	61.66	56.34	66.97	62.86	53.91	66.4
	GW 102	R	544075	178898	58.53	60.28	62.77	-	77.60	56.76	64.31	46.65	49.35	60.47	62.88	54.17	59.4
	GW 103	R	540935	176575	54.88	42.71	54.56	43.19	36.49	29.82	38.45	34.02	42.56	45.88	42.01	42.43	42.2
	GW 104	R	540743	177072	70.35	54.37	56.87	52.79	47.08	32.32	48.50	47.42	51.76	45.62	51.00	52.48	50.9
	GW 105	R	541143	174294	59.93	58.06	56.18	56.62	63.27	54.07	57.51	45.99	50.19	56.18	47.14	51.31	54.7
	GW 106	R	543505	178576	43.82	40.64	48.26	39.41	46.85	35.78	38.08	-	37.07	43.07	41.93	43.95	41.7
	GW 23	R	540420	177706	38.01	47.19	45.74	41.14	57.87	37.83	40.62	35.19	36.35	46.62	44.90	38.64	42.5
	GW 24	R	543806	177951	44.75	47.88	56.32	50.25	71.78	59.76	66.54	50.69	48.23	52.07	52.96	45.25	53.9
	GW 25	R	540099	174881	-	38.65	39.44	35.48	42.31	33.88	40.42	33.02	34.75	42.41	39.52	36.57	37.9
	GW 26	R	544015	173139	34.79	33.28	37.55	30.41	27.51	21.93	25.63	25.54	23.45	34.42	-	13.70	28.0
	GW 27	R	541645	177874	46.52	34.93	40.02	38.14	34.90	28.33	41.91	32.76	37.45	40.04	40.55	34.37	37.5
	GW 28	R	542656	176207	44.35	42.34	43.23	35.52	38.04	25.43	34.19	30.40	30.87	38.73	42.69	36.38	36.8
	GW 29	R	541167	178512	72.85	75.87	77.86	65.79	69.66	54.18	64.35	49.04	45.85	57.33	67.74	58.74	63.3
	GW 30	R	541372	177070	44.71	43.74	45.40	-	41.19	31.93	40.85	32.64	36.04	-	38.25	39.64	39.4
	GW 31	R	543383	175664	36.07	34.40	31.90	30.89	33.51	28.55	29.40	21.39	28.06	33.58	33.99	29.48	30.9
	GW 32	R	540664	177235	53.74	52.21	54.61	45.14	40.54	31.34	42.91	40.20	41.39	49.58	55.62	46.86	46.2
	GW 33	R	537971	176776	50.17	53.52	60.89	55.10	70.05	55.02	62.45	51.91	42.33	54.26	59.28	43.17	54.8
	GW 34	R	545490	178543	43.25	35.40	47.82	40.75	40.11	33.92	37.76	35.87	37.23	35.76	43.71	46.57	39.8
	GW 35	R	539527	178281	53.05	52.15	61.50	67.72	66.58	43.83	61.28	62.38	42.45	64.76	55.44	59.12	57.5
	GW 36	R	539320	179234	70.33	52.09	56.95	57.45	49.71	37.43	55.53	56.74	55.26	55.89	54.86	59.73	55.2
	GW 37	B	546630	179557	32.58	26.94	26.46	22.79	23.79	16.34	22.36	21.49	22.00	29.63	29.20	27.12	25.1
	GW 38	B	541885	175045	32.88	31.91	36.52	33.52	38.24	34.29	34.05	28.46	26.35	31.45	39.03	32.87	33.3
	GW 39	B	543986	174660	24.69	21.57	23.38	18.43	19.94	14.33	17.42	17.36	18.74	21.65	23.50	23.64	20.4
	GW 40	B	544065	176996	24.73	19.22	22.85	18.90	19.55	12.28	17.30	17.21	18.28	23.91	21.17	23.34	19.9
	GW 41	R	543391	172765	54.58	47.56	57.77	55.37	53.26	-	50.63	52.20	52.11	46.76	55.70	54.75	52.8
	GW 42	R	538317	177652	41.51	48.25	51.53	47.57	61.60	42.05	53.36	40.47	41.47	50.82	47.37	40.73	47.2
	GW 43	R	537353	177632	70.47	47.96	47.28	50.52	54.84	37.32	60.15	46.82	42.07	48.27	60.56	48.46	51.2
	GW 44	R	543096	174439	54.71	45.28	53.10	49.90	59.12	46.10	49.10	51.17	49.09	-	56.47	48.75	51.2
	GW 48	R	538044	176960	45.20	43.11	45.63	42.97	40.92	23.19	36.40	34.34	34.65	39.96	43.34	37.01	38.9

