Air Quality Consultants

Air Quality Monitoring Study:
London School Streets

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Document Control

Client	Greater London Authority, FIA Foundation and Bloomberg Philanthropies	Principal Contact	Rosalind O'Driscoll (Greater London Authority)

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Report Prepared By:	Ricky Gellatly & Dr Ben Marner

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Air Quality Consultants Ltd
23 Coldharbour Road, Bristol BS6 7JT Tel: 0117 974 1086
119 Marylebone Road, London NW1 5PU Tel: 020 3873 4780
aqc@aqconsultants.co.uk

Registered Office: 23 Coldharbour Road, Bristol BS6 7JT
Companies House Registration No: 2814570

Executive Summary

An air quality monitoring study has been carried out utilising 30 AQMesh sensors, based on the approach used in the Breathe London network. Sensors were installed near to schools in Brent, Enfield and Lambeth. The aim of the study was to investigate the air quality benefits of new School Streets, installed as part of the Mayor's Streetspace for London plan, in response to the coronavirus pandemic. Sensors were installed adjacent to, and at the ends of, sections of road that would be closed at certain times of the day on school days as part of the School Streets initiative. Comparator sites were also installed outside schools where no interventions were implemented, i.e. schools that were not part of the School Streets initiative.

A range of approaches have been used to identify the influence of the road closures on measured pollutant concentrations. The confounding effects of COVID-related travel restrictions and day-to-day changes to the weather have made it difficult to identify the precise effect of many of the individual interventions on air quality, but isolating the benefits of individual interventions is never straightforward even using the most sophisticated techniques. It is important to note, however, that simply because the air quality benefits at some sites could not be identified from the monitoring data, this does not mean that benefits did not occur in terms of a reduction in emissions.

However, at some of the sites, a clear benefit has been seen. The comparison of concentration profiles at similar sites (typically one with a School Streets intervention and one without), has identified average reductions in nitric oxide (NO) concentrations of up to 8 μg/m^3 (34%) during the morning intervention period, which equates to a reduction in daily average (school day) concentration of approximately 5%. The resultant reduction in nitrogen dioxide (NO_2) during the school drop-off period has been estimated as being up to 6 μg/m^3 (23%). The morning intervention alone is thus expected to have reduced daily average NO_2 by up to 0.4 μg/m^3, or 2%. This demonstrates that School Streets can play a role in reducing peak exposure to pollution concentrations outside of schools.

In addition to this monitoring study, as part of the Streetspace for London and School Streets initiative, TfL commissioned research to explore parents' awareness, attitudes and any changes to their travel behavior as a result of a School Street being introduced. A modal shift towards active means of travel, such as walking, cycling or scooting has many benefits to children and parents/carers alike, but in terms of specific benefits to air quality it is the reduction in private car use for drop-off and pick-up that is most relevant. The survey found that 18% of parents/carers at School Streets schools reported driving less as a result of the intervention, separate to the change in behavior as a result of the pandemic. It has not been possible to quantify the precise reduction in the number of car trips as a result of the interventions, and, therefore, the resultant reduction in emissions (nitrogen oxides, particulate matter and carbon dioxide) cannot be determined. Nonetheless, there will be beneficial reduction in both emissions and pollutant concentrations associated with the reduction in parent/carer trips to schools with School Streets.

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1 Introduction

1.1 Air Quality Consultants Ltd (AQC), in association with partners of the "Breathe London" project (Acoem Air Monitors, CERC and Prof. Roderic Jones of the University of Cambridge), have been commissioned to carry out an air quality monitoring study to investigate the air quality benefits of the School Streets in London. The study has been co-funded by the Greater London Authority, FIA Foundation and Bloomberg Philanthropies.

1.2 In response to the Covid-19 pandemic, the Mayor's Streetspace for London Plan is creating more space on streets so that people can walk or cycle whilst maintaining social distancing and reduce pressure on public transport to accommodate social distancing and the resultant drop in capacity. The Streetspace Plan also includes specific recommendations on maintaining social distancing to enable children to return safely to school. In this respect, the advice is for children/parents/carers to walk, cycle or scoot wherever possible and to avoid driving unless essential. 'School Streets' restrict vehicle access during drop-off and pick-up times, and consequentially reduce levels of traffic and pollution in the immediate vicinity of schools during these times.

Aims and Objectives of the Project

1.3 The principal aim of this project has been to quantify the air quality benefits of introducing School Streets by measuring changes to pollutant concentrations during those periods that the intervention is operating. In addition, TfL commissioned an Attitudinal Survey to explore changes to travel behaviour as a result of School Streets, the conclusions of which have been considered in this report.

1.4 The key objectives of the project were to identify simple, sharable messages that can be easily communicated on the air quality benefits associated with School Streets, so as to support a case for potentially making School Streets permanent.

1.5 In total, 30 AQMesh sensors were installed in the London Boroughs of Brent, Enfield and Lambeth. These monitors continuously measure nitric oxide (NO) and nitrogen dioxide (NO_2), while also measuring temperature, humidity and atmospheric pressure in order to compensate for the effects of changes in meteorological conditions on measured pollutant concentrations.

1.6 This report describes the strategy for the deployment of the monitors, the quality assurance process for the measured data, and the results of the subsequent data analysis.

2 Methodology

Monitoring Strategy

2.1 Initial details of proposed School Streets interventions were requested from a number of London Boroughs in early August 2020. Plans with sufficient detail to inform the deployment of monitors for schemes that might have a discernible effect on traffic emissions (i.e. those with road closures), were only available at that time from the London Boroughs of Brent, Enfield and Lambeth; as such, these Boroughs became the focus of the study. The School Streets interventions in these Boroughs typically involve the closure of a section of road for social distancing at times when students will be walking to and from school. The study has focussed on Primary Schools only, which is where School Streets interventions are also focussed.

2.2 The plans for all School Streets in the three Boroughs were evaluated, with a focus on identifying the busiest roads that would be closed. This is because these are the roads where there is the greatest potential to isolate changes caused by the road closure from other concurrent variations in air quality. However, none of the roads to be closed carried significant amounts of traffic (as it is not practical to close major thoroughfares).

2.3 It was also identified that there would be a benefit in comparing measurements along a section of road closed as part of the School Streets interventions to those along a similar road where no interventions were proposed. As such, roads with Primary Schools that were not School Streets were also considered, for use as comparator sites.

2.4 Once the preferred monitoring locations had been identified, permission was sought from the Schools to be part of the study, and from the Boroughs in terms of permission to attach the monitors to street furniture. Monitors were deployed as soon as possible after permission was granted in order to maximise the sampling period. However, in Enfield there was a delay to obtaining permission to attach the monitors to street furniture, and the monitors were installed later than most of those in Lambeth and Brent.

2.5 Details of the 30 monitoring locations selected are provided in Table 1. Plans of the specific settings of the monitoring locations are provided in Figure 1 to Figure 14. It should be noted that the monitor at Site 19 was initially deployed at the Holloway Lane automatic monitoring site in Islington for calibration of the network (as described later in this Section), which is why it was deployed at the school later than the other monitors.

2.6 The affected roads in Brent were intended to be closed between 8.15-9.15am & 2.30-4.00pm; in Enfield it was 8.15-9.15am & 2.45-3.45pm, and in Lambeth it was 7.45-9.15am & 2.15-3.45pm. It is understood that the road closures at some schools were not implemented for the full periods as described above, and a local decision was taken to re-open the road once the children had entered or left the school; there is also the possibility that the implementation times varied from day-by-day.

It has not been possible to account for this in the analysis presented in this report. It is also noted, however, that the closure of a road for a short period of time has the potential to reduce traffic volumes over a longer period; either because parents choose other modes of transport or because all road users select alternative routes.

2.7 Half-term for all schools was the week beginning 26 October 2020, during which period there were no School Streets road closures.

Table 1: Monitoring Locations and Details

Borough	Site ID	School	School Street?	Easting (m)	Northing (m)	Installation Date & Time
Brent	1	St Mary's RC	No	525129	183247	18/09/2020 10:30
	2	St Robert Southwell	Yes [a]	520247	188417	18/09/2020 12:00
	3	Kingsbury Green	Yes	520175	188629	18/09/2020 16:00
	4		Yes	520082	188677	18/09/2020 11:10
	5		Yes	519858	188744	18/09/2020 12:10
	6	St Mary's CoE	Yes	521290	184699	18/09/2020 12:50
	7	Byron Court	No	517047	186961	18/09/2020 13:40
	8	Uxenden Manor	Yes	518213	188524	18/09/2020 14:50
	9		Yes	518282	188456	18/09/2020 14:00
	10		Yes	518165	188823	18/09/2020 14:10
Enfield	11	De Bohun	Yes	528678	195419	16/10/2020 12:11
	12		Yes	528750	195477	09/10/2020 11:46
	13		Yes	528835	195504	09/10/2020 11:20
	14	Churchfield	No	533939	194071	09/10/2020 12:10
	15	St Mary's	No	535731	196201	09/10/2020 13:10
	16	Kingfisher Hall	Yes	535368	196548	09/10/2020 13:10
	17		Yes	535292	196501	09/10/2020 13:09
	18		Yes	535448	196532	09/10/2020 14:09
	19	St Andrew's	No	533114	197189	12/11/2020, 13:07

Borough	Site ID	School	School Street?	Easting (m)	Northing (m)	Installation Date & Time
Lambeth	20	Van Gogh	Yes	531004	176946	16/09/2020 09:41
	21		Yes	530992	176831	16/09/2020 13:10
	22		Yes	530979	176730	16/09/2020 12:10
	23	Holy Trinity	No	530773	173729	01/10/2020 09:56
	24	Christ Church & Orchard	Yes	530652	173539	16/09/2020 11:09
	25		Yes	530618	173478	16/09/2020 11:09
	26		Yes	530600	173428	16/09/2020 12:10
	27	Streatham Wells	No	531088	172926	16/09/2020 11:09
	28	Walnut Tree Walk	Yes	531024	179004	01/10/2020 10:39
	29		Yes	531082	178954	01/10/2020 11:11
	30		Yes	531022	178873	01/10/2020 11:32

[a] The adjacent road became a School Street on 7 December 2020.

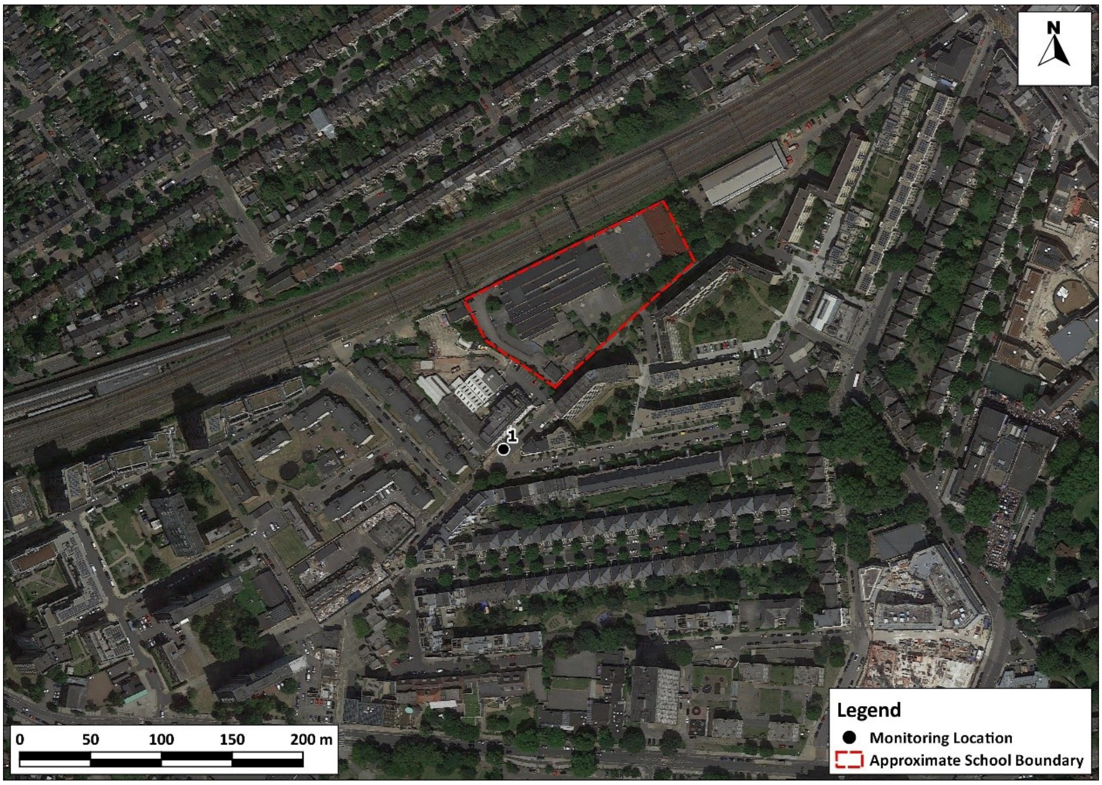

Figure 1: Monitoring Location 1

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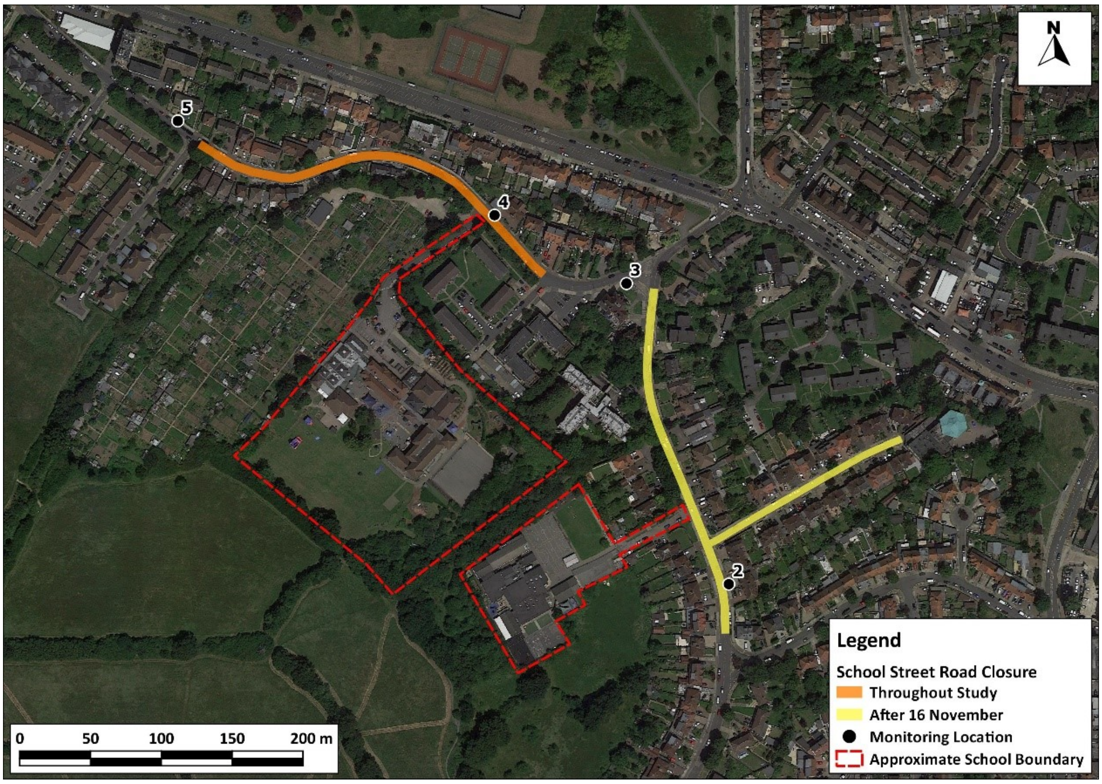

Figure 2: Monitoring Locations 2 to 5

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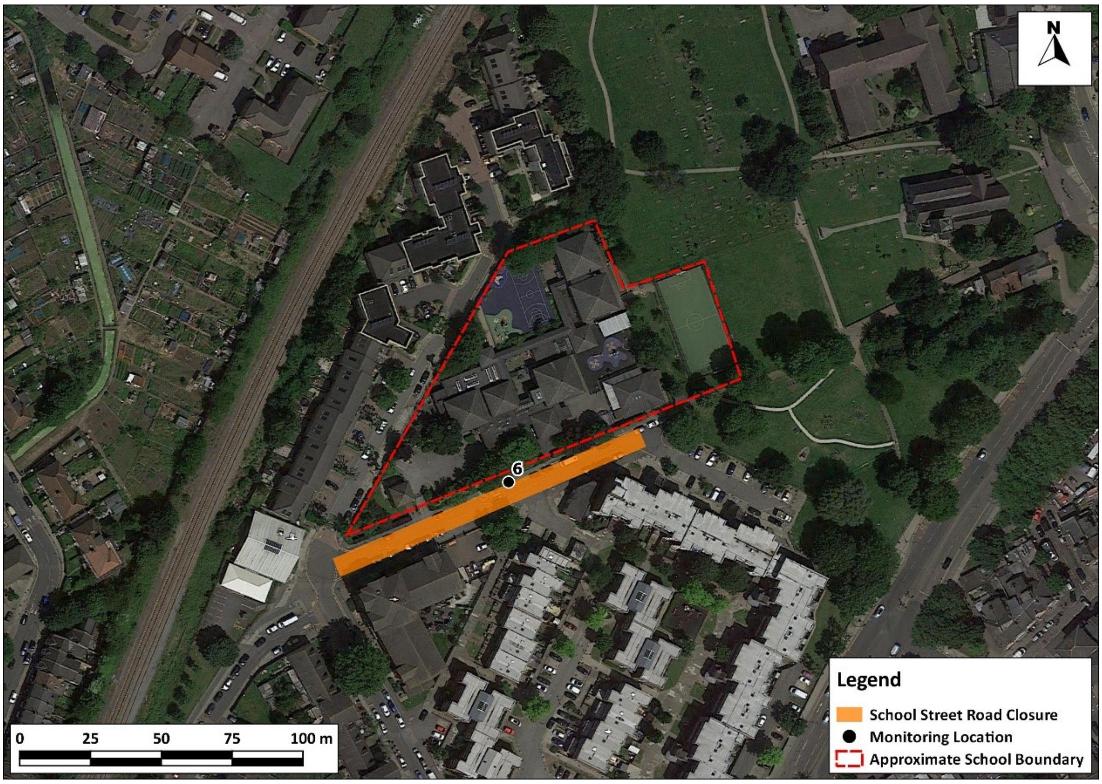

Figure 3: Monitoring Location 6

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Figure 4: Monitoring Location 7

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Figure 5: Monitoring Locations 8 to 10

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Figure 6: Monitoring Locations 11 to 13

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Figure 7: Monitoring Location 14

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Figure 8: Monitoring Locations 15 to 18

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Figure 9: Monitoring Location 19

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Figure 10: Monitoring Locations 20 to 22

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Figure 11: Monitoring Location 23

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Figure 12: Monitoring Locations 24 to 26

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Figure 13: Monitoring Location 27

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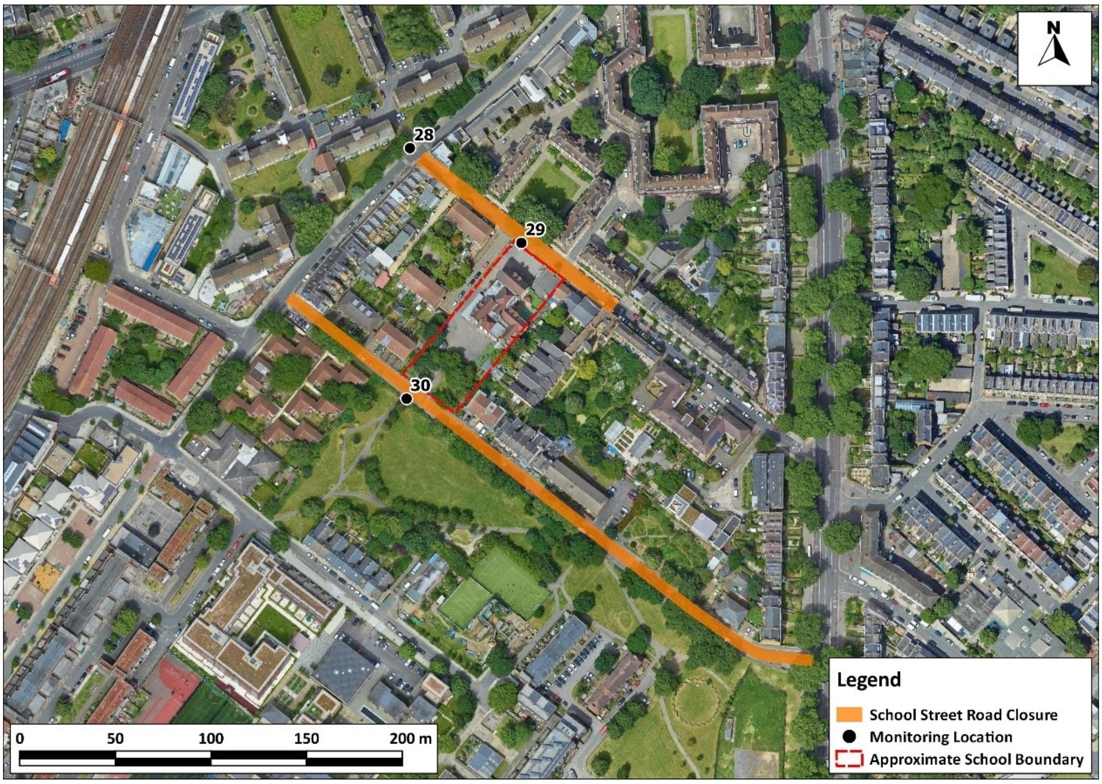

Figure 14: Monitoring Locations 28 to 30

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QA/QC Procedures

2.8 Each sensor system (pod) is fitted with two electrochemical sensors, one for Nitric Oxide (NO) and the other for Nitrogen Dioxide (NO_2). These were calibrated at the factory in Stratford Upon Avon, Warwickshire, by comparison with a chemiluminescence monitor, which is designated as a reference monitoring device, for a period of at least 5 days. The output of the pods was then adjusted such that they agreed with the reference data source.