Borough	Site Code	Class	X	Y	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Mean NO_2 Concentration
	GW 49	R	543472	179217	57.59	45.23	50.72	51.52	50.25	38.81	52.99	48.50	48.74	51.85	45.92	47.46	49.1
	GW 50	R	540203	178367	76.46	57.01	62.90	66.49	56.17	44.09	70.50	69.37	68.39	67.26	65.15	62.91	63.9
	GW 51	R	539638	179024	46.30	38.41	47.61	44.58	44.67	32.86	45.35	42.13	39.25	49.80	-	48.25	43.6
	GW 52	R	542842	179108	42.02	49.05	54.05	43.35	52.96	46.43	41.54	35.08	34.39	44.60	43.53	38.60	43.8
	GW 53	R	542181	176878	39.22	32.43	40.47	33.72	36.81	24.56	32.08	32.55	30.50	34.13	37.42	35.23	34.1
	GW 54	R	541915	175039	45.06	45.55	52.95	63.24	74.27	56.56	67.12	61.18	53.26	62.35	71.62	61.19	59.5
	GW 55	R	545005	175097	49.68	51.17	60.14	49.47	63.80	50.33	53.00	38.92	37.30	47.04	50.02	43.63	49.5
	GW 56	R	543679	172598	50.66	44.50	51.98	47.35	54.62	50.83	46.52	46.57	48.97	44.97	37.96	48.55	47.8
	GW 57	R	538968	177955	36.76	38.35	39.76	33.79	37.55	28.86	33.09	30.65	30.30	35.81	34.47	36.78	34.7
	GW 58	R	538143	176712	44.74	46.28	51.48	42.77	50.18	44.13	46.85	36.37	39.39	47.14	47.65	38.49	44.6
	GW 59	R	541883	175016	39.63	41.23	47.13	42.16	50.94	42.74	45.49	33.32	33.03	40.96	47.31	36.68	41.7
	GW 60	R	544086	178882	34.07	29.77	39.89	34.83	42.78	33.11	33.37	31.35	32.76	37.34	33.87	34.12	34.8
	GW 61	R	539687	179123	37.37	38.28	43.13	37.97	32.95	27.11	36.58	36.98	39.90	40.68	39.17	40.60	37.6
Royal Borough of Kensington and Chelsea	KC 31	R	524342	181271	45.44	43.98	52.70	37.27	44.38	44.14	42.82	34.69	40.46	44.33	47.26	45.44	43.7
	KC 32	B	524784	179599	-	26.05	29.29	27.55	21.93	17.94	20.53	19.82	21.85	59.12	21.14	-	26.8
	KC 33	R	525355	178841	108.67	84.43	83.78	82.62	79.83	87.21	91.86	76.41	88.63	84.11	86.39	108.67	85.7
	KC 34	B	527164	178103	46.82	-	52.19	42.92	40.25	35.33	34.03	28.77	34.96	32.28	48.39	46.82	39.8
	KC 35	R	527192	179185	-	55.77	71.18	59.34	68.78	-	68.44	-	-	58.39	-	-	63.2
	KC 38	R	525548	178556	86.62	82.46	76.01	66.47	79.13	76.35	86.59	74.49	74.43	73.48	78.28	86.62	77.3
	KC 39	B	526317	177022	33.90	34.43	37.11	32.67	30.58	25.79	28.02	20.33	26.31	32.85	40.20	33.90	31.2
	KC 40	B	527214	179153	-	-	-	-	-	-	29.87	-	26.18	35.27	40.15	-	34.2
	KC 41	B	524294	181200	32.98	35.40	40.97	28.73	32.21	25.45	-	26.49	25.79	37.33	39.53	32.98	32.9
	KC 42	B	525191	180705	40.71	43.78	45.35	41.56	34.83	31.57	35.31	32.03	37.52	42.65	41.73	40.71	39.2
	KC 43	B	525950	177487	30.95	37.64	38.01	31.28	31.20	27.64	24.60	21.50	19.71	30.92	38.20	30.95	30.6
	KC 44	B	527335	178810	37.93	38.63	41.22	34.35	35.27	28.05	31.22	28.40	35.04	43.14	40.38	37.93	36.2
	KC 45	R	525263	178936	41.86	44.69	57.19	47.48	46.71	43.58	43.13	39.58	40.98	46.39	54.15	41.86	45.9
	KC 47	B	524046	181758	32.43	30.72	34.71	26.56	26.08	21.10	23.35	20.97	24.13	29.54	36.18	32.43	28.2
	KC 48	R	528011	178675	70.71	62.64	62.96	59.17	63.40	62.63	30.92	47.83	50.90	64.82	48.82	70.71	57.3
	KC 49	R	527516	179395	-	-	-	-	-	-	35.53	-	-	-	-	-	48.1
	KC 50	R	527726	177727	42.39	37.16	39.01	39.05	40.65	44.73	27.57	33.31	37.93	-	-	42.39	39.3