2.9 Quality assurance and control was managed using techniques developed as part of the Breathe London project.

2.10 Each pod was also compared with every other pod at this time, such that the level of agreement between the devices is as close as possible.

2.11 It is of note that the levels of NOx at the factory in Stratford Upon Avon are likely to be much lower than the levels in London; therefore, it was decided that one pod selected from the batch was co-located with a London reference monitoring site in order to adjust the calibration. As each of the pods had previously been shown to be comparable, it is reasonable to assume that any changes made to the calibration of the chosen pod would also apply to the other 29 pods. The pod chosen for co-location was pod 630 (Site 19 in Table 1) and it was co-located at a monitoring site at Holloway Road, Islington for the period of 30/09/20 until 12/11/20, after which it was moved to a site adjacent to St Andrews School, as part of the network. The pod was compared to a reference pod ("reference pod 17") from the Breathe London Pilot Project which had already been scaled to agree with the reference monitor at that location, the results of which can be seen in Figure 15. This pod is hereafter referred to as the "gold" pod, as it carries the traceability of the reference monitor.

Figure 15: Results of the co-location of Pod 630 with reference pod 17 at Holloway Rd, Islington

2.12 The entire pod network was operated at 1-minute average time resolution from the date of installation until around December 20th 2020, when they were collected from site and returned to the factory.

2.13 In addition to comparison with reference pod 17, the chemiluminescence data from the Holloway Road site were used to scale each pod in the network against all others in the network using the Network Calibration Method (NCM). This method extracts the background or regional signal which is common to all locations in the Schools Streets network and uses this to verify the scaling of each individual pod such that comparability between them is optimal, the "gold" pod providing traceability to the chosen reference monitor at Holloway Road, Islington. This is applied using an advanced algorithm developed within the Breathe London project and shown to provide reliable results. The process is shown in Figure 16.

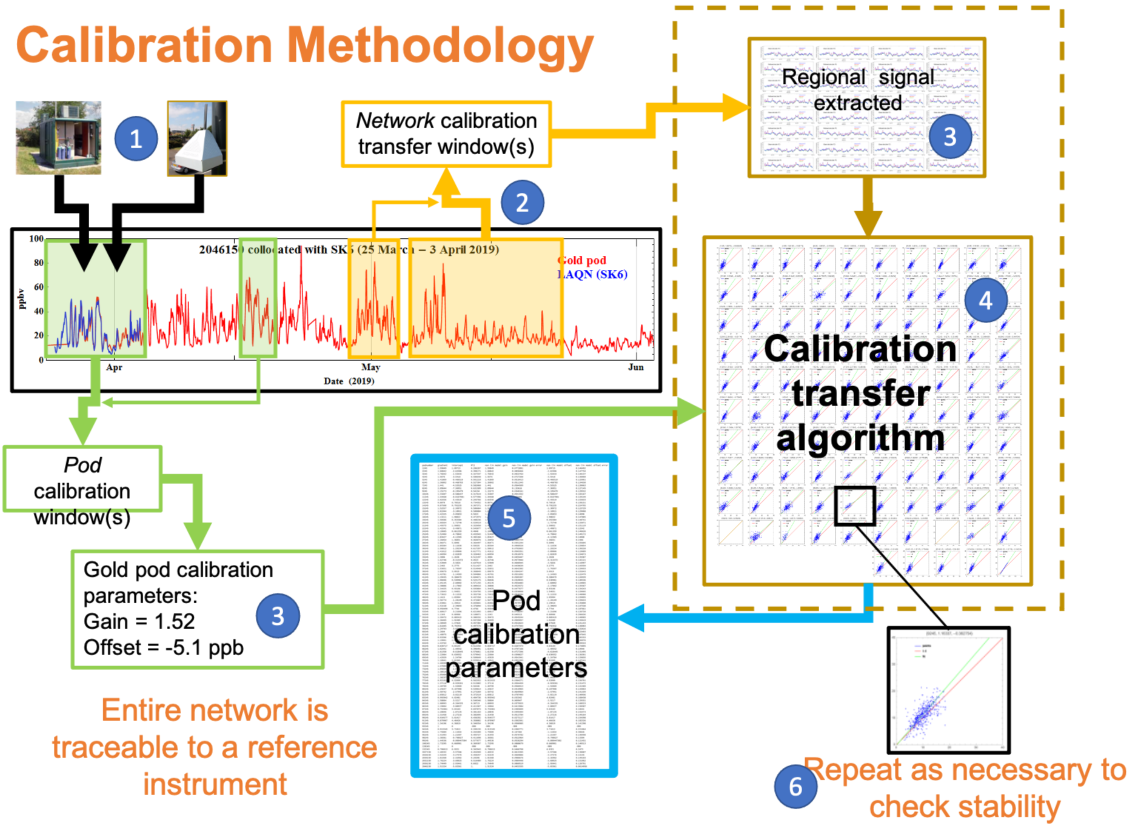


Figure 16: Network Calibration Method

2.14 The steps of the above process are described as follows:

- co-locate one chosen sensor from the network with a reference data source and "calibrate" it to agree;
- collect fast data (1min averages) from all the sensor in the network for a period of time (ideally 1-4 weeks);
- extract the regional signal from that data;
- use the regional signature to adjust each sensor to agree with all of the others and to the calibrated sensor;
- now all sensors in the network are comparable with one another and traceable to the reference;
- repeat over time as necessary.

2.15 The sensor devices (pods) have the ability to detect major faults and failures and to flag these in the dataset. Depending on the status of the data received, Acoem Air Monitors were able to assign a Valid or Invalid flag depending on the nature and severity of the status flags received. Invalid data were ignored in the subsequent analysis.

2.16 In addition, each week during the project, data from each location were plotted and visually checked in order to identify any obvious anomalies. This process identified two pods which had sensor issues, and as a result, data for the periods affected were flagged and / or redacted from the final dataset.

2.17 Data capture overall was good and over 98% across the entire network. Most locations delivered 100% data capture, and only three or four sites suffered any degree of data loss. Where it was possible to correct a problem, remedial action was taken, such as sensor replacement; however, this leads to a possible "step change" requiring additional scaling correction. This was the case at only one location during the project. A second location experienced problems towards the end of the project and there was insufficient time to replace and recalibrate the sensor. The data in both cases were redacted.

2.18 When viewing data from all 30 locations, the level of similarity in the concentration trends is very high (see Figure 18), suggesting that much of the NOx pollution recorded is regional in nature, particularly so for NO_2 and less so for NO. Together with the changing levels of COVID-19 restrictions during the period, this makes it more challenging to identify any reductions related to the short term street closure program at certain sites.

Data Analysis

2.19 The scaled raw data provided by Acoem Air Monitors and CERC have been processed by AQC to identify the influence of the School Streets road closures on air quality adjacent to the identified schools. As already discussed in Paragraph 2.2, it was not possible to gather data for a period prior to the implementation of the School Streets interventions, so there are no baseline concentrations for comparison. Nor were concurrent traffic activity data available for the roads adjacent to the schools. The analysis has, therefore, focussed on identifying differences in the diurnal profile of concentrations between different monitors, specifically focussing on the periods when roads were closed due to the School Streets interventions. Tests have also been applied to seek to identify any statistically significant differences between concentrations during interventions and those when no intervention is in place.

2.20 The analysis has focussed on the 15-minute data; there was judged to be little benefit in using 1-minute data, given that all road closures were, in principal, for a minimum of one hour; thus, any effects should be evident in the 15-minute data. The data are time ending, i.e. the data for 7.45am represents an average of concentrations between 7.30 and 7.45am.

2.21 The analysis has considered both NO and NO_2 concentrations, although a discernible signal is expected to be most likely for NO, as the majority of local road traffic NOx emissions will be in the form of NO, with the proportion of NO_2 increasing with time and distance from the source.

Limitations

2.22 It is recognised that it is difficult to identify the influence of the School Streets interventions on pollutant concentrations, especially given that the interventions were implemented on relatively minor roads where the contribution from local traffic will be relatively small. These difficulties were recognised by Defra's Air Quality Expert Group (Defra Air Quality Expert Group, 2020a) in its report related to assessing the effectiveness of interventions on air quality:

"The assessment of interventions can be challenging for several reasons. These challenges include the common situation where interventions rarely occur in isolation from other changes that affect air quality and the difficulty in detecting and quantifying changes if the interventions are small. Indeed, not every intervention is detectable in terms of quantifying changes in pollutant concentrations or health outcomes, even using sophisticated analysis techniques".

3 Traffic

3.1 In addition to the usual complexities in determining the effect of an air quality intervention, the School Streets were all implemented over a period during which social and travel restrictions were introduced in relation to the COVID-19 pandemic. This caused appreciable changes to traffic volumes. This causes additional difficulty when analysing air quality measurements made over this period and when attempting to isolate the specific cause of changes to concentrations. Figure 17 describes the change in vehicle kilometres driven on London's roads, based on data provided by TfL. The vertical dashed lines on the plot represent dates when specific COVID-related restrictions were implemented; these were:

- the black line represents 16 March 2020, when people were encouraged to work from home if they could;
- the first red line represents the imposition of the national lockdown on 23 March 2020;
- the yellow line represents the first lifting of lockdown measures on 11 May 2020, when those who could not work from home were encouraged to return to work;
- the purple line represents 1 June 2020, when some primary school children returned to school, restrictions on leaving home were replaced by a prohibition on staying overnight away from home, and some non-essential shops re-opened;
- the pink line represents 13 June 2020, when "support bubbles" were implemented and some restrictions on gatherings were relaxed;
- the brown line represents 4 July 2020, when social distancing rules were relaxed further, more facilities were allowed to open and rules on gatherings were further relaxed;
- the turquoise line represents 14 September 2020, when the "Rule of Six" was implemented;
- the green line represents the entry of Greater London into Tier 2 restrictions on 17 October 2020;
- the time between the red lines represent the second national lockdown between 5 November and 2 December 2020;
- the blue line represents the entry in Tier 3 restrictions on 16 December 2020; and
- the orange line represents the entry in Tier 4 restrictions on 20 December 2020.

3.2 These 'background' changes to traffic flows have been taken into account when designing, and conducting, the following data analysis.

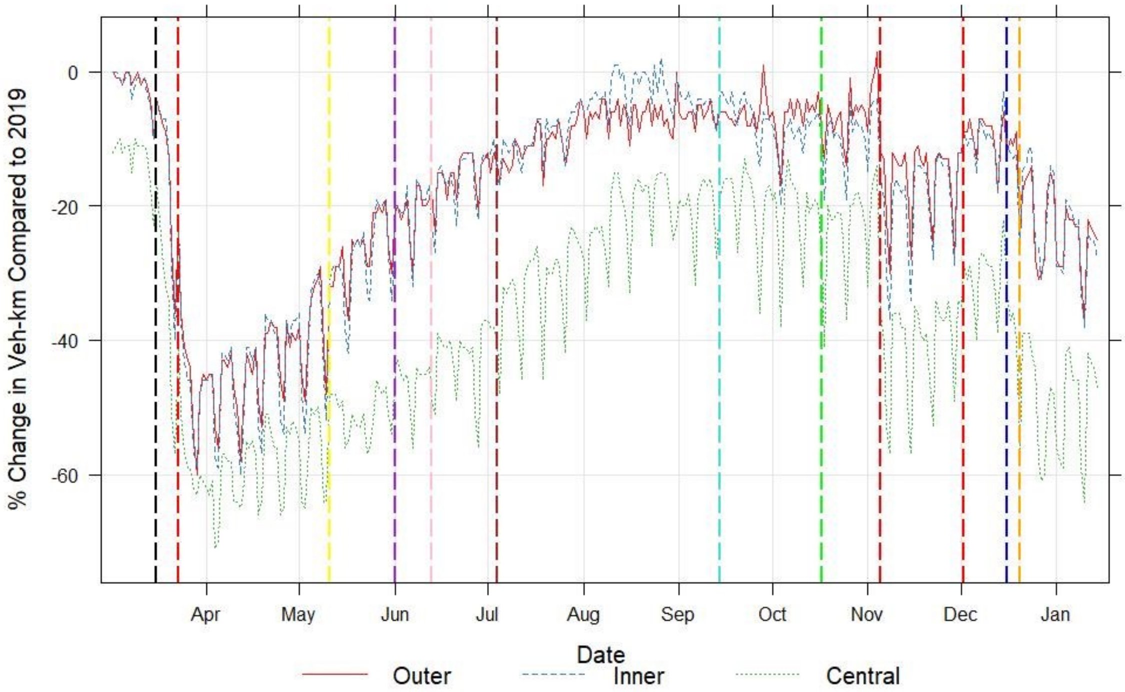


Figure 17: Changes in Vehicle kms driven in London Compared to 2019

4 Preliminary Analysis

Time Series

4.1 A time series of NO and NO_2 concentrations at each site is presented in Figure 18; the plot is not helpful in considering concentrations at individual sites, but highlights that the pattern of concentrations across all sites is generally very similar, suggesting that the measured levels are dominated by regional, rather than local effects. The vertical dashed lines have been added to demonstrate that there is no obvious effect on concentrations as a result of the differing COVID-related restrictions that were in place at different times in Greater London; instead, measured concentrations will have been affected by seasonal and meteorological factors. This should not be taken to suggest that the COVID-related restrictions have not affected air quality, and detailed analyses which account for the confounding effects of meteorology have shown that earlier restrictions had an appreciable effect (AQC, 2020a) (AQC, 2020b) (AQC, 2020c) (Defra Air Quality Expert Group, 2020b). Figure 18 illustrates that short-term temporal changes to pollutant concentrations are invariably dominated by changes to the weather and not to changes in local emissions. The identified restrictions represented by vertical dashed lines were as follows:

- the green line represents the entry in Tier 2 restrictions on 17 October 2020;
- the time between the red lines represent the second national lockdown between 5 November and 2 December 2020;
- the blue line represents the entry in Tier 3 restrictions on 16 December 2020; and
- the orange line represents the entry in Tier 4 restrictions on 20 December 2020.

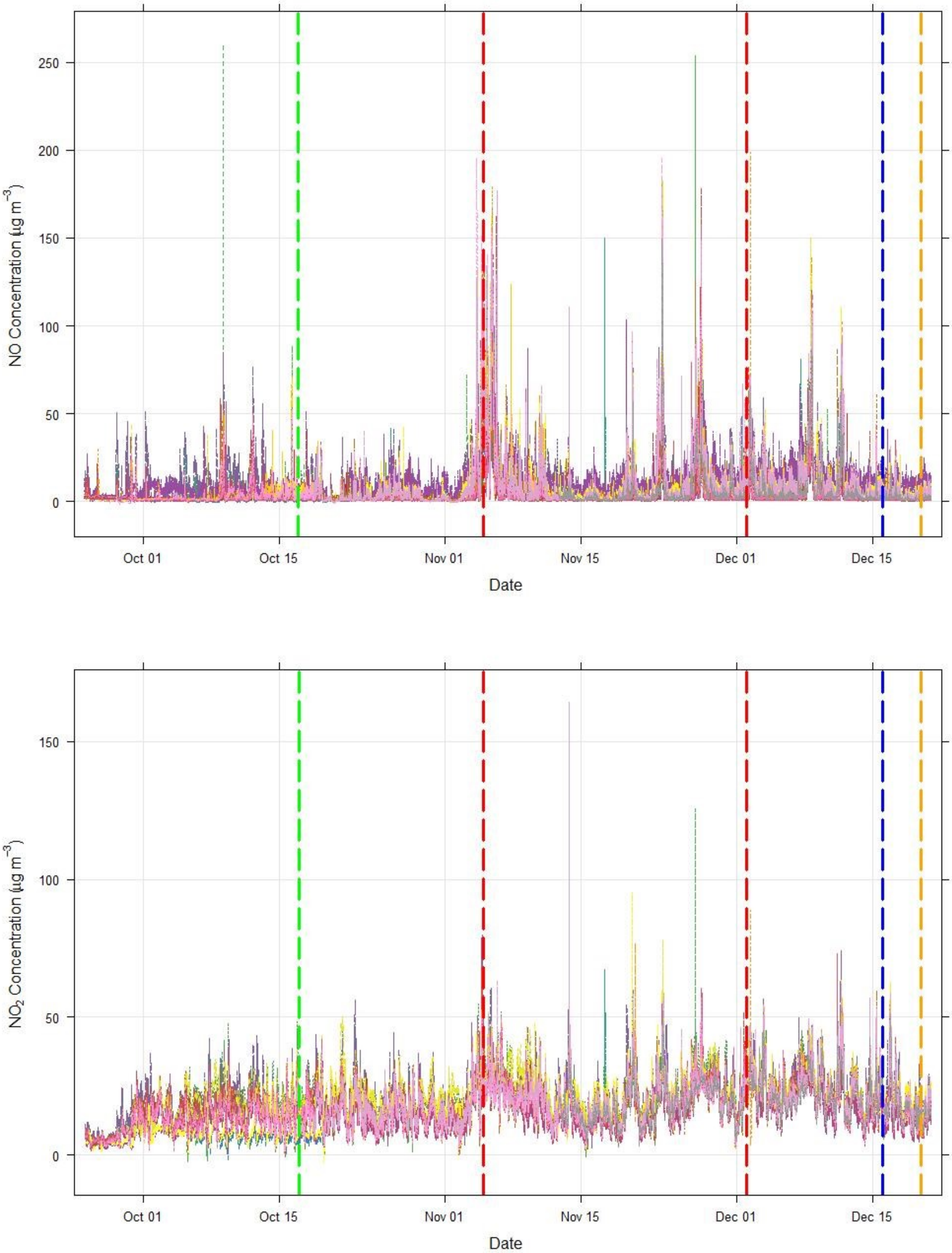


Figure 18: Time Series of NO (top) and NO_2 (bottom) Concentrations at All Sites (µg/m^3)

Diurnal Profiles

4.2 The first step in analysing the results has been to reduce the dataset to focus on the relevant time periods. Weekends, and the week of half-term has been stripped out of the dataset. The remaining weekday data have been averaged by timestamp, i.e. the measured concentration at 8:30am, for example, on every term-time weekday has been averaged to derive a single average concentration for this time of day. The average diurnal profiles of NO and NO_2 concentrations at each site are presented in Figure 19 to Figure 23. It should be noted that the profile presented in Figure 19 for Site 2 is that for the period before the adjacent road became a School Street; the effect of the change in status for this road is investigated later in this report.

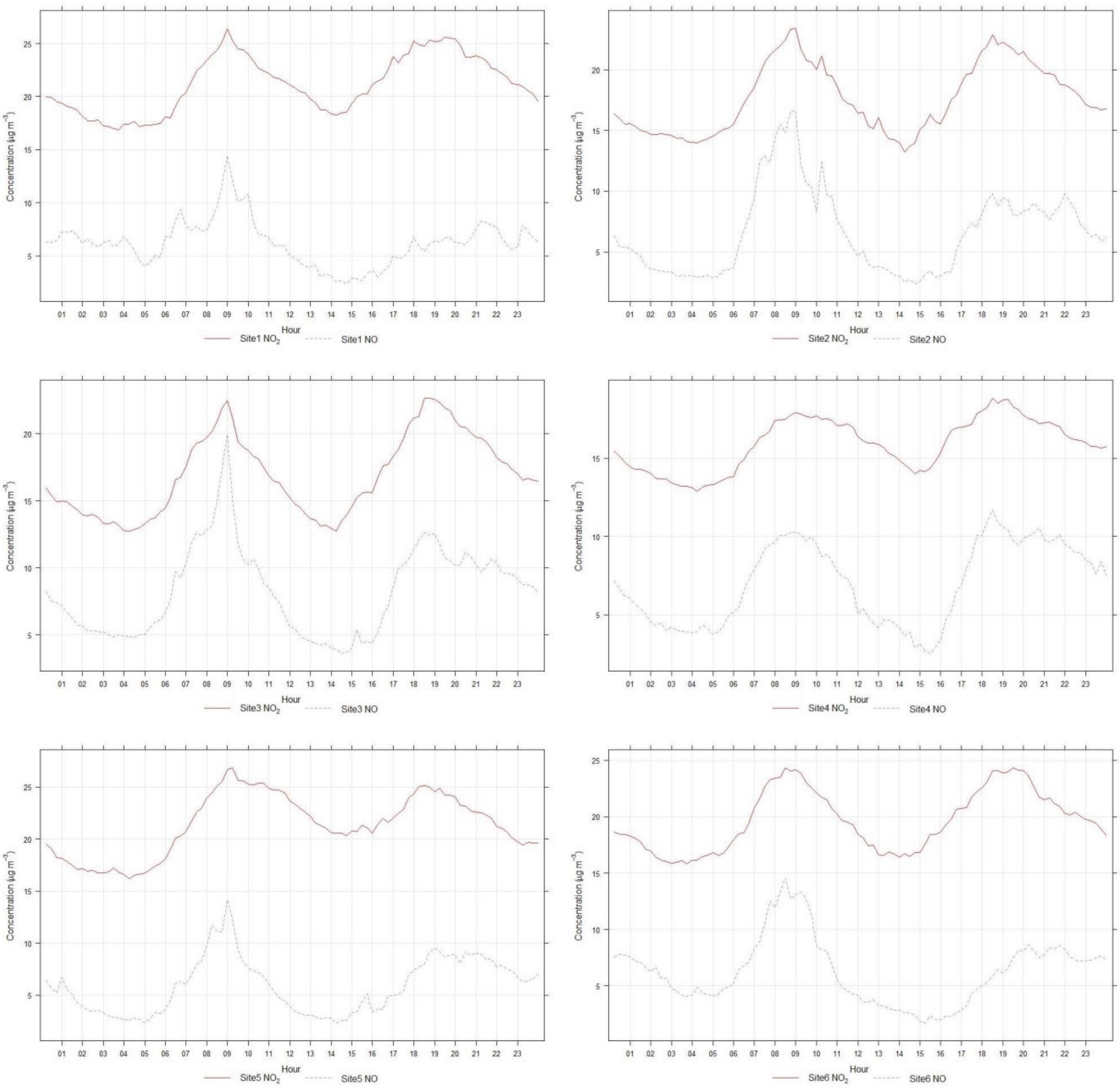


Figure 19: Average Diurnal Profile of NO and NO_2 Concentrations at Sites 1 to 6 ($\mu g/m^3$)

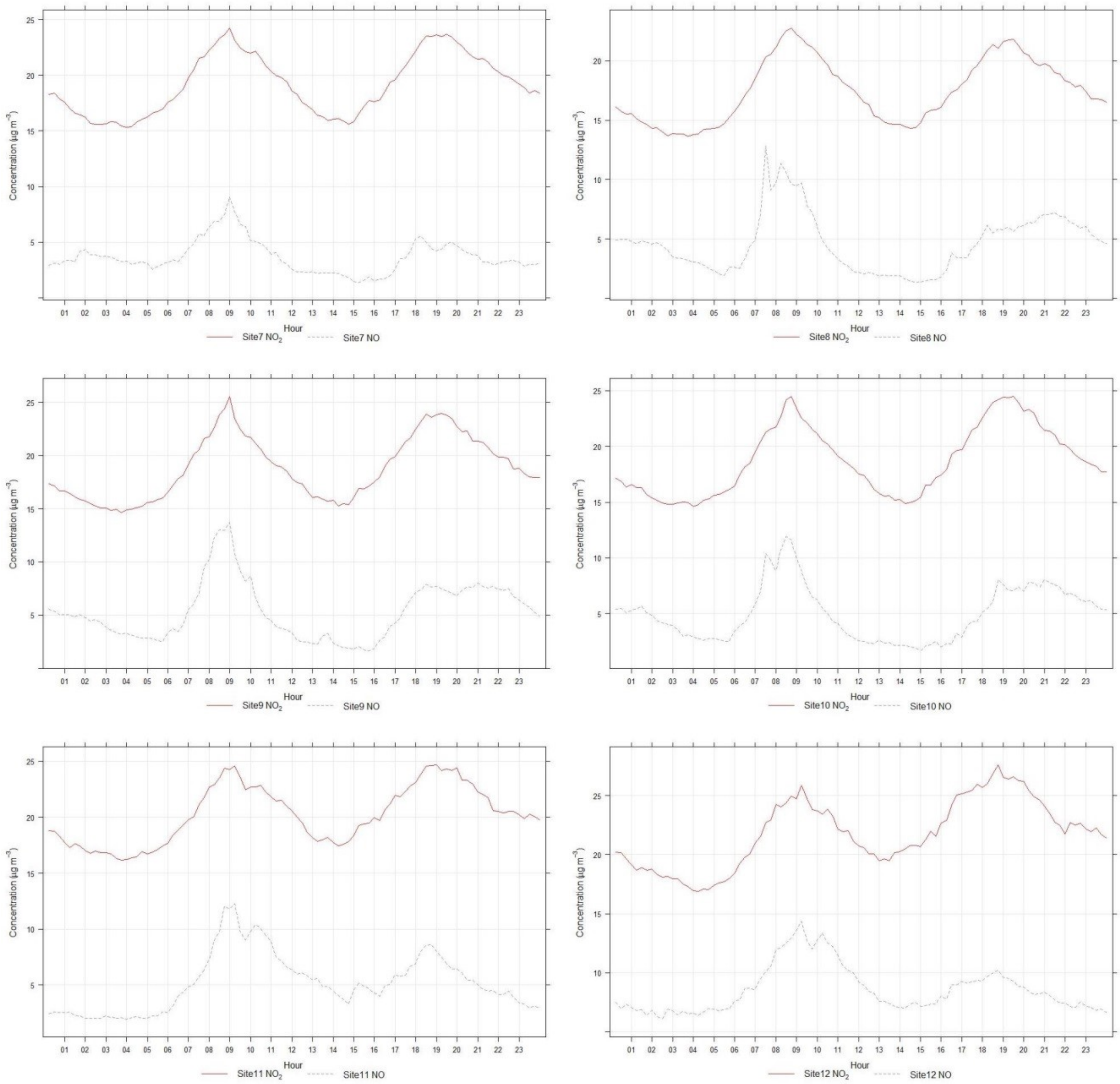


Figure 20: Average Diurnal Profile of NO and NO_2 Concentrations at Sites 7 to 12 (µg/m^3)

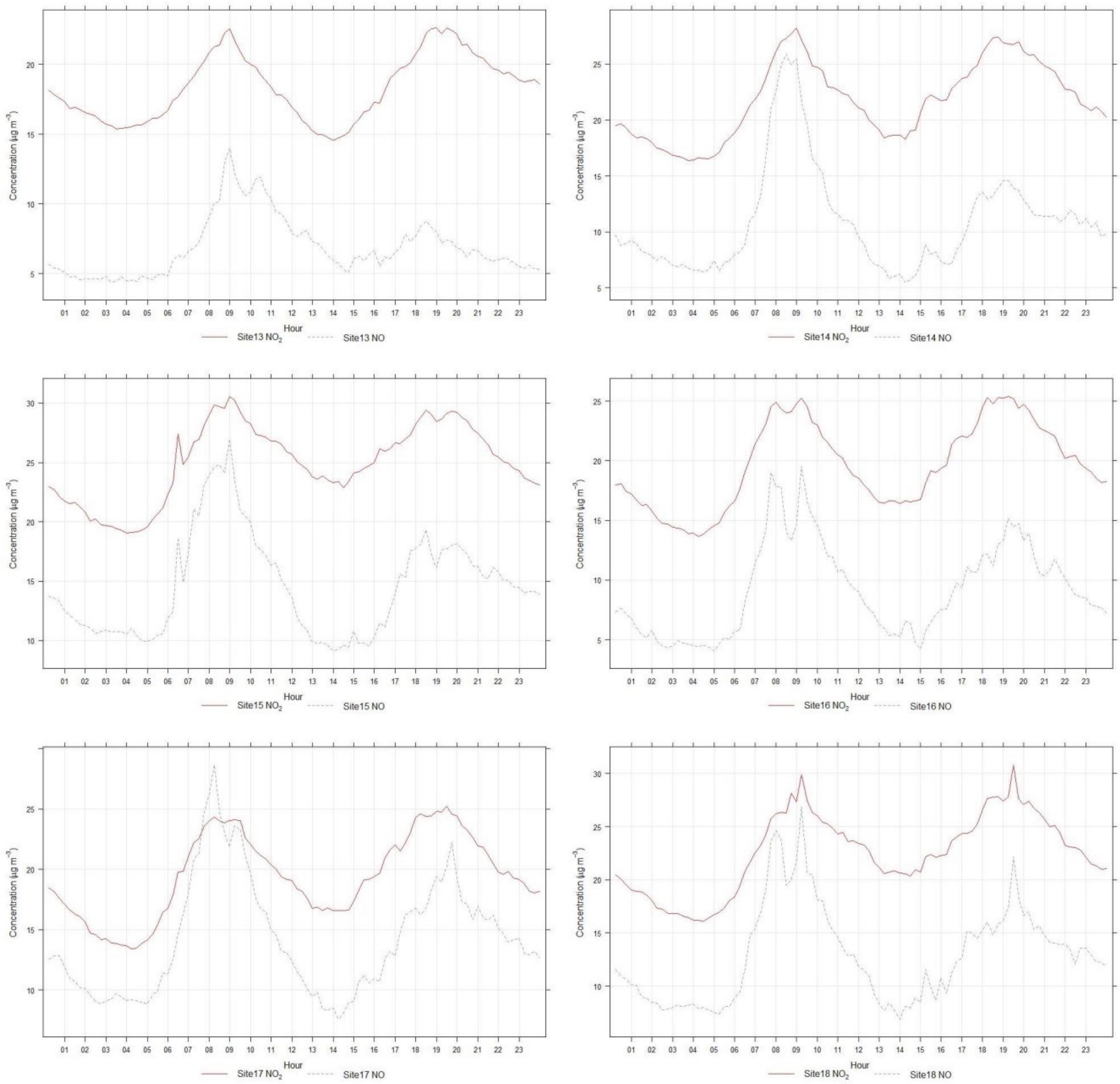


Figure 21: Average Diurnal Profile of NO and NO_2 Concentrations at Sites 13 to 18 (µg/m^3)

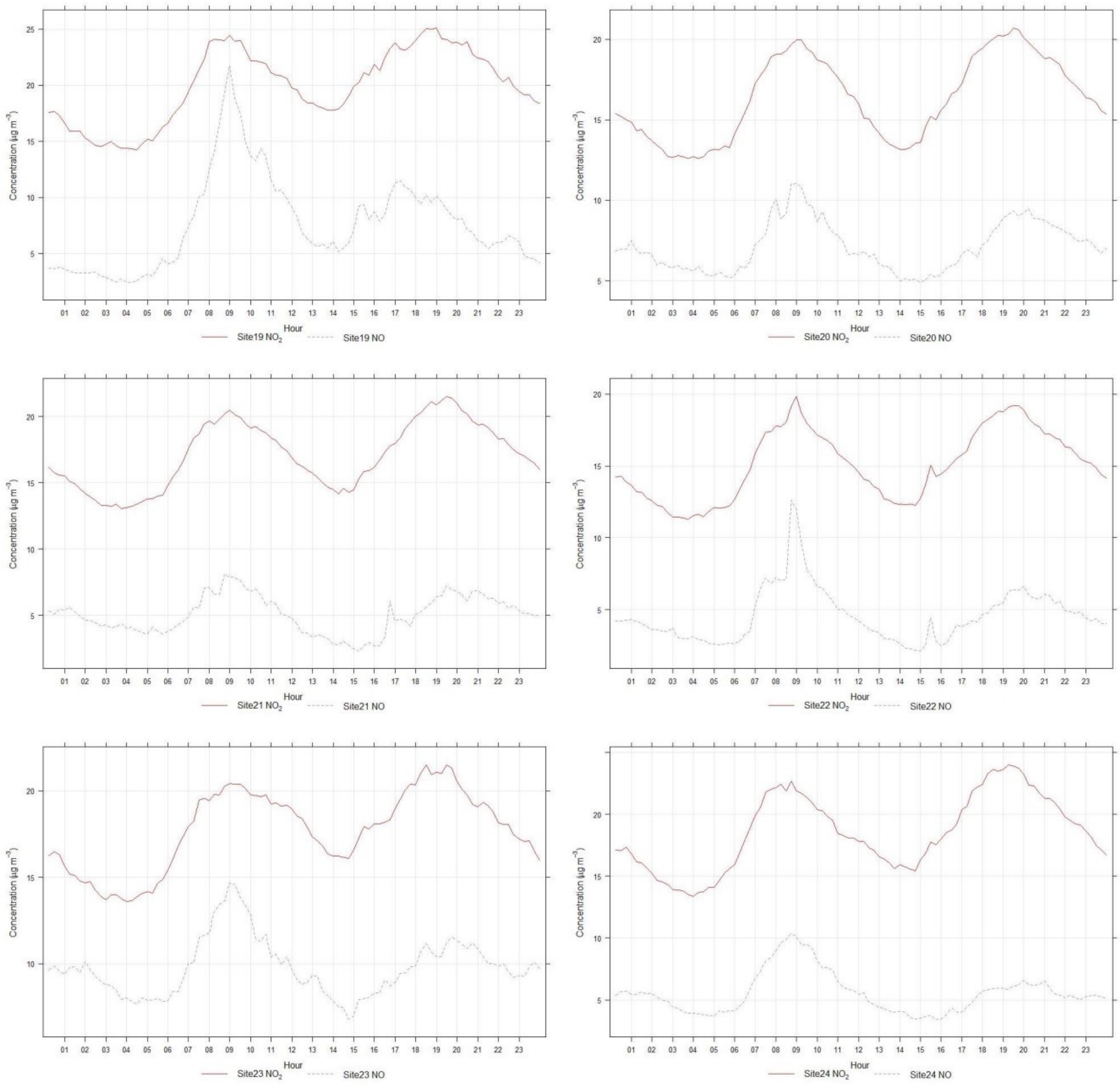


Figure 22: Average Diurnal Profile of NO and NO_2 Concentrations at Sites 19 to 24 (µg/m^3)

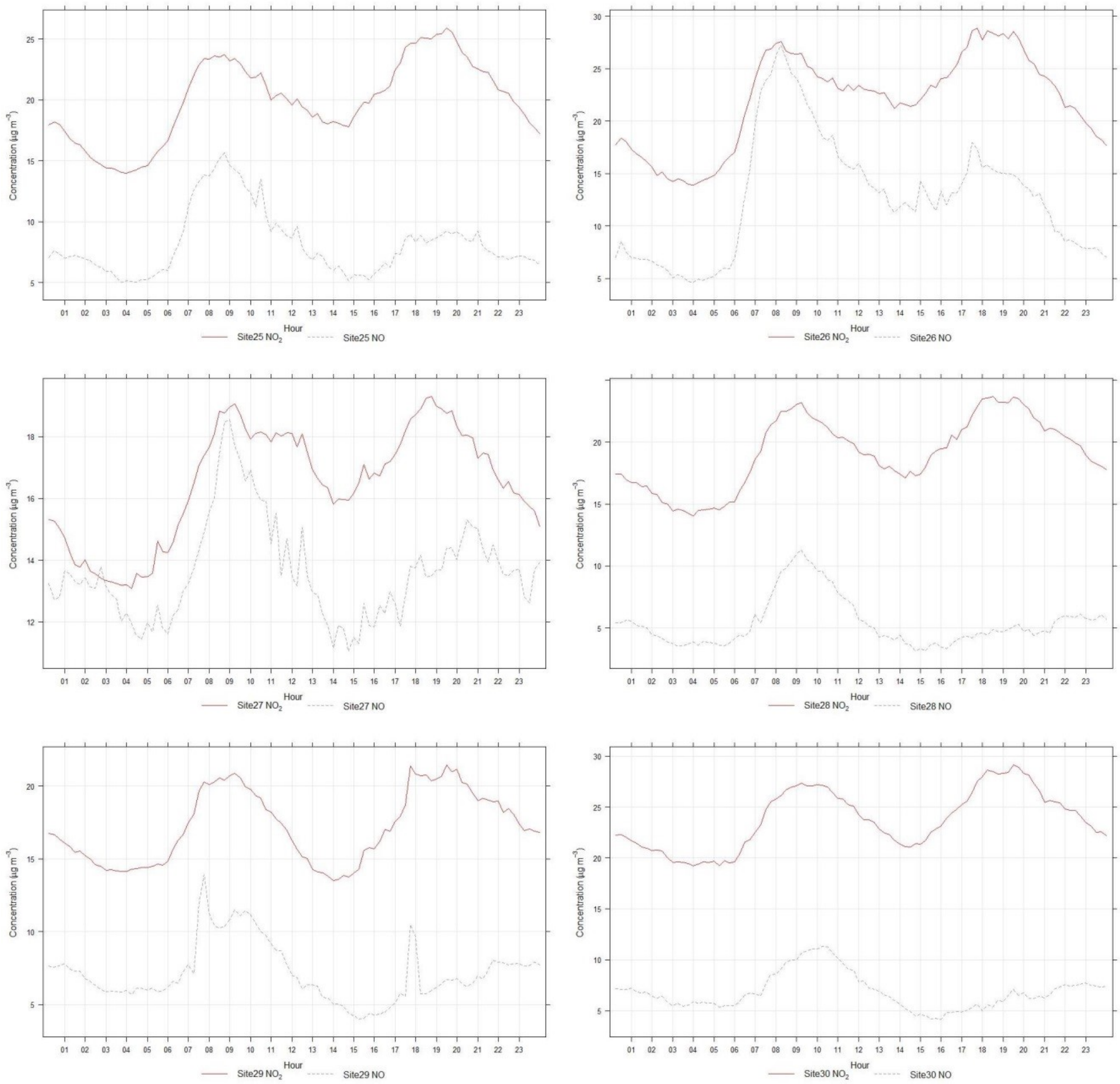


Figure 23: Average Diurnal Profile of NO and NO_2 Concentrations at Sites 25 to 30 (µg/m^3)

4.3 As mentioned in the previous section. There were limitations to the data collected in this study. Most notably the lack of baseline data and significant fluctuation in London-wide traffic volumes. Most of the diurnal profiles for monitors located at School Streets do not show a definitive change in concentrations during the periods of closure of the adjacent roads, although some do. Sites 16, 17 and 18 at Kingfisher Hall School in Enfield appear to have a dip in concentrations (especially NO) between 8.15-9.15am, although there is no obvious reduction in the afternoon.

4.4 Sites 20, 21 and 22 outside Van Gogh School in Lambeth also appear to have a dip in concentrations (again especially NO) in the mornings, around the times that the adjacent Hackford Road would have been closed and, to a lesser extent, a spike in concentrations following the re-opening of the road after the afternoon closure (although this appears a little early, especially for Site 22). The morning dip in concentrations at Sites 20, 21 and 22 appears to end at around 8.45am, while the road at Van Gogh School was reopened at around 9.05am.

4.5 Site 29 on Walnut Tree Walk, outside Walnut Tree Walk Primary School, also appears to show a dip during the morning closure, this time for the full period 7.45-9.15am; however, this may be a visual artefact of the large increase in concentrations immediately before 7.45am. Subsequent analysis of the raw data for this Site suggests that a few isolated spikes in concentrations (perhaps vehicle idling under the sensor) are skewing the profile, and there is no dip in concentrations if these are removed.

4.6 It should be noted that the morning road closures typically coincide with the peak traffic period, while the afternoon closures do not, occurring well before 5pm. As a result, it would be reasonable to expect the afternoon road closures to have less effect on pollutant concentrations than those in the morning.

4.7 While this initial analysis has highlighted a few sites where the influence of the School Streets interventions may be identifiable in the measured data, further investigation was required to support the confidence in conclusions, and to quantify the reduction in concentrations. This further analysis is described below.

Comparison of Profiles at Different Sites

4.8 A potential approach to identifying the effect of a School Streets intervention is by determining differences between the diurnal profiles at sites which are near to one another, either by:

- comparing sites that are located along the same road, but at different settings in terms of the likely influence of the School Street closure on that road, e.g. one may be in the centre of the closed section of road, where emissions may be lower than at sites at either end of the road closure, where cars may be stopping and turning around; or
- comparing sites that are located in a similar setting outside of schools in the same general area, but with one being a School Street and the other not.