Borough	Site Code	Class	X	Y	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Mean NO_2 Concentration
	KC 51	B	527690	177800	32.70	31.14	30.57	27.42	29.12	26.18	13.41	21.22	26.05	25.14	31.40	32.70	27.2
	KC 52	R	527411	178659	45.77	51.39	58.48	46.53	58.95	57.48	25.82	39.47	47.79	47.42	51.41	45.77	48.4
	KC 53	B	523792	181189	42.33	40.03	45.70	38.37	42.17	36.48	21.53	40.10	42.37	39.59	43.46	42.33	39.8
	KC 54	R	526550	178968	71.47	66.40	70.97	56.56	53.70	53.03	50.87	41.39	-	-	60.43	71.47	58.4
	KC 55	B	526608	177429	51.54	47.10	46.59	39.84	39.69	35.50	17.34	31.26	31.29	44.32	47.78	51.54	40.0
	KC 56	R	527268	178089	60.01	60.83	68.51	62.16	62.58	66.30	36.04	53.74	55.39	56.57	58.67	60.01	58.4
	KC 57	R	527889	179145	49.19	51.12	50.02	44.27	55.24	49.38	23.58	40.74	51.15	50.31	43.13	49.19	46.3
	KC 58	R	525630	179674	50.00	52.24	50.24	49.64	51.18	53.54	26.38	42.11	48.07	47.49	43.82	50.00	46.8
	KC 59	R	525342	179464	72.22	65.43	67.52	57.10	74.58	73.02	35.28	61.11	76.50	70.88	59.51	72.22	65.2
	KC 60	R	526231	178425	61.36	48.23	57.21	44.11	57.52	50.85	28.81	44.64	49.36	54.79	58.25	61.36	50.5
	KC 61	R	526377	177867	44.20	48.28	51.04	43.91	54.41	43.03	21.12	35.96	44.62	46.31	49.83	44.20	44.5
	KC 64	R	524825	178902	45.73	44.16	50.12	40.16	44.92	36.36	21.52	34.17	41.50	51.87	46.57	45.73	41.7
	KC 65	R	523899	182113	36.36	40.25	34.07	33.50	37.74	30.84	15.64	27.66	31.71	39.57	38.93	36.36	34.0
	KC 66	B	524541	181893	44.47	42.38	44.52	34.90	36.31	31.68	18.25	30.42	35.58	46.22	44.53	44.47	37.9
	KC 67	B	524056	182148	45.13	40.21	41.96	35.94	32.53	25.73	16.47	32.24	38.37	39.63	42.21	45.13	36.3
	KC 68	R	526863	179060	45.69	47.65	47.39	43.43	40.97	38.02	18.40	35.57	41.68	45.24	43.70	45.69	41.5
	KC 69	B	523587	180893	40.07	40.07	43.28	28.66	35.12	28.65	16.78	34.07	32.47	38.34	42.66	40.07	35.2
London Borough of Hammersmith and Fulham	HF1	R	525760	176732	35.83	32.53	34.86	33.69	-	25.17	32.42	29.08	36.04	33.33	42.34	35.88	53.6
	HF2	R	526146	176205	46.84	42.94	46.45	-	47.81	33.50	57.70	51.69	52.85	44.59	54.00	-	43.0
	HF3	R	525819	175810	76.99	58.80	67.49	68.88	77.09	62.76	90.84	89.53	82.19	81.91	79.99	72.75	57.8
	HF4	B	525652	175821	31.38	27.38	37.89	30.45	26.59	21.45	23.19	22.36	24.75	30.28	33.66	28.37	42.8
	HF5	R	524406	175969	-	40.24	-	53.65	67.71	60.78	60.53	-	-	55.21	57.53	46.94	33.7
	HF6	R	524846	176325	45.75	43.32	51.58	45.81	51.50	47.21	48.50	44.65	45.98	47.24	43.67	42.37	47.8
	HF7	R	524633	176585	55.10	48.79	53.94	53.62	63.06	20.29	73.88	59.89	58.90	56.41	55.58	54.10	75.8
	HF8	B	523595	177206	31.37	28.94	37.54	26.83	24.66	19.22	21.61	20.12	24.79	31.27	34.70	30.91	28.1
	HF9	R	522606	179008	41.88	42.33	-	44.05	44.98	38.99	44.81	39.31	38.64	44.45	53.42	41.22	55.3
	HF10	R	523856	178863	34.79	32.50	38.89	34.72	32.81	26.63	30.74	26.11	30.18	33.21	37.31	33.74	46.5
	HF11	R	523436	178632	86.70	61.99	71.31	76.28	86.32	69.39	82.54	-	73.37	77.27	86.14	68.28	54.5
	HF12	R	524200	177875	37.94	36.11	34.85	30.42	35.93	29.47	29.39	24.40	27.37	31.36	43.22	33.32	27.7
	HF13	R	523129	178331	51.29	41.65	43.81	50.94	59.70	45.89	53.87	53.55	57.87	46.14	38.63	-	43.1

Borough	Site Code	Class	X	Y	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Mean NO_2 Concentration
	HF14	R	522777	178552	59.22	45.62	54.90	57.61	52.70	39.39	55.84	54.30	55.90	51.56	55.67	52.23	32.6
	HF15	R	522024	180896	36.24	30.85	35.77	31.80	36.87	30.86	27.91	23.95	30.32	28.92	30.32	36.49	76.3
	HF16	R	523305	180176	58.36	46.85	55.14	54.85	56.41	42.73	58.76	56.85	51.38	42.84	54.63	51.30	32.8
	HF17	R	522693	179595	38.47	38.57	46.59	36.41	36.11	32.55	33.38	30.90	30.55	34.37	35.17	38.78	49.4
	HF18	R	522220	179281	58.00	52.77	55.28	53.75	51.92	49.84	51.96	45.58	50.02	47.52	-	37.18	52.9
	HF19	R	522006	179760	53.83	51.56	50.58	56.39	46.97	39.40	53.98	55.32	46.70	54.58	52.23	52.44	31.7
	HF20	R	521564	179685	35.09	32.72	38.13	31.97	29.91	22.88	26.60	26.12	29.13	30.83	36.05	31.95	52.5
	HF21	R	523313	179900	-	54.75	-	66.40	64.41	53.42	-	70.08	61.29	61.49	60.19	-	36.0
	HF24 (HF32)	R	523329	178484	68.24	57.95	71.03	65.02	69.86	60.47	64.59	57.99	55.07	64.68	67.94	58.24	50.3
	HF 25 (HF44)	B	525386	176816	30.02	26.34	34.42	20.02	26.51	21.02	22.11	20.07	23.33	31.30	33.08	32.96	51.2
	HF 26 (HF45)	B	522480	180655	36.20	32.02	41.22	29.90	31.30	26.09	24.76	29.97	30.44	33.80	31.60	36.50	30.9
	HF27 (HF47)	B	522013	181106	45.99	39.35	43.48	41.62	34.08	30.59	44.63	40.16	40.13	42.27	45.73	41.03	61.5
	HF28 (HF48)	R	524647	177657	38.17	38.27	43.59	-	70.65	31.67	39.06	36.65	-	44.61	45.84	39.13	63.4
	HF29 (HF50)	R	525273	177273	50.52	44.21	52.37	52.10	49.20	33.03	48.70	50.16	54.00	50.38	48.99	51.20	26.8
	HF30 (HF53)	B	523801	179498	40.28	39.84	-	34.06	39.54	26.99	29.86	30.94	29.99	-	41.82	40.06	32.0
	HF31 (HF54)	R	522550	180963	61.05	69.65	77.88	70.08	82.91	78.67	70.13	48.32	54.50	86.80	69.92	63.63	40.8
	HF32 (HF60)	B	522550	182790	45.70	35.67	37.01	37.00	29.35	22.65	32.58	33.50	36.24	25.83	41.87	44.75	42.8
	HF33 (HF61)	R	522850	180060	40.42	40.43	42.13	39.05	37.80	34.69	37.93	38.76	37.15	42.07	41.95	41.98	48.7
	HF34 (HF62)	B	522745	179179	31.39	30.90	34.29	26.56	25.56	20.22	22.56	24.31	-	29.55	29.58	32.97	35.3
	HF35 (HF63)	R	524148	178358	42.12	46.42	54.96	50.72	57.53	49.62	50.98	42.84	39.24	53.45	46.48	46.32	69.5