4.9 This part of the analysis seeks to identify those pairs or combinations of Sites worthy of further investigation.

Sites 2 to 5

4.10 As shown in Figure 2, Sites 2 to 5 are all local to one another. Site 4 is located outside the Kingsbury Green Primary School gates, while Sites 3 and 5 are at either end of the section of Kenton Lane that was closed every morning and afternoon on schooldays during the study period. Site 2 is located as near as possible to the entrance to the nearby St Robert Southwell Primary School on Slough Lane; a School Street was only implemented on Slough Lane from 7 December 2020 (before and after analysis of the effects of the implementation are presented later). If traffic on Kenton Lane were a significant source of NO and/or NO_2, it would be reasonable to expect a distinct reduction in concentrations at Site 4 during the times that the road was closed, and the same would be true for Sites 3 and 5, although these may be influenced by blocked traffic that had to turn around. With no road closure on Slough Lane prior to 7 December, it might also be reasonable to expect a higher relative profile at this Site for the School Street closure periods than at the other Sites. Figure 24 presents the profiles for these four Sites on the same plots, for ease of comparison. The profile for Site 2 is that for term-time weekdays before 7 December.

4.11 The profiles in Figure 24 are all of a very similar shape, especially for NO, suggesting that concentrations at each of the Sites are influenced by the same sources. Given the shape of the profiles, with peaks around the morning and evening rush hours, the primary influence must be road traffic emissions, from the local and neighbouring road networks. There is no evidence in the NO plot to suggest a significant effect on concentrations from the closure of Kenton Lane either in the morning or afternoon.

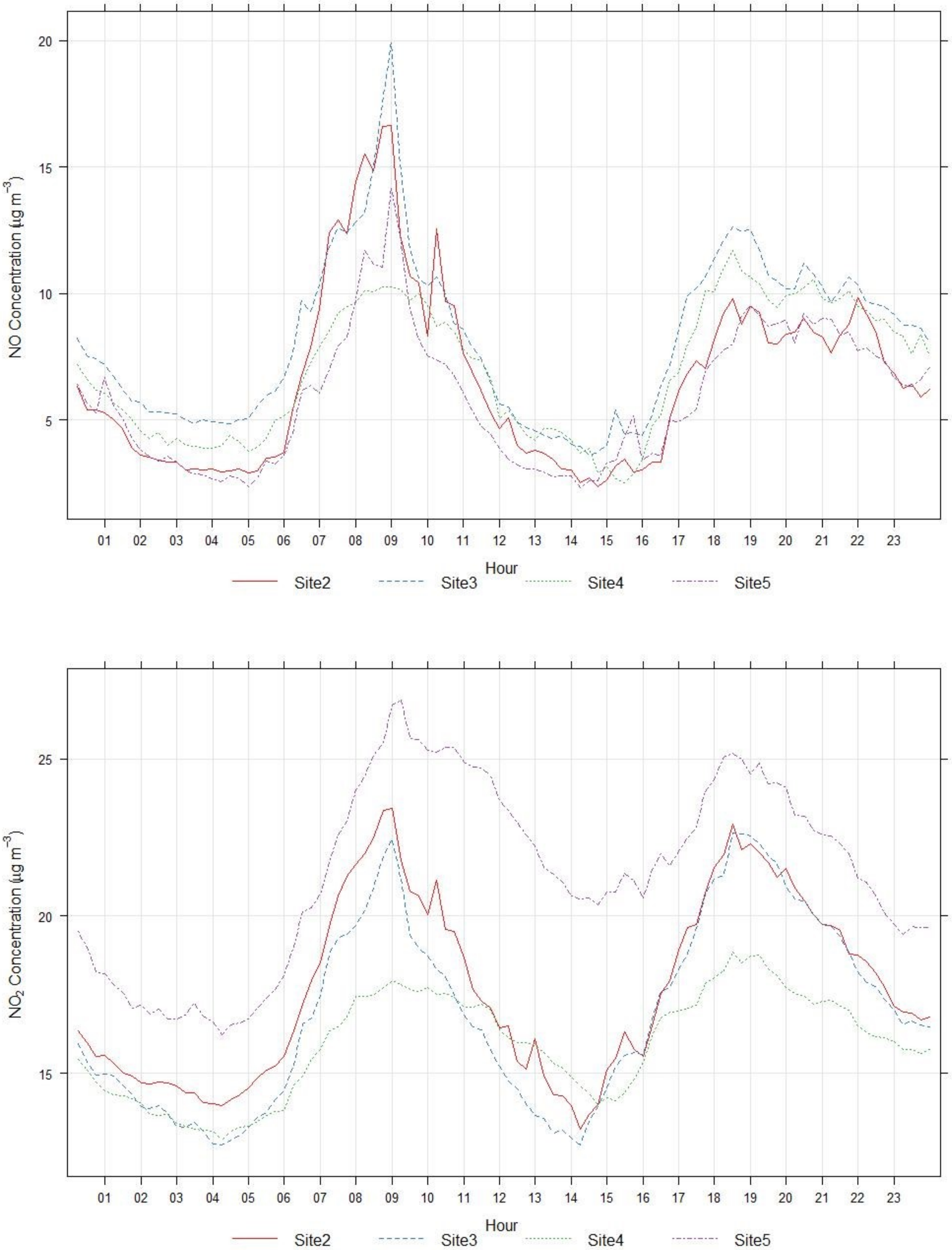


Figure 24: Average Diurnal Profile of NO and NO_2 Concentrations at Sites 2 to 5 (µg/m^3)

Sites 1 and 6

4.12 Sites 1 and 6 are both located in the south-eastern part of Brent, along roads that are dead-ends with schools along them. Site 6 is located along a School Street, while Site 1 is not. The profiles in Figure 25 are remarkably similar, considering that the Sites are some 4km from one another. This further emphasises that during the three months of the study it is regional emissions that are the principal driver of concentrations, rather than traffic emissions from the local roads adjacent to the monitors. There is no evidence in the profiles to suggest a notable influence on concentrations at Site 6 as a result of the School Street intervention, as compared to Site 1. By contrast, the morning NO profile for Site 1 looks more like what might have been expected at a School Streets site with a distinct flattening of the morning increase in concentrations during times when measures would have been in place (although the flat period does start much earlier than any of the interventions). This highlights that caution must be applied before assuming that any changes in concentrations are necessarily a result of the interventions.

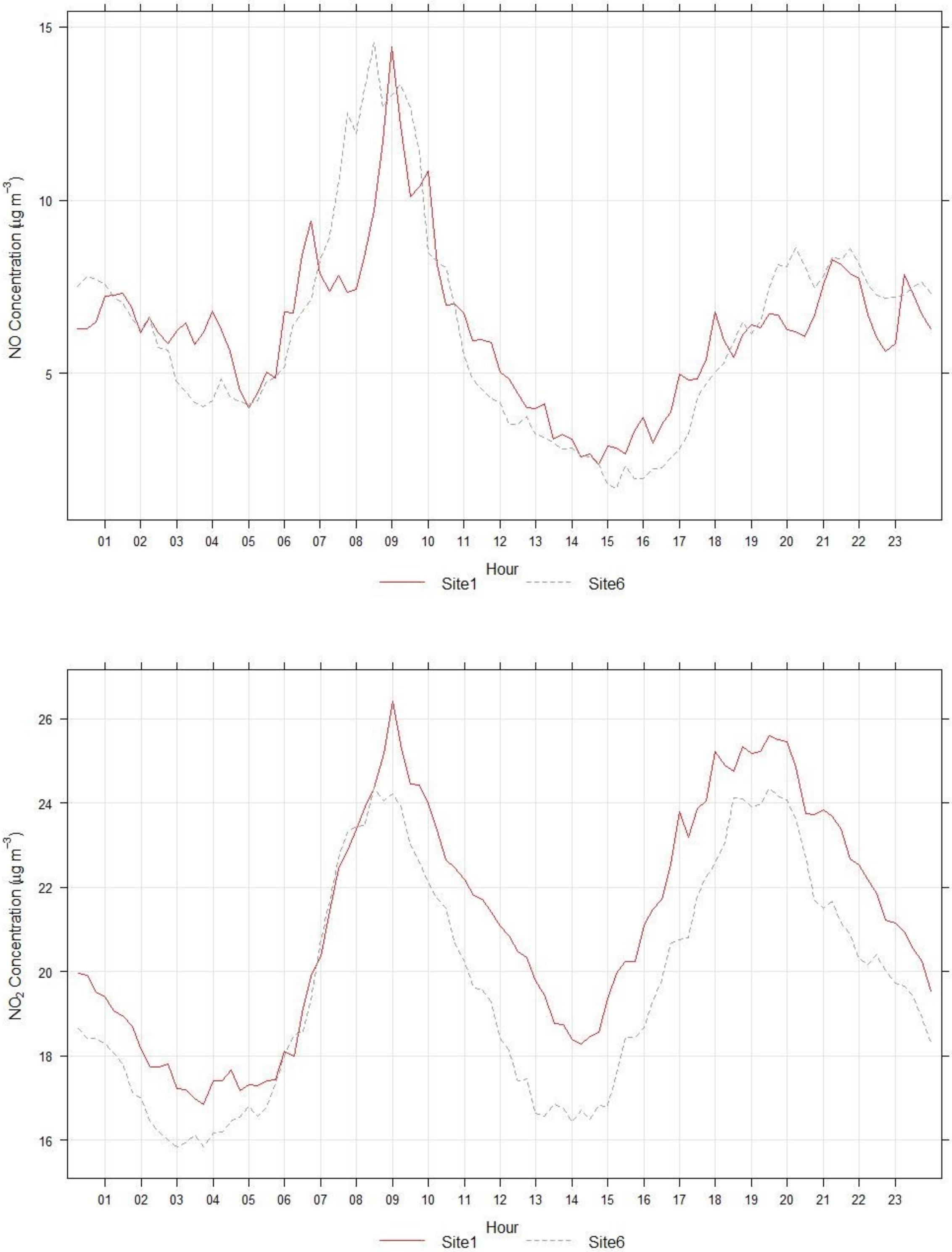


Figure 25: Average Diurnal Profile of NO and NO_2 Concentrations at Sites 1 and 6 (µg/m^3)

Sites 8 to 10

4.13 Sites 8 to 10 are located along Falcon Way/Cranleigh Gardens, near to the entrance to Uxendon Manor Primary School. Site 8 is located near to the centre of the closed section of Falcon Way, with Site 9 at the southern end of the closure and Site 10 further north at the junction of Cranleigh Gardens and Oakdale Avenue. The profiles in Figure 26 are all very similar, again suggesting concentrations dominated by regional effects, and show no obvious features to suggest a significant impact on NO or NO_2 concentrations as a result of the School Streets interventions.

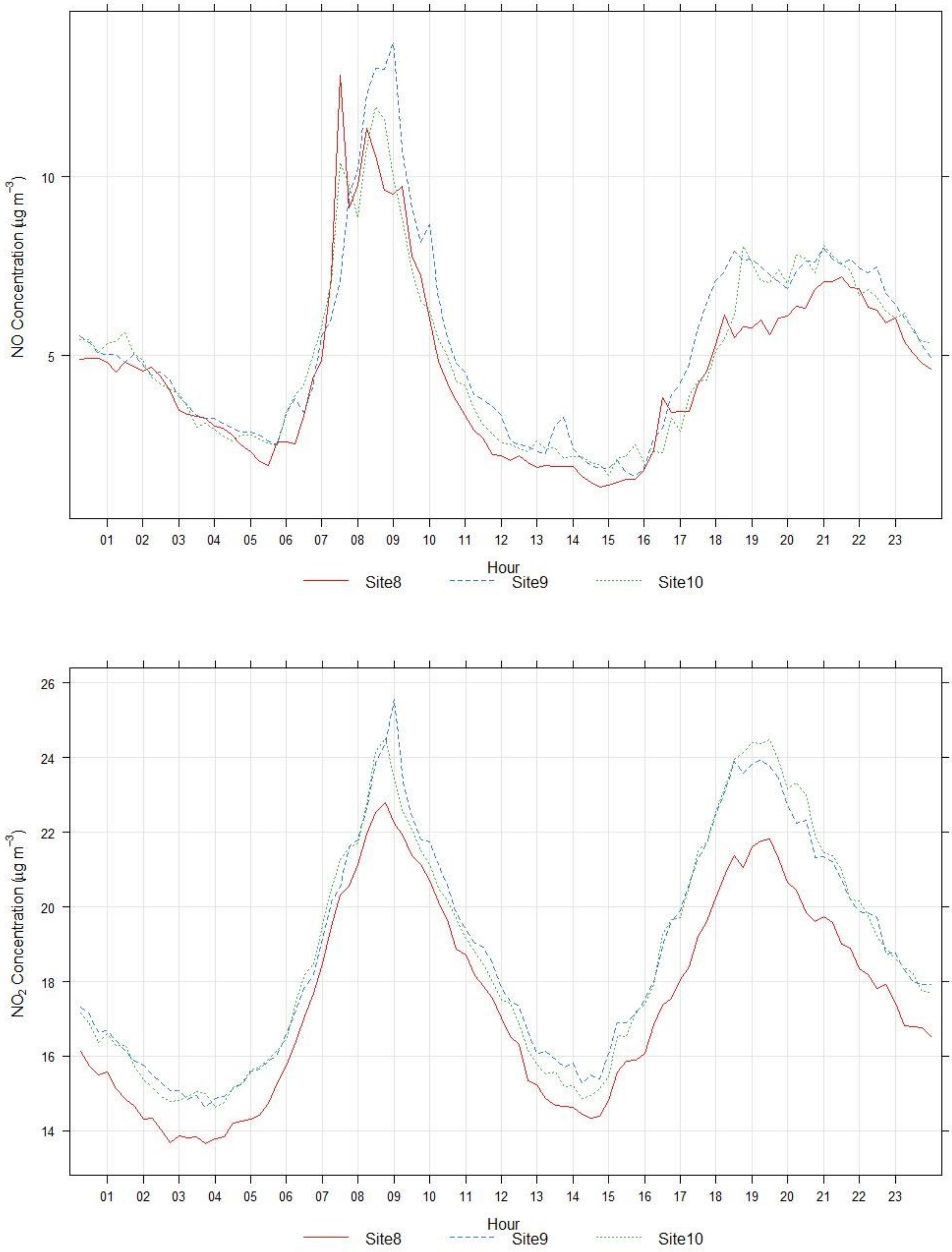
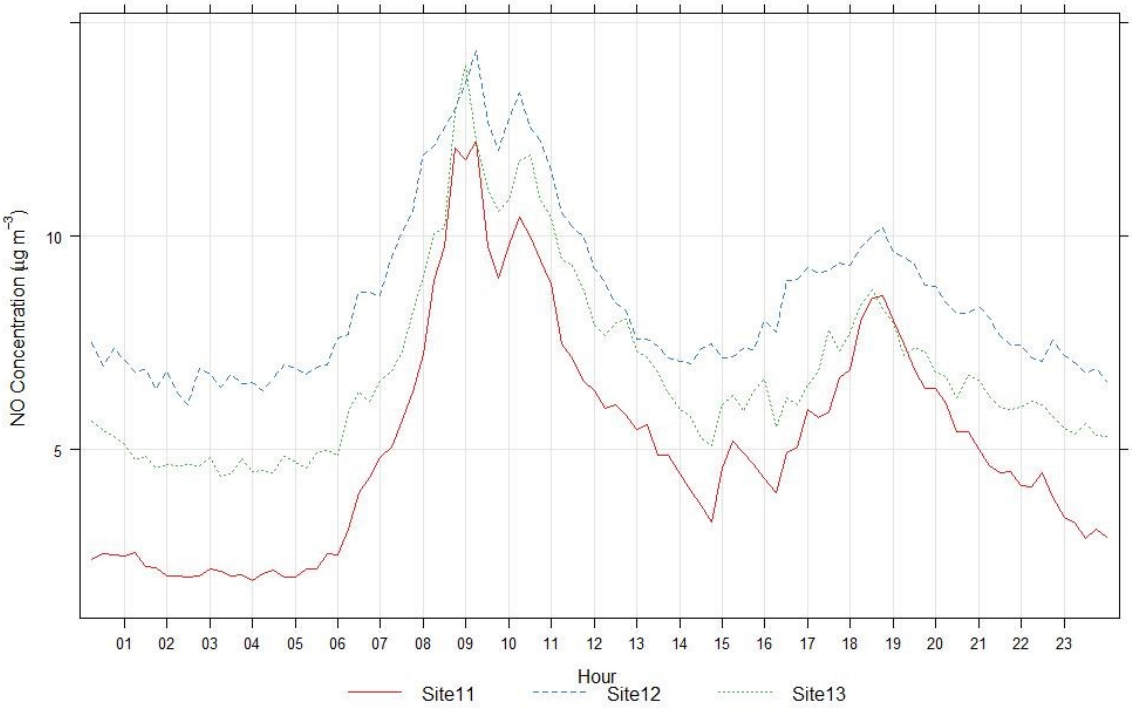


Figure 26: Average Diurnal Profile of NO and NO_2 Concentrations at Sites 8 to 10 (µg/m^3)

Sites 11 to 13

4.14 Sites 11 to 13 are located along Green Road outside De Bohun Primary School. Site 8 is located near to the centre of the closed section of Green Road, with the other two at either end. The profiles in Figure 27 show no obvious features to suggest a significant impact on NO or NO_2 concentrations as a result of the School Streets intervention.



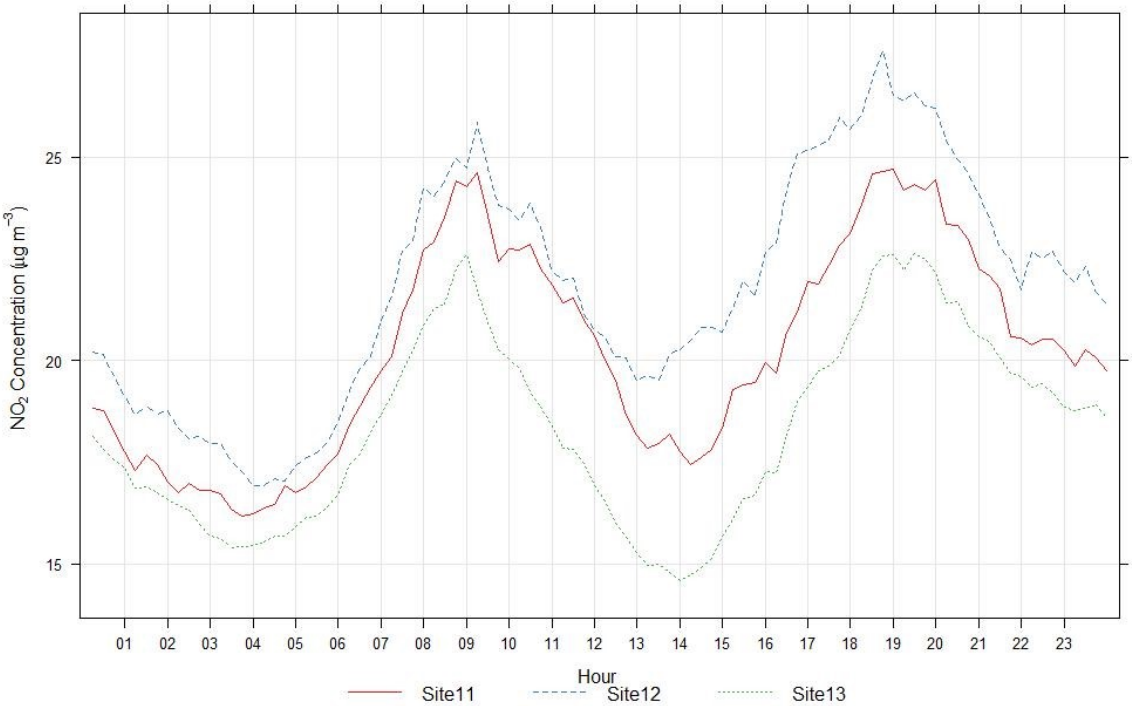


Figure 27: Average Diurnal Profile of NO and NO_2 Concentrations at Sites 11 to 13 (µg/m³)

Sites 14 to 19

4.15 Sites 14 to 19 are all located outside schools in the east of Enfield. Sites 14, 15 and 19 are located where no School Streets interventions were implemented, while Sites 16, 17 and 18 are located on The Ride, a School Street outside Kingfisher Hall Primary Academy. Site 16 is located near to the centre of the closed section of The Ride, with the other two at either end. The NO profile for Site 16 in Figure 28 appears to show a distinct reduction in concentrations between about 7:45am and 9:15am, with Site 18 showing a less obvious reduction, starting slightly later. There is also a reduction at Site 17, although this only begins after 8.15am. Site 16 again shows a slight dip around 3pm, during the afternoon road closure, while NO concentrations at the other sites are increasing. The profiles for NO_2 show no such obvious influences. The reductions at Sites 16 and 18, and possibly 17, show the clearest indications of the School Streets influences on pollutant concentrations.