Borough	Site Code	Class	X	Y	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Mean NO_2 Concentration
	HF36 (HF64)	R	524747	178158	-	45.72	54.32	53.24	56.12	49.56	59.93	59.68	57.60	67.11	50.73	54.68	35.2
	HF37 (HF65)	R	523926	176940	49.54	50.99	50.28	55.60	50.20	41.96	53.84	46.97	43.66	42.51	54.83	50.84	39.5
	HF38 (HF66)	B	524680	176880	34.22	36.91	39.00	31.40	29.27	25.85	27.14	22.89	25.96	34.97	37.92	36.25	28.0
London Borough of Newham	NH1	R	538280	185359	41.29	105.96	46.00	42.92	42.06	39.75	42.79	37.50	-	44.02	43.29	41.49	52.4
	NH2	R	539572	184659	37.12	32.58	42.48	34.38	33.48	30.10	36.25	41.50	37.86	40.70	42.58	43.02	41.8
	NH3	R	541954	185430	34.48	32.18	37.27	34.48	38.35	35.07	37.73	-	38.57	-	53.38	47.50	51.2
	NH4	R	542831	183618	41.91	-	39.72	32.68	39.16	33.31	34.48	33.46	34.53	26.25	43.22	43.53	46.0
	NH6	B	539859	182655	31.85	33.49	32.03	23.41	26.36	18.09	22.47	-	21.96	29.35	34.74	33.18	47.9
	NH7	B	541492	182332	34.12	31.75	35.45	28.53	36.96	31.99	-	36.75	34.07	36.76	34.78	35.20	37.7
	NH8	R	542688	183202	32.26	29.01	34.84	32.91	32.67	32.83	32.12	26.88	23.09	25.56	31.42	34.75	38.9
	NH10	B	539747	181477	34.90	31.21	32.93	25.34	27.34	23.76	26.86	28.58	31.12	33.96	33.86	35.47	36.6
	NH11	R	542583	180201	42.15	36.35	42.18	36.23	30.37	29.15	37.36	36.22	35.78	43.47	46.22	39.87	27.9
	NH12	R	543762	180784	35.52	34.03	41.57	39.31	35.54	24.58	35.31	37.37	36.75	45.09	41.46	40.42	34.2
	NH13	R	541134	184098	38.11	37.10	46.94	-	-	40.41	39.86	38.78	31.76	29.00	43.35	42.01	30.7
	NH16	R	539164	185158	66.95	49.11	55.35	50.62	57.89	50.85	63.95	61.29	56.19	53.62	62.05	57.66	30.4
	NH17	R	542729	185047	49.20	47.46	51.00	42.29	43.90	34.49	46.36	-	33.80	36.06	45.13	-	37.9
	NH19	R	539906	181702	60.81	43.98	55.46	50.28	47.10	53.77	53.91	55.05	46.59	49.10	60.43	55.25	37.2
	NH20	R	539456	181499	65.31	109.30	65.46	60.20	79.63	83.25	67.78	46.90	43.29	50.70	46.53	-	38.7
	NH21	R	538657	183973	43.58	38.09	45.47	31.82	38.45	35.65	35.74	35.85	37.10	36.50	44.50	37.57	57.1

Appendix B – Co-Location Sites – Triplicate Diffusion Tube Monthly Mean NO_2 Concentrations, 2018