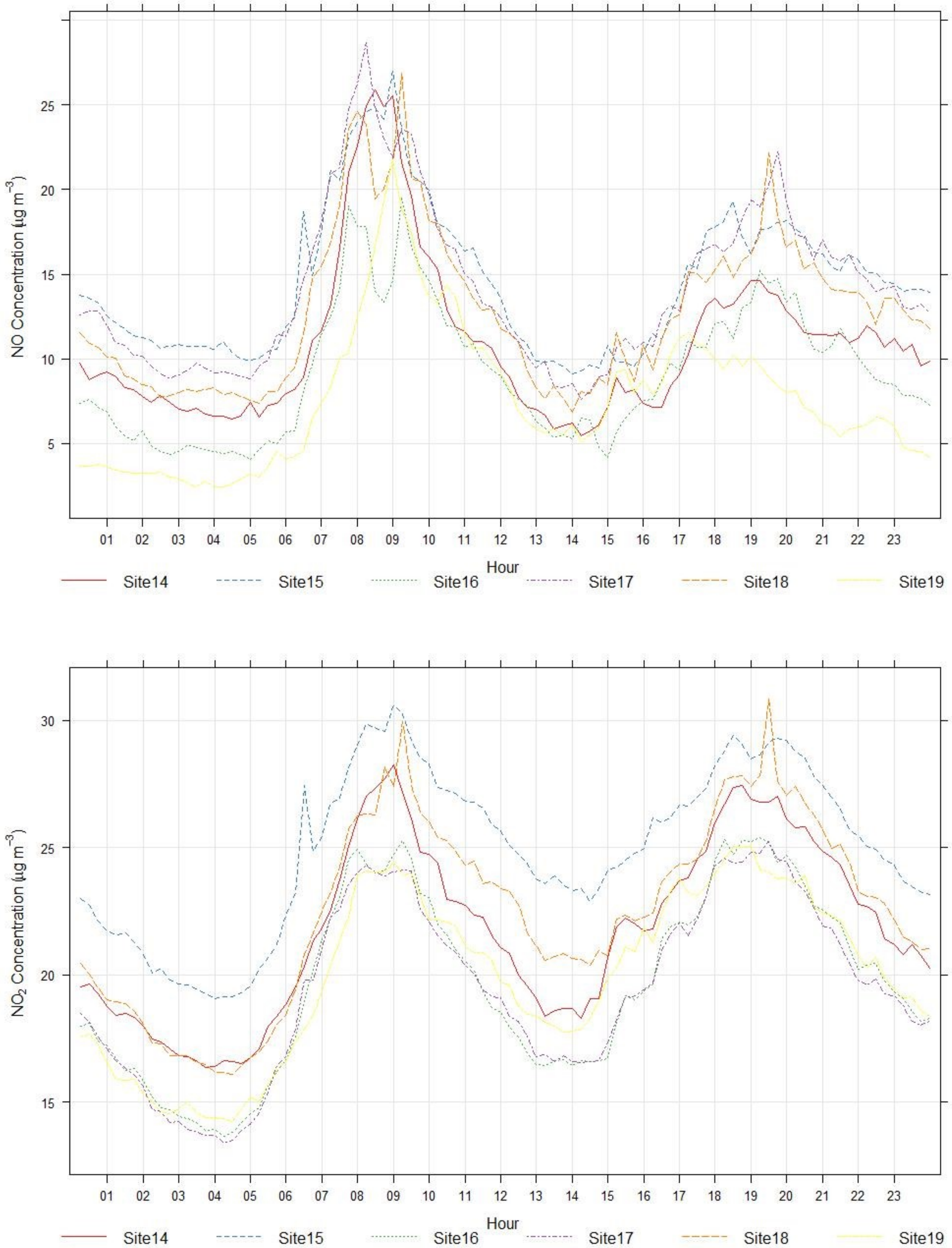


Figure 28: Average Diurnal Profile of NO and NO_2 Concentrations at Sites 14 to 19 (µg/m^3)

Sites 20 to 22

4.16 Sites 20 to 22 are located along Hackford Road outside Van Gogh Primary School in Lambeth. Site 21 is located near to the centre of the closed section of Hackford Road, with Site 20 at the northern end, opposite Southey Road, and Site 22 at the southern end at the junction with Durand Gardens/Hillyard Street. All three profiles for NO in Figure 29 show a dip in concentrations between about 7:45/8am and 8:45am; this is a shorter period than the road closures were supposed to be implemented for, but may be related to early reopening of the road once the children had entered the school. None of the profiles show an obvious influence in the afternoon.

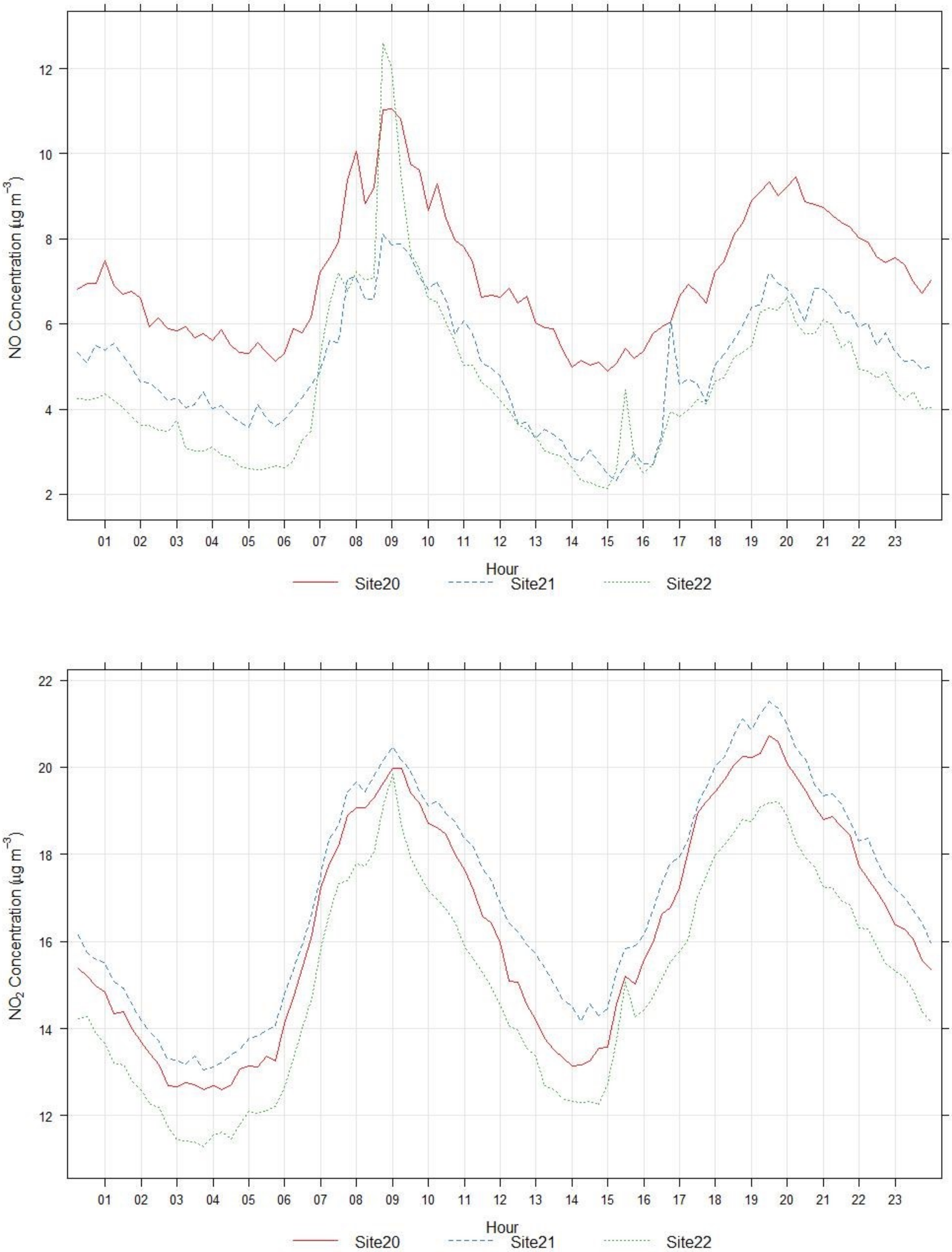


Figure 29: Average Diurnal Profile of NO and NO_2 Concentrations at Sites 20 to 22 (µg/m^3)

Sites 23 to 27

4.17 Sites 23 to 27 are closely located in Streatham Hill (see Figure 11, Figure 12 and Figure 13). Sites 23 and 27 are located outside schools with no School Streets interventions, on the north and south sides of the A205, respectively (but distant from this major road). Site 25 is located near the centre of the closed section of Cotherstone Road outside the Christchurch and Orchard Primary Schools, with Site 24 near the northern end of the road closure and Site 26 near the southern end, very close to the A205. With Site 26 being closest to the A205, it unsurprisingly tended to measure the highest concentrations, in particular during peak traffic periods. None of the profiles for Sites 24-26 in Figure 30 show a clear influence of the road closures, with the profiles being very similar in shape to those at Sites 23 and 27.

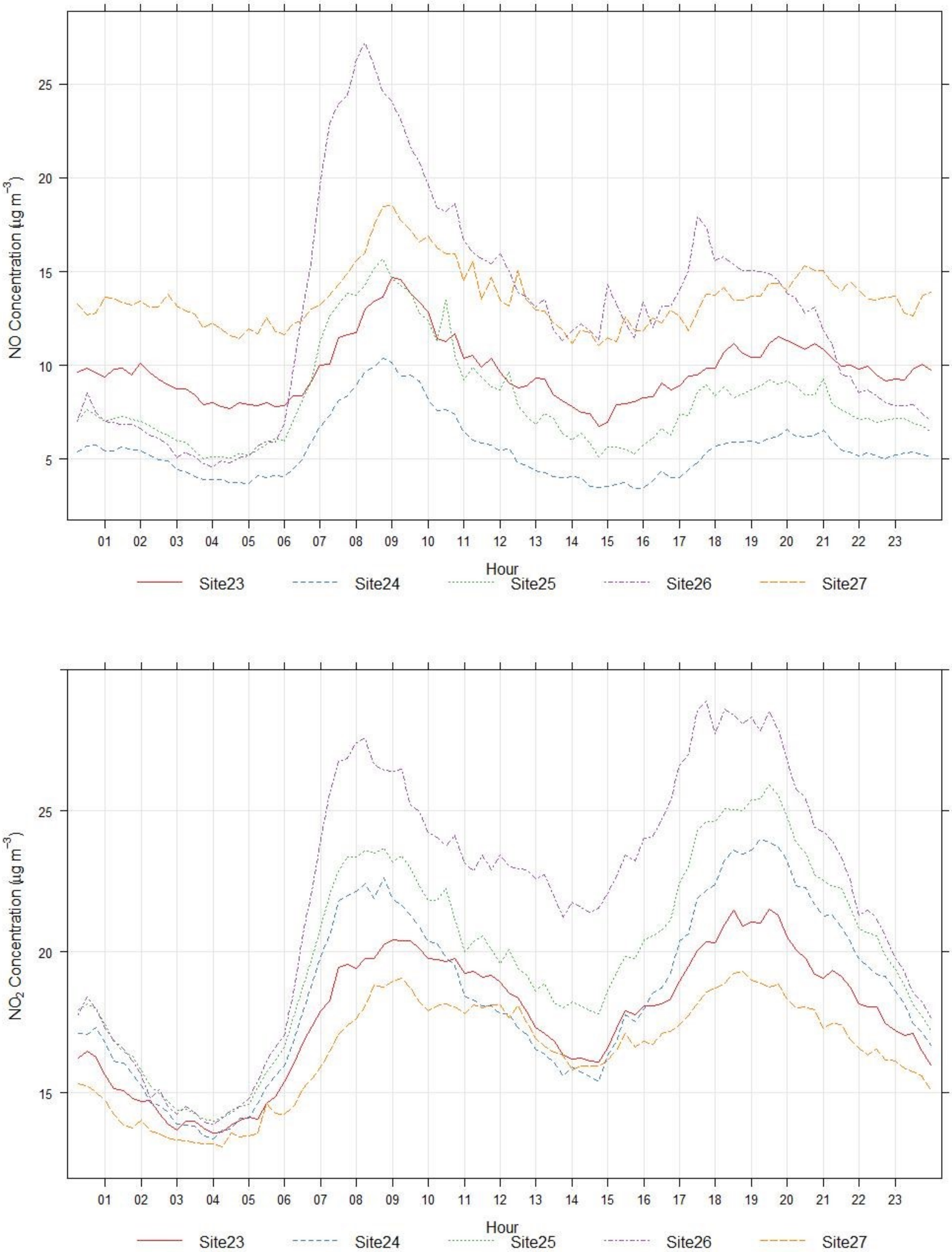
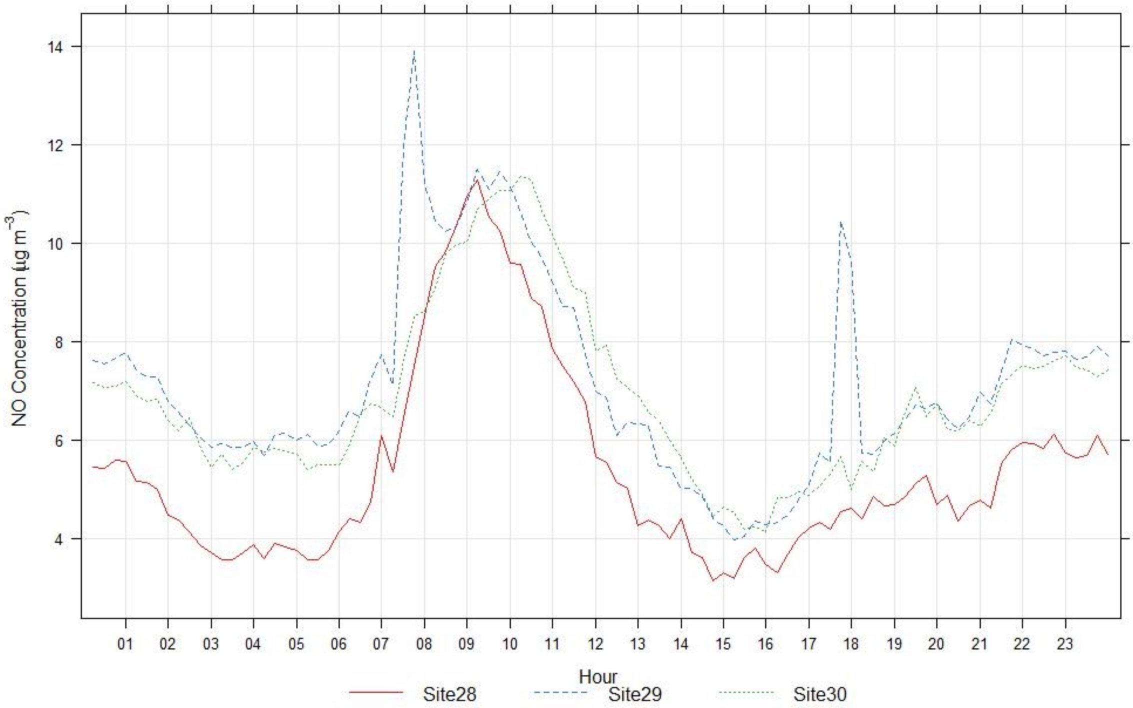


Figure 30: Average Diurnal Profile of NO and NO_2 Concentrations at Sites 23 to 27 (µg/m^3)

Sites 28 to 30

4.18 Sites 28 to 30 are all located outside Walnut Tree Walk Primary School (see Figure 14). The profiles in Figure 31 do not clearly show the influence of the road closures. The NO profile for Site 29 appears to show a dip during the morning closure, but examination of the raw data has highlighted that this is due to the spike in average concentrations around 7:30-7:45 am, rather than any real dip in concentrations. This elevation in average concentrations, and that shown at around 17:45, are due to a number of spikes at these times (on multiple different days) in the raw data. There is no reason to think that the spikes are not genuine, and may have been related to vehicles idling close to the monitor.



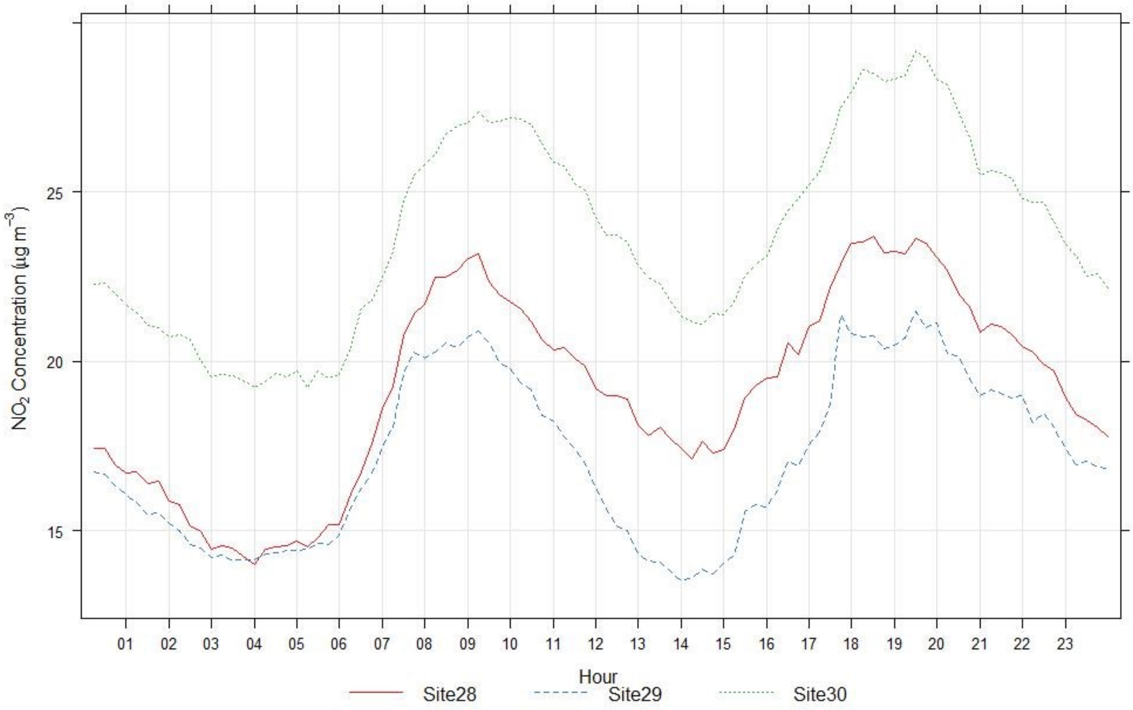
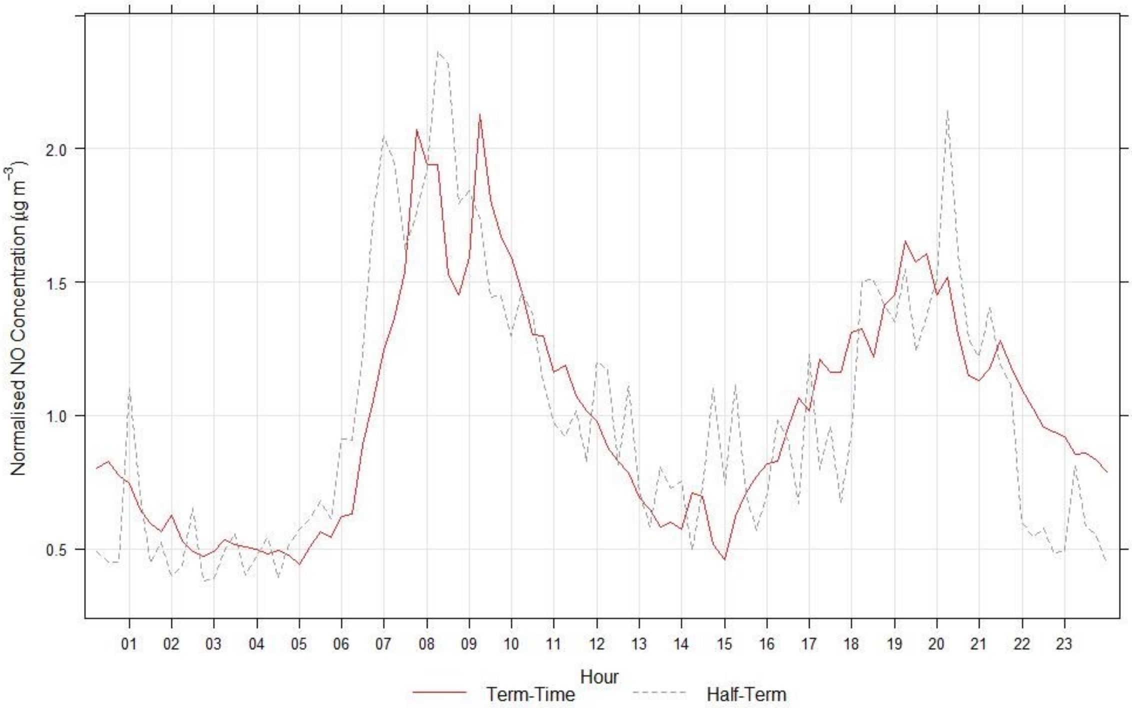


Figure 31: Average Diurnal Profile of NO and NO_2 Concentrations at Sites 28 to 30 (µg/m^3)

Half Term

4.19 The plots below (Figure 32 to Figure 37) compare the normalised (where 1 is the average concentration) profile of pollutant concentrations on weekdays during half term to those during term time at a selection of sites where School Streets were implemented, to see if the comparison identifies a clear difference between concentrations during the road closure periods to be seen. The analysis has focussed on those sites where a potential effect as a result of the School Streets interventions has been identified in the above time average plots, namely Sites 16-18 and 20-22.

4.20 In all cases, the profiles are quite different, with increased noise in the half-term datasets, likely due the relatively small number of data points that are being averaged, when compared to the term-time dataset. The profiles are not similar enough to allow a robust comparison of concentrations during the intervention periods.



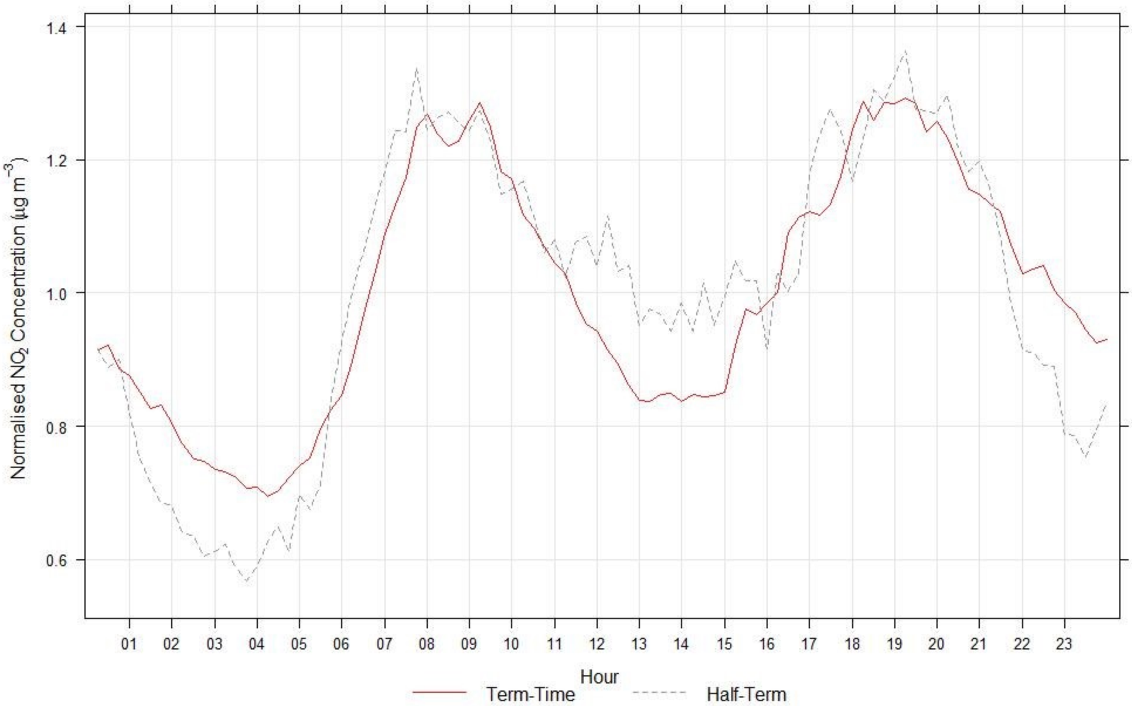
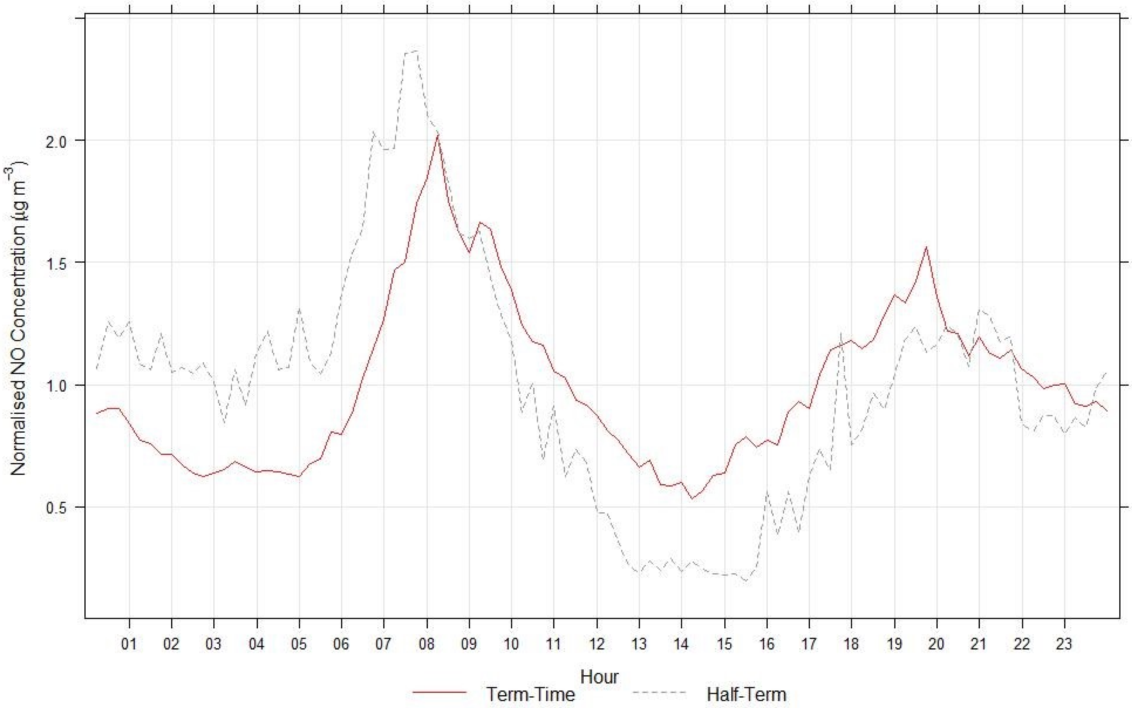


Figure 32: Normalised Diurnal Profiles of NO and NO_2 Concentrations at Site 16 during Term-time and during Half-term (µg/m^3)



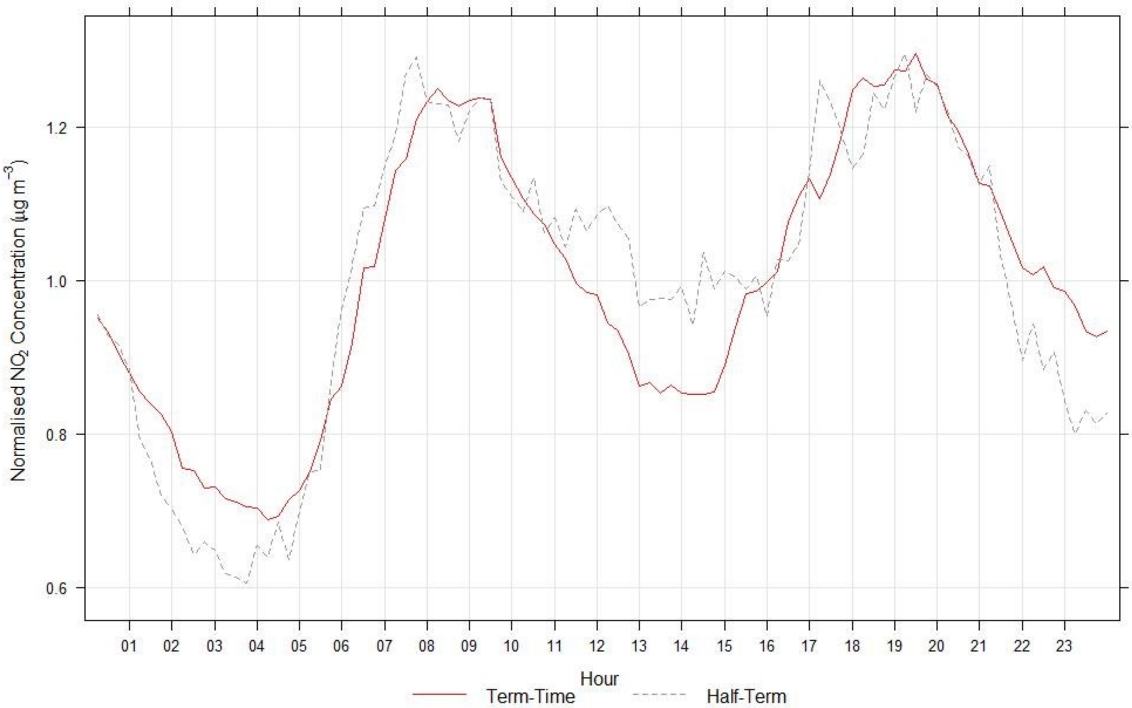
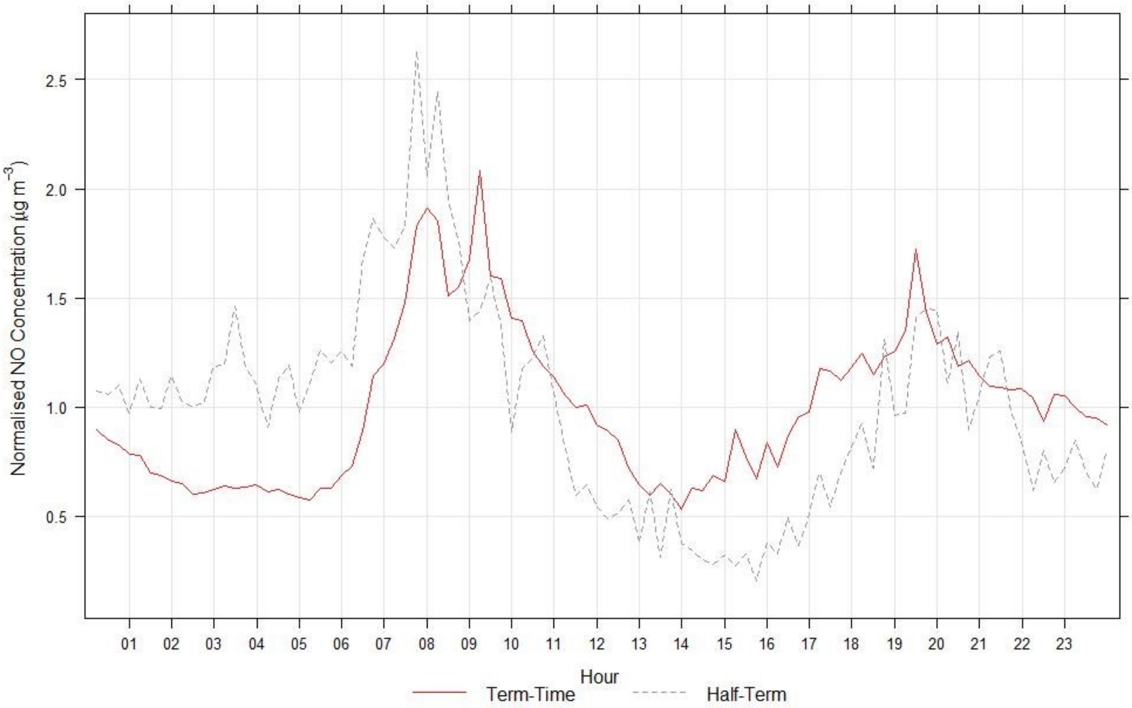


Figure 33: Normalised Diurnal Profiles of NO and NO_2 Concentrations at Site 17 during Term-time and during Half-term (µg/m^3)



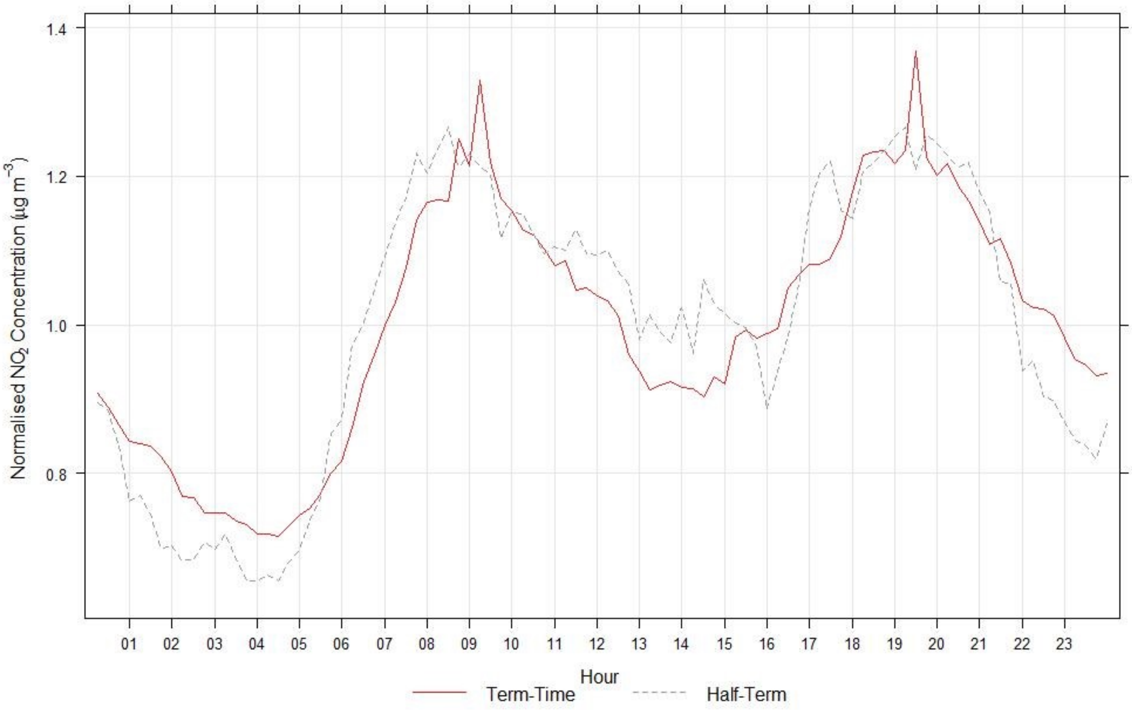


Figure 34: Normalised Diurnal Profiles of NO and NO_2 Concentrations at Site 18 during Term-time and during Half-term (µg/m^3)

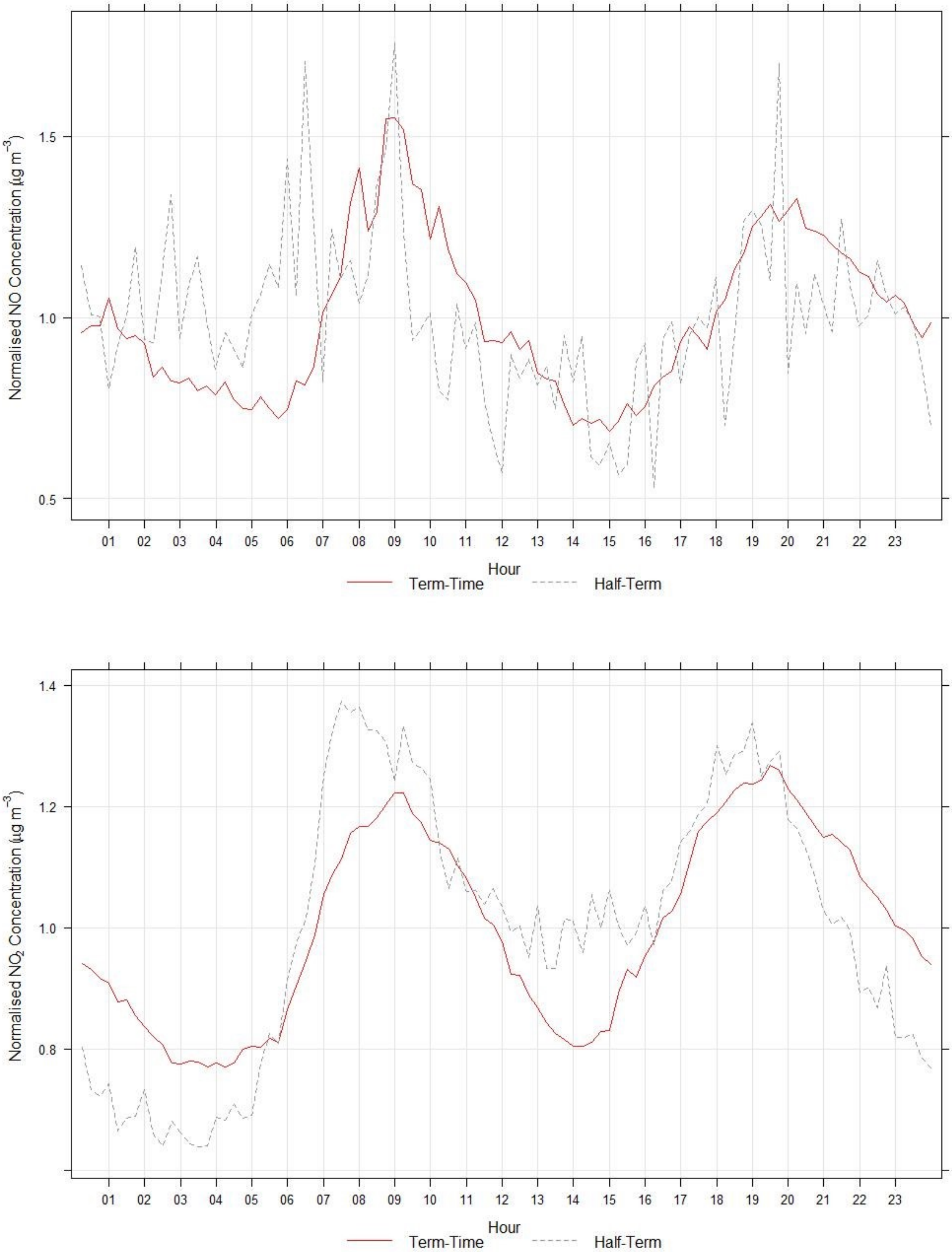


Figure 35: Normalised Diurnal Profiles of NO and NO_2 Concentrations at Site 20 during Term-time and during Half-term (µg/m^3)

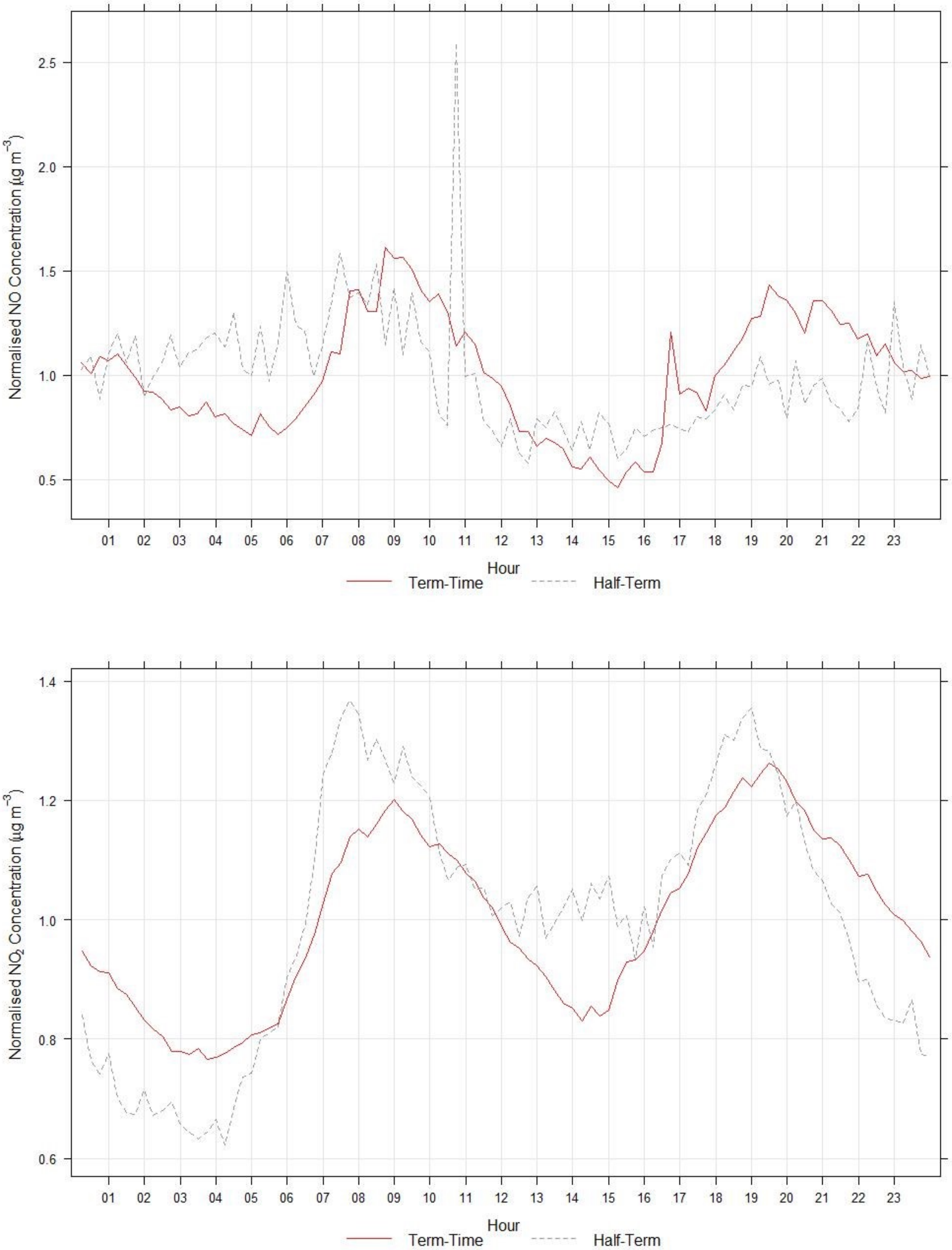


Figure 36: Normalised Diurnal Profiles of NO and NO_2 Concentrations at Site 21 during Term-time and during Half-term (µg/m^3)