Co-Location Site	Diffusion Tube Code	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Mean NO_2 Conc (μg/m^3)
Kensington North Kensington	KC47	32.4	30.7	34.7	26.6	26.1	21.1	23.3	21.0	24.1	29.5	36.2	33.1	28.2
Kensington Cromwell Road	KC54	71.5	66.4	71.0	56.6	53.7	53.0	50.9	41.4	-	-	60.4	59.3	58.4
LWEP Bloomsbury	LB	48.0	46.2	49.6	44.6	44.5	34.8	34.5	34.2	36.5	22.3	43.0	47.6	40.5
Croydon Park Lane	CY98	50.5	55.4	63.2	58.6	62.8	56.0	60.9	53.2	51.9	55.2	53.9	47.5	55.8
Croydon London Road	CY55	45.1	68.3	70.6	59.6	75.3	64.1	57.7	45.0	45.6	54.6	51.4	48.5	57.2
Greenwich Eltham	GW39	24.7	21.6	23.4	18.4	19.9	14.3	17.4	17.4	18.7	21.6	21.0	23.6	20.2
Greenwich Blackheath	GW58	44.7	46.3	51.5	42.8	50.2	44.1	46.8	36.4	39.4	47.1	47.7	38.5	44.6
Greenwich Westhorne Av	GW59	39.6	41.2	47.1	42.2	50.9	42.7	45.5	33.3	33.0	41.0	47.3	36.7	41.7
Greenwich Burrage	GW60	34.1	29.8	39.9	34.8	42.8	33.1	23.3	31.3	32.8	37.3	33.9	34.1	33.9
Greenwich John Harrison Way	GW61	37.4	38.3	43.1	38.0	33.0	27.1	36.6	37.0	39.9	40.7	39.2	40.6	37.6
Greenwich Woolwich Flyover	GW50	76.5	57.0	62.9	66.5	56.2	44.1	70.5	69.4	68.4	67.3	65.1	62.9	63.9
Greenwich Bexley Falconwood	GW55	49.7	51.2	60.1	49.5	63.8	50.3	53.0	38.9	37.3	47.0	50.0	43.6	49.5
Newham Cam Road	NHM21	43.6	38.1	45.5	31.8	38.5	35.7	35.7	35.8	37.1	36.5	44.5	37.6	38.4
Hammersmith Shepherd's Bush Green	HF21	-	54.8	-	66.4	64.4	53.4	-	70.1	61.3	61.5	60.2	-	61.5

A – Data capture with less than 3 tubes

Appendix C – Co-Location Sites – Automatic Monthly NO_2 Concentrations, 2018

Co-Location Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Mean NO_2 Conc ($\mu g/m^3$)
Kensington North Kensington	34.1	36.5	35.5	27.4	24.0	18.4	20.8	21.1	25.1	30.8	30.5	27.5	27.6
Kensington Cromwell Road	56.1	56.0	57.9	51.3	48.6	42.9	39.6	33.5	38.6	44.9	50.8	49.3	47.5
LWEP Bloomsbury	44.0	46.1	44.9	39.6	39.4	26.5	28.6	24.9	29.7	37.9	36.0	41.8	36.6
Croydon Park Lane	37.6	47.6	45.2	42.0	42.0	33.8	42.2	37.0	37.8	43.4	44.9	42.6	41.3
Croydon London Road	42.7	51.7	55.5	52.9	61.6	52.7	52.5	35.7	40.1	47.5	48.7	46.1	49.0
Greenwich Eltham	18.6	19.8	20.3	16.7	17.9	11.7	14.7	12.0	16.5	20.9	20.7	21.9	17.6
Greenwich Blackheath	32.9	39.8	44.5	38.9	42.3	33.1	36.0	26.1	28.3	33.7	35.4	38.2	35.8
Greenwich Westhorne Av	36.4	43.3	46.0	37.6	44.3	44.8	38.5	28.4	31.8	37.7	39.7	36.1	38.7
Greenwich Burrage	33.7	41.3	40.2	35.1	44.1	33.1	31.6	27.7	31.2	36.9	31.6	34.4	35.1
Greenwich John Harrison Way**	-	-	-	-	-	-	16.9	26.7	32.0	36.1	36.1	38.9	31.1
Greenwich Woolwich Flyover	61.5	61.1	61.3	60.9	51.8	37.9	59.8	57.1	59.2	56.9	54.9	58.5	56.7
Greenwich Bexley Falconwood	38.4	48.0	48.8	39.8	47.1	34.7	39.9	27.0	31.8	38.3	37.4	38.7	39.1
Newham Cam Road	31.9	32.7	32.9	29.1	27.2	18.1	25.8	22.5	26.3	33.6	34.5	34.2	29.1
Hammersmith Shepherd's Bush Green**	69.7	71.6	66.1	74.4	77.0	65.6	67.2	62.5	75.8	72.3	65.5	68.7	69.7

A – Data Capture below 75%

* – No data capture

**Data not included in bias adjustment due to poor data capture and precision.