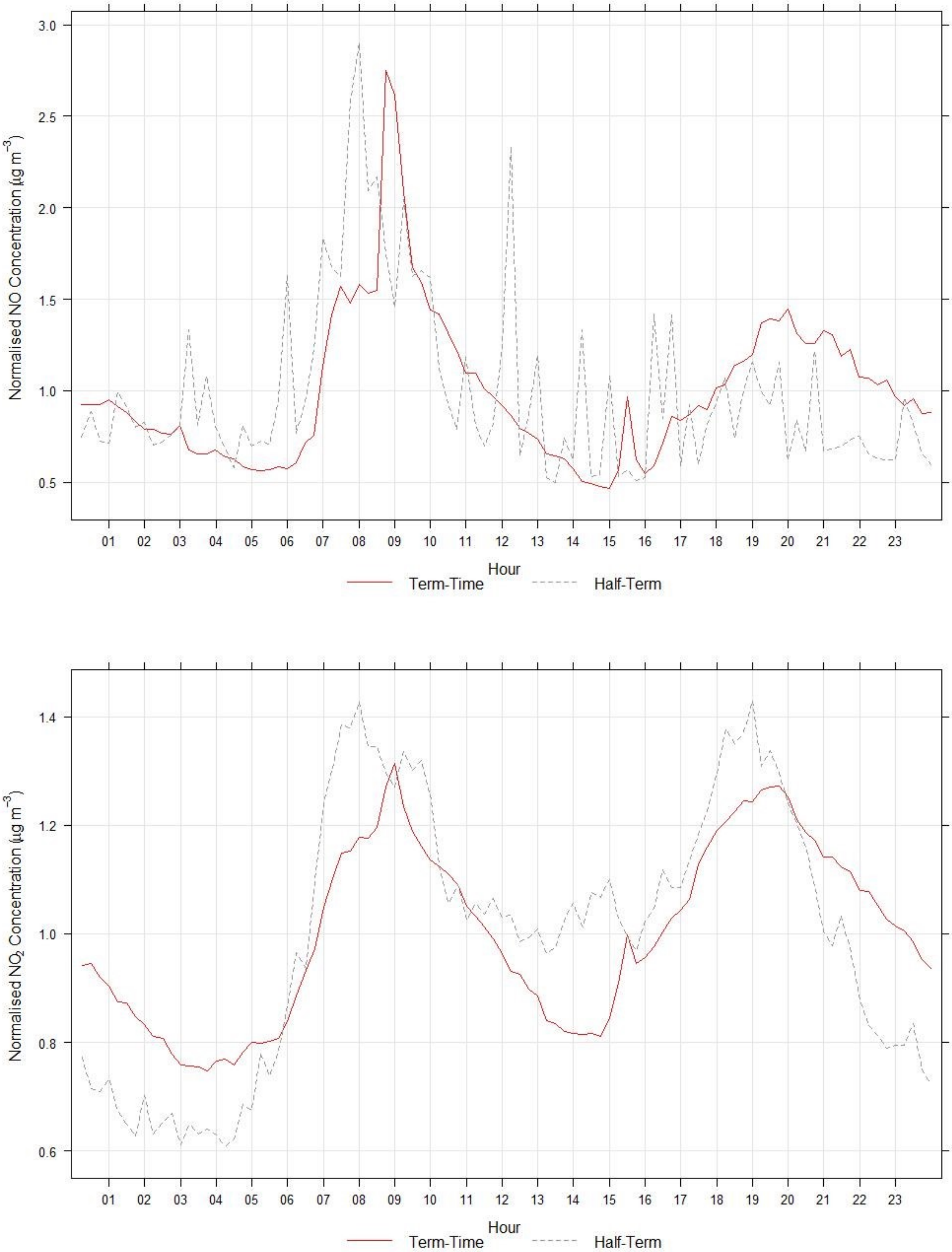


Figure 37: Normalised Diurnal Profiles of NO and NO_2 Concentrations at Site 22 during Term-time and during Half-term (µg/m^3)

Site 2

4.21 Site 2 is located as near as was possible to the entrance to St Robert Southwell Primary School on Slough Lane. When the Site was first established it was a control site; however, a School Street was implemented on Slough Lane from 7 December 2020. Figure 38 compares the profile of pollutant concentrations on term-time weekdays before and after 7 December. While NO concentrations appear suppressed on mornings after 7 December, the opposite is true of afternoons; it is likely that the differences between the plots are a result of seasonal and meteorological factors and not related to the implementation of the School Street.

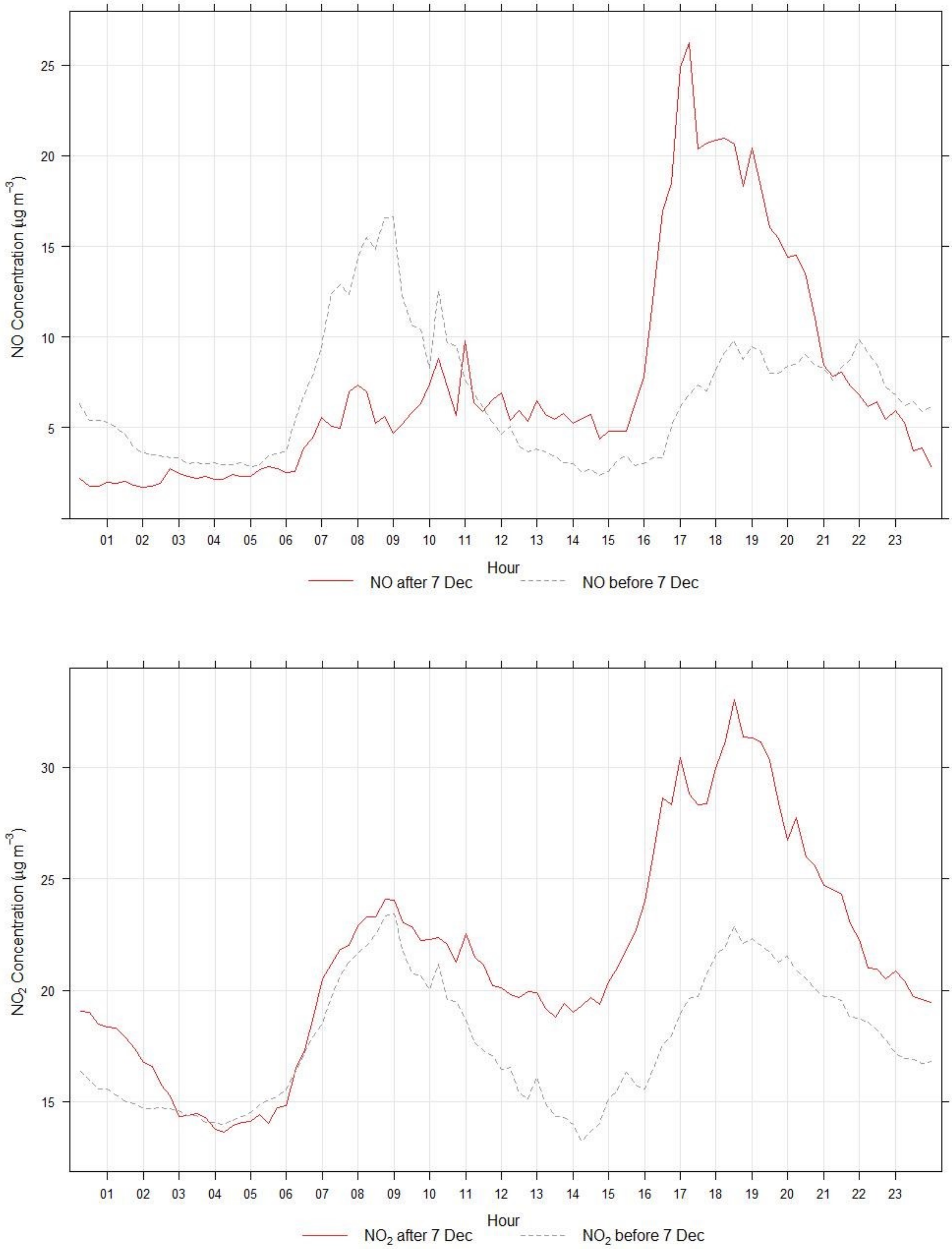


Figure 38: Average Diurnal Profile of NO and NO_2 Concentrations at Site 2 Before and After 7 December (µg/m^3)

5 Detailed Analysis

Comparisons of Paired Sites

5.1 In order to determine whether there is an underlying difference in profiles between Sites that are similar in nature, other than the influence that a School Street might have, concentrations at Sites where a greater School Street influence might be expected have been plotted against those where the effect would be expected to be smaller. Concentrations at the Site where an influence is apparent have then also been subtracted from those at the comparison site, to isolate the difference in concentrations during the specific periods of interest. The analysis has again focussed on those Sites where a potential effect as a result of the School Streets interventions has been identified in the diurnal profiles, namely Sites 16-18 and 20-22. It is not known why these particular roads have shown a greater apparent effect than others. In the absence of traffic count data, it is hypothesised that they have higher traffic flows, in particular during the morning peak period.

Site 16

Comparison to Site 14

5.2 Figure 39 presents the average diurnal profile of NO concentrations at Sites 16 and 14, with the difference between the two lines coloured to highlight those periods when the difference is greatest. Site 14 was selected for the comparison due to its profile for NO being the most similar to Site 16 outside of the periods of School Streets interventions (as shown in Figure 28). The differences between the two profiles are usually small, but between 7:45-9:15am the differences are far greater. The School Streets in Enfield were only implemented between 8:15-9:15am, but it is possible that the intervention affected route choice (or transport mode) over a longer period.

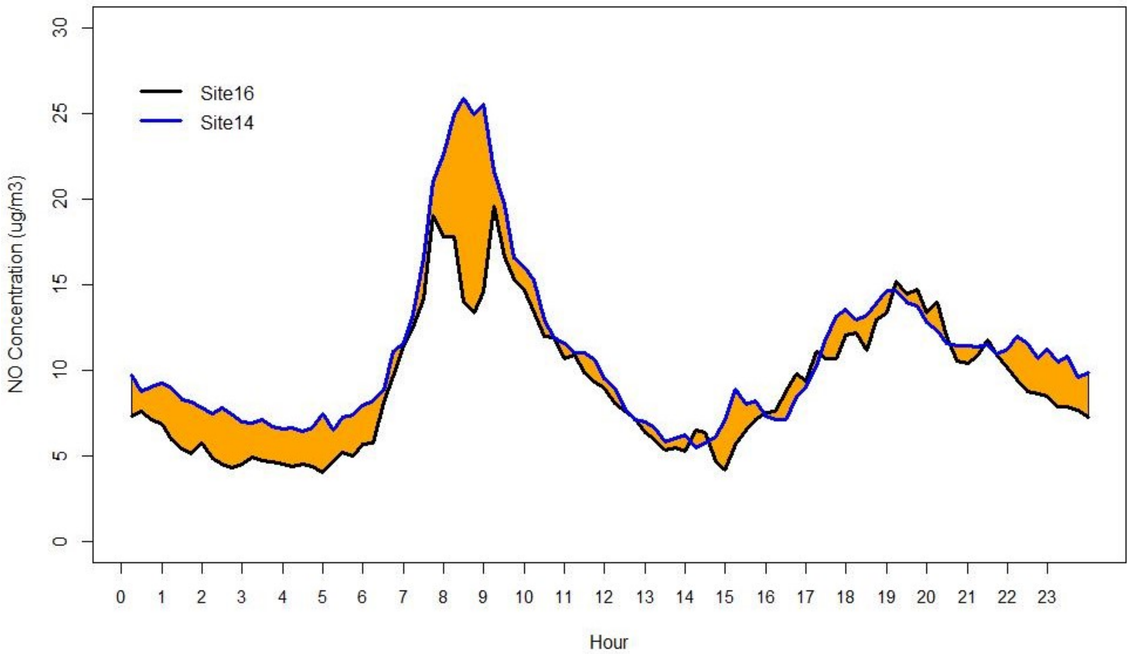


Figure 39: Average Diurnal Profile of NO Concentrations at Sites 16 and 14 (µg/m^3)

5.3 Figure 40 presents the average diurnal profile of NO and NO_2 concentrations at Site 16 with those at Site 14 subtracted. The afternoon dip in concentrations at Site 16 is largely in line with the underlying variability in concentrations between the sites, but highlights that the reduction in concentrations in the morning shows a dramatic reduction in concentrations of up to about 7-8 µg/m^3.

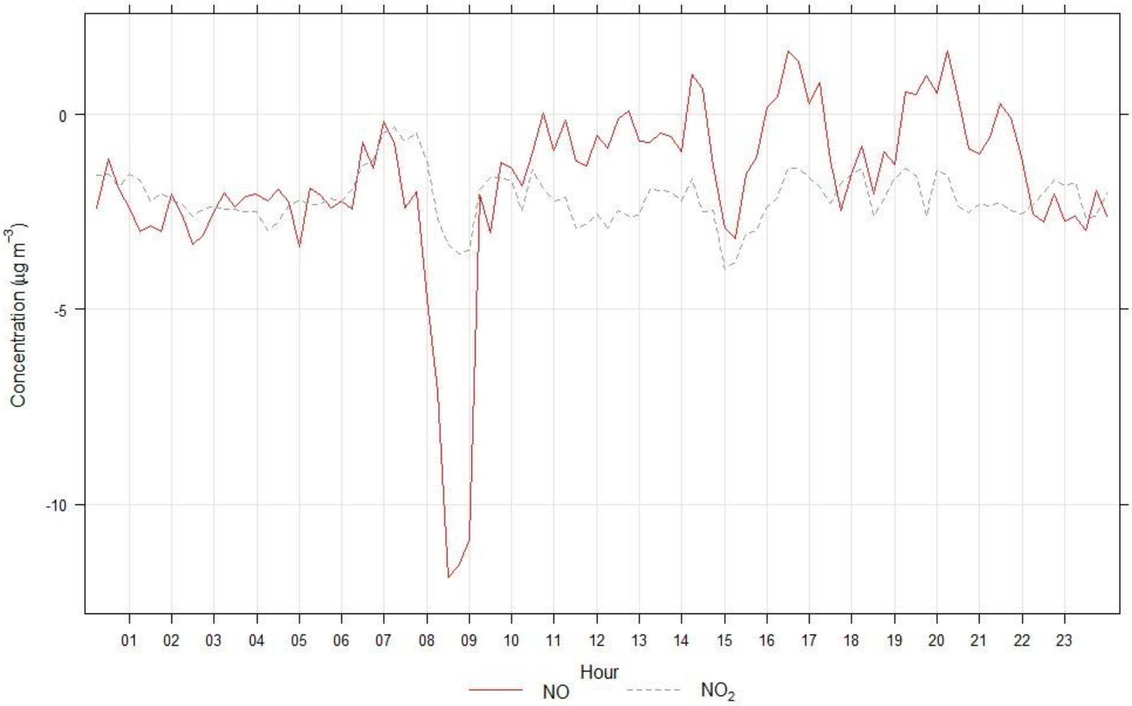


Figure 40: Average Diurnal Profile of NO Concentrations at Site 16 with Concentrations at Site 14 Subtracted (µg/m^3)

5.4 Time-averaged concentrations, such as those in Figure 40, can often by driven by a small number of isolated events. For example, just one period with significantly lower/higher concentrations might cause a significant change to the mean. If this were the case, then the effect is unlikely to have been caused by the road closure, which would have had a systematic effect on measured concentrations throughout the intervention.

5.5 To investigate whether the dip in concentrations shown in Figure 40 is the result of a few isolated events, Figure 41 presents the week-by-week time series of concentrations at Site 16 with those at Site 14 subtracted, with the five days of each school week in which monitoring was carried out presented. There is a clear negative spike in concentrations every morning of the first week of the monitoring study, suggesting a systematic rather than isolated event. While these appear to extend over a longer period than the interventions, it is not possible to be certain as to how long each road closure might have affected traffic flows, and how long it took for traffic to return to ‘normal’ after reopening. After this first week, the apparent trend becomes less obvious, although there are repeated events with negative spikes in concentrations around this time of the morning, e.g. on 19 and 21 October, on 4, 6, 9, 18, 20, 23, 26, 27 and 30 November, and on 2, 7 and 8 December. There is no single event, or small number of events, that would appear to be driving the effect, and the negative spikes observed during the morning intervention periods do not stand out as outliers in terms of the typical variability in the difference in concentrations between the two Sites, i.e. there are numerous other occasions when the difference in concentrations, be it positive or negative, is of a similar magnitude.

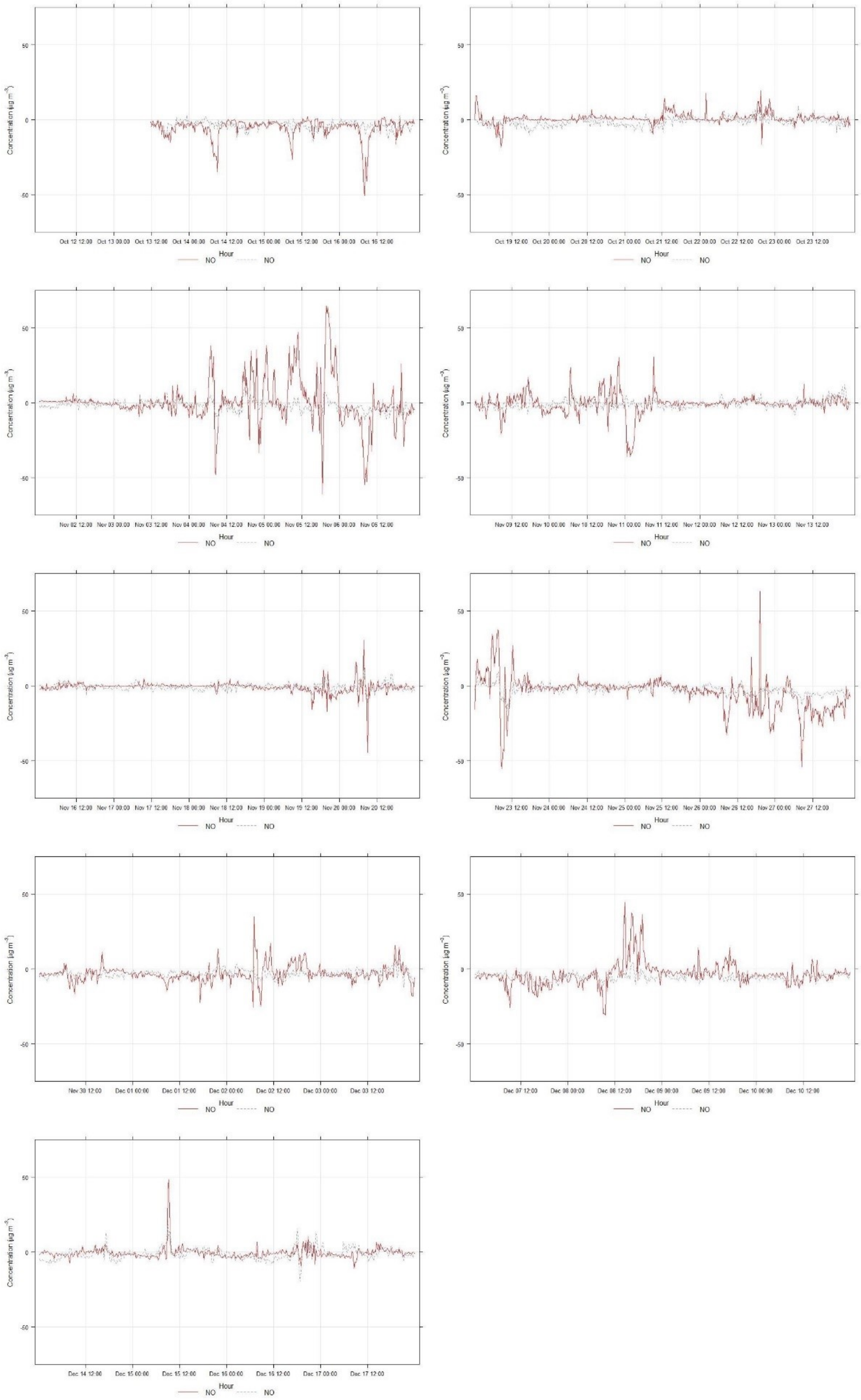


Figure 41: Measured School Day Concentrations at Site 16 with Concentrations at Site 14 Subtracted (µg/m^3)

5.6 This is tested further in Figure 42, which shows the frequency distribution of 15-minute NO concentrations after subtracting Site 14 from Site 16 and then dividing by Site 14, i.e. the difference in concentration between the sites relative to the concentration at Site 14. During the road closures (the bars marked 'Intervention'), there is a clear systematic tendency for lower concentrations; i.e. lower concentrations occur on a high proportion of hours. This indicates that the dip shown in Figure 40 is the effect of lower concentrations over a significant period of time during the interventions, rather than being driven by a small number of individual spikes. This, in turn, adds confidence to the conclusion that it is likely to be the road closure driving the reduction shown in Figure 40.

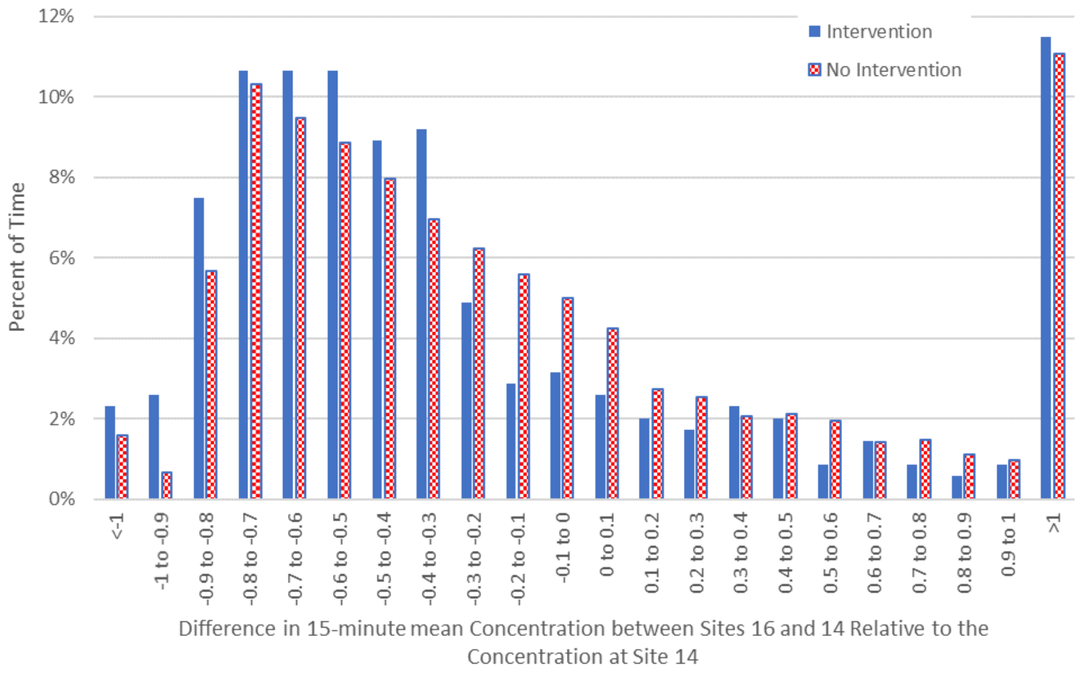


Figure 42: Difference in 15-Minute Mean NO Concentrations at Site 16 and Site 14 Relative to the Concentration at Site 14, Showing Frequency of Different Values

5.7 It is reasonable to conclude that the road closure implemented as part of the School Streets programme was likely to have been a principal driver of the reduction in concentrations shown in Figure 40. The lack of a corresponding drop in concentrations in the afternoon may simply be because the afternoon road closure does not align with rush hour traffic, while the morning closure does.

5.8 Analysis of the raw data behind the plots has identified that, between 8:15-9:15am, NO concentrations at Site 16 were, on average, 9.11 µg/m^3 lower than at Site 14. Over the rest of the day, excluding the afternoon intervention period, the average difference was only 1.36 µg/m^3. This implies a School Streets-related reduction of around 7.75 µg/m^3. The average measured NO concentration during the drop-off period a Site 16 (15,4 µg/m^3) would thus have been 7.75 µg/m^3 higher without the intervention, suggesting the road closure reduced NO concentrations during the drop-off period by 34%. Averaged over the course of the day, this equates to the daily average (school day) concentration being 0.52 μg/m^3 lower than it would have been without the intervention, or 5.3% of the total concentration that would otherwise have been measured at Site 16. The intervention on The Ride is thus estimated to have reduced NO concentrations outside the gates of Kingfisher Hall Primary Academy by 34% during the drop-off period and by 5% as a daily average.

5.9 The NO_2 measurements are too strongly affected by confounding influences to allow as a clear demonstration of the effects of the School Streets intervention as seen for NO. However, the principal source of roadside NO_2 concentrations is NO emitted by road vehicles. It is possible to provide a broad estimate of the reduction in NO_2 which would accompany the observed reductions in NO. For this, it has been assumed that 50% of NO forms NO_2 within the local area. In practice, conversion rates depend on a suite of factors, importantly the availability of ozone, which is often depleted close to busy roads. Because the School Streets roads are all relatively quiet, the rate of NO conversion can be expected to be relatively rapid and the assumption of 50% conversion is unlikely to significantly overstate the effect of the interventions on NO_2 on average. Because the molecular weight of NO_2 (46) is greater than that of NO (30), a further conversion is required. It is thus assumed that each μg/m^3 of NO equates to 0.77 μg/m^3 of NO_2 (i.e. 0.5 x 46 / 30). Applying this conversion, a 7.75 μg/m^3 reduction in NO during the intervention period equates to a reduction in NO_2 of around 5.9 μg/m^3. A 0.52 μg/m^3 reduction in daily-average NO concentrations would be expected to lead to a 0.39 μg/m^3 reduction in NO_2 concentrations. As with NO, these inferred reductions can be compared with the values measured at Site 16 to suggest that NO_2 concentrations during the drop-off period were reduced by 23% as a result of the intervention, with the reduction in daily mean concentrations being 2%.

Comparison to Site 15

5.10 Figure 43 and Figure 44 present a similar analysis, but this time with concentrations at Site 15 plotted against or subtracted from those at Site 16. Figure 43 highlights that NO concentrations at Site 15 were consistently higher than those at Site 16, potentially due to Site 15 being closer to the A110. The morning dip in concentrations at Site 16 is again apparent in Figure 44, but less obvious than in the previous comparison, principally due to the presence of other dips in concentrations. An earlier dip around 6:30am appears to be caused by a spike in concentrations around that time at Site 15.

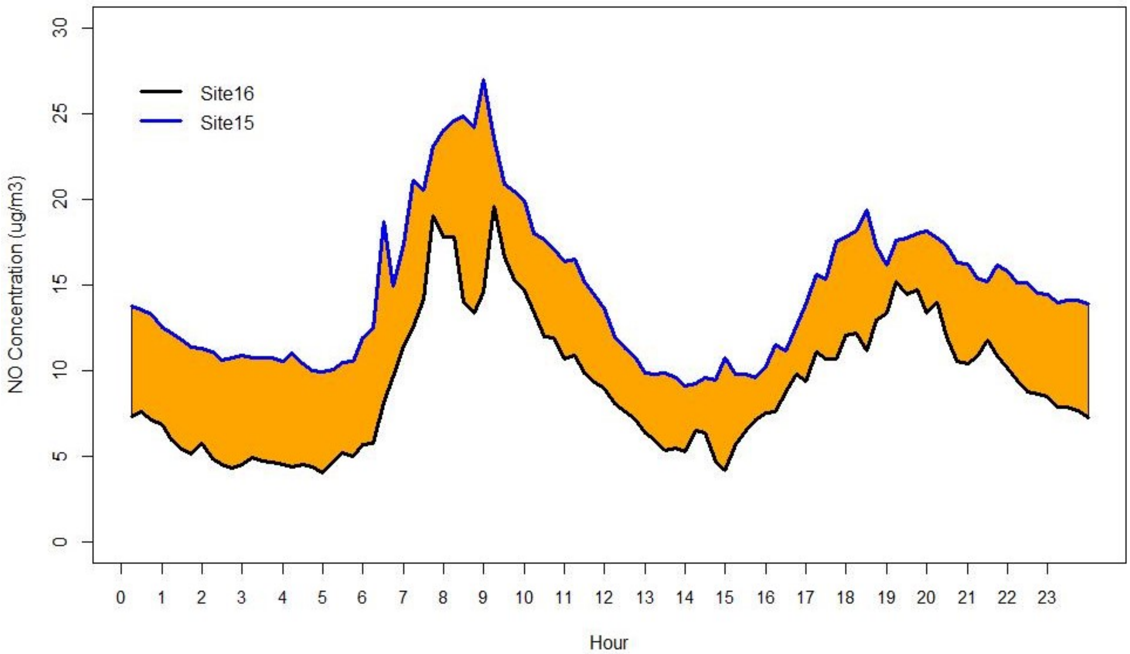


Figure 43: Average Diurnal Profile of NO Concentrations at Sites 16 and 15 (µg/m³)

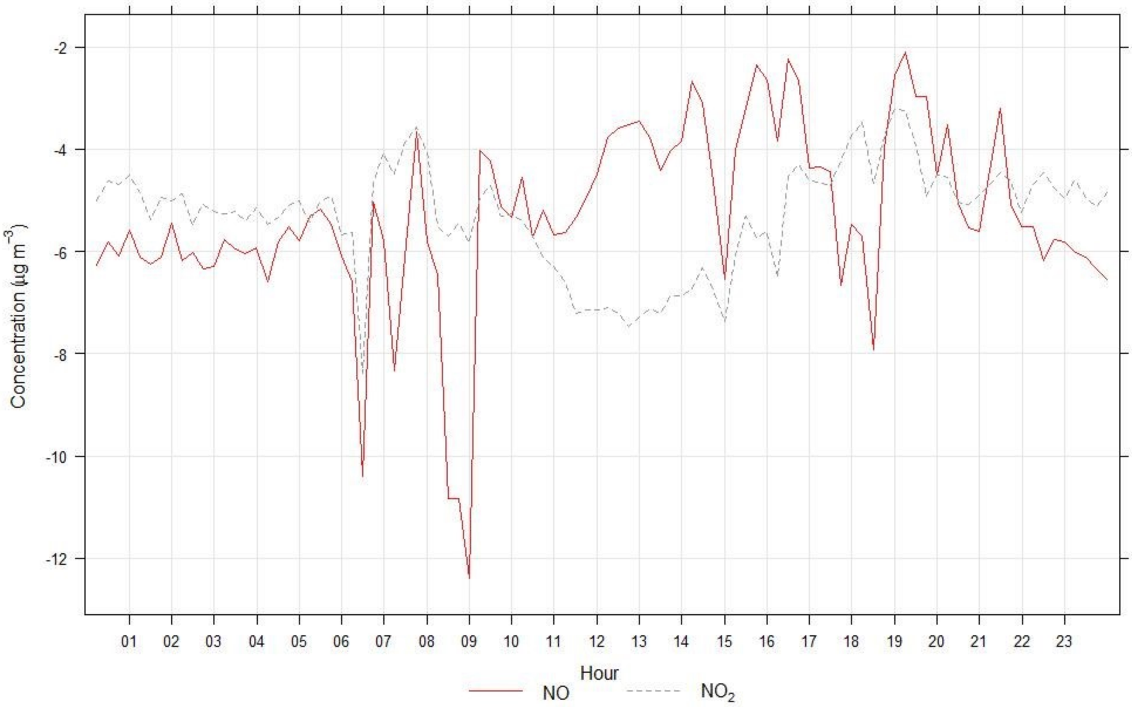


Figure 44: Average Diurnal Profile of NO Concentrations at Site 16 with Concentrations at Site 15 Subtracted (µg/m³)

5.11 To investigate whether the dip in concentrations shown in Figure 44 is the result of a few isolated events, Figure 45 presents the week-by-week time series of concentrations at Site 16 with those at Site 15 subtracted, with the five days of each school week in which monitoring was carried out presented. While they do not occur every day, it is clear that there were frequently negative spikes in concentrations around the times of the morning School Streets interventions, again suggesting a systematic rather than isolated event.

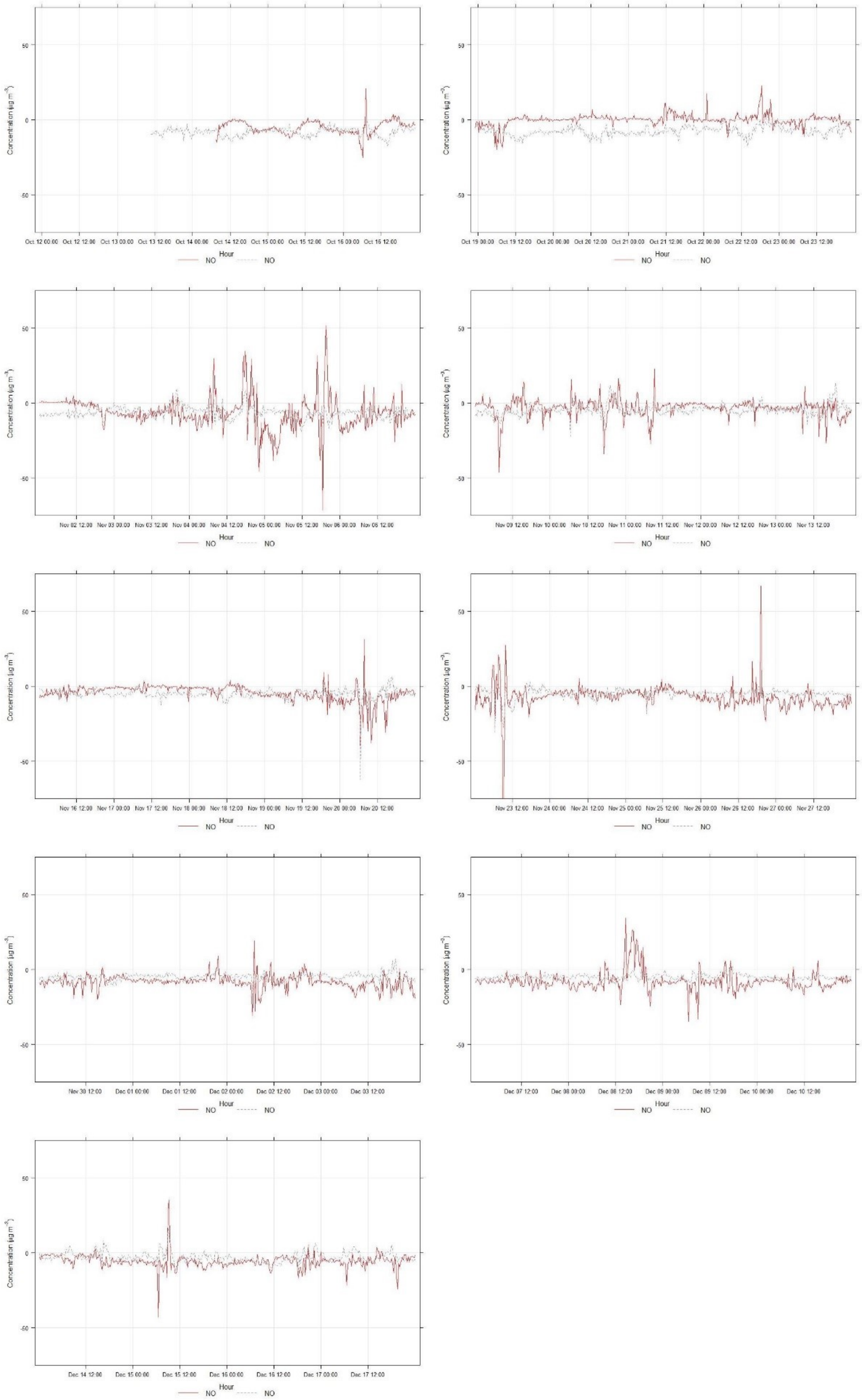


Figure 45: Measured School Day Concentrations at Site 16 with Concentrations at Site 15 Subtracted (µg/m^3)

5.12 This is tested further in Figure 46, which shows the frequency distribution of 15-minute NO concentrations expressed as the difference in concentration between the sites relative to the concentration at Site 14. Again, the tendency for lower concentrations is driven by a large proportion of periods with moderately lower measurements, rather than a few periods with significantly lower values.

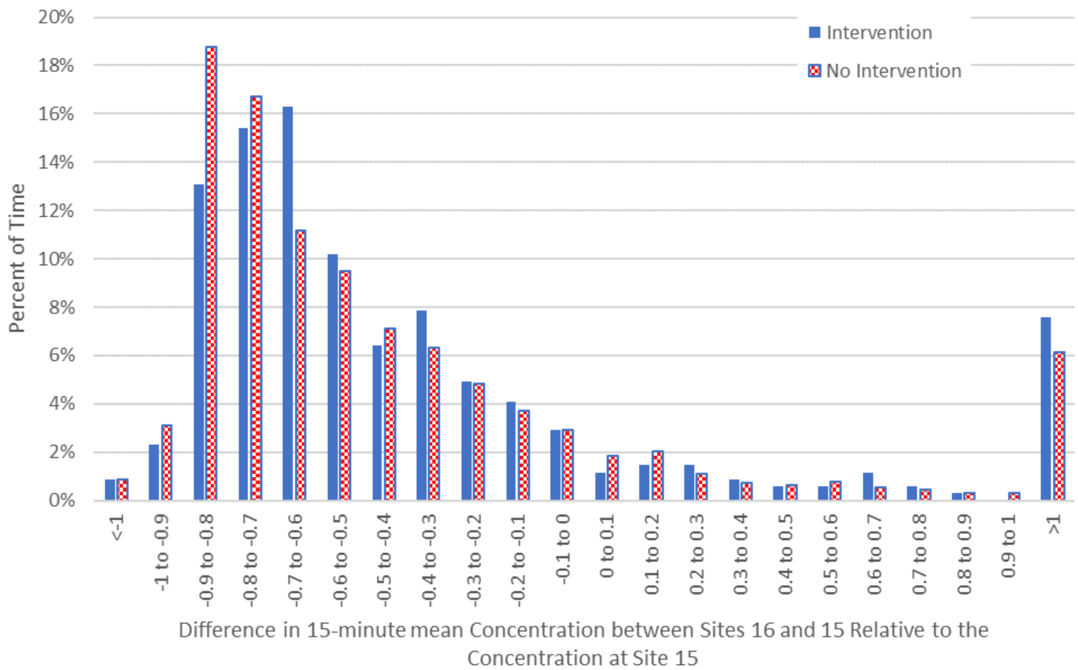


Figure 46: Difference in 15-Minute Mean NO Concentrations at Site 16 and Site 15 Relative to the Concentration at Site 15, Showing Frequency of Different Values

5.13 On balance, it is considered that the comparison of Site 16 with Site 14 better isolates the effect of the School Streets intervention than using Site 15. Given this conclusion, it is not judged relevant to reproduce the analysis described in Paragraph 5.8 for this pairing.

Comparison to Site 17

5.14 Figure 47 and Figure 48 present concentrations at Site 17 plotted against or subtracted from those at Site 16. Figure 47 highlights that concentrations at Site 17 were consistently higher than those at Site 16, likely due to Site 17 proximity to the busy Hertford Road (A1010) to the west. It also highlights that a dip is present at Site 17 at a similar time to that at Site 16: thus, this comparison may understate the influence of the School Streets intervention, as it would appear that both sites are affected.

5.15 There remains a distinct dip during the morning road closure period in Figure 48, although it is less obvious, being preceded by an earlier dip that may relate more to emissions from Hertford Road than those along The Ride. As has already been noted, Site 17 also shows a dip in concentrations between 8.15-9.15am, thus, it is not an ideal comparator for these purposes as it may understate the influence of the School Streets intervention, but it does reinforce that there was a greater reduction at Site 16 during the morning closure.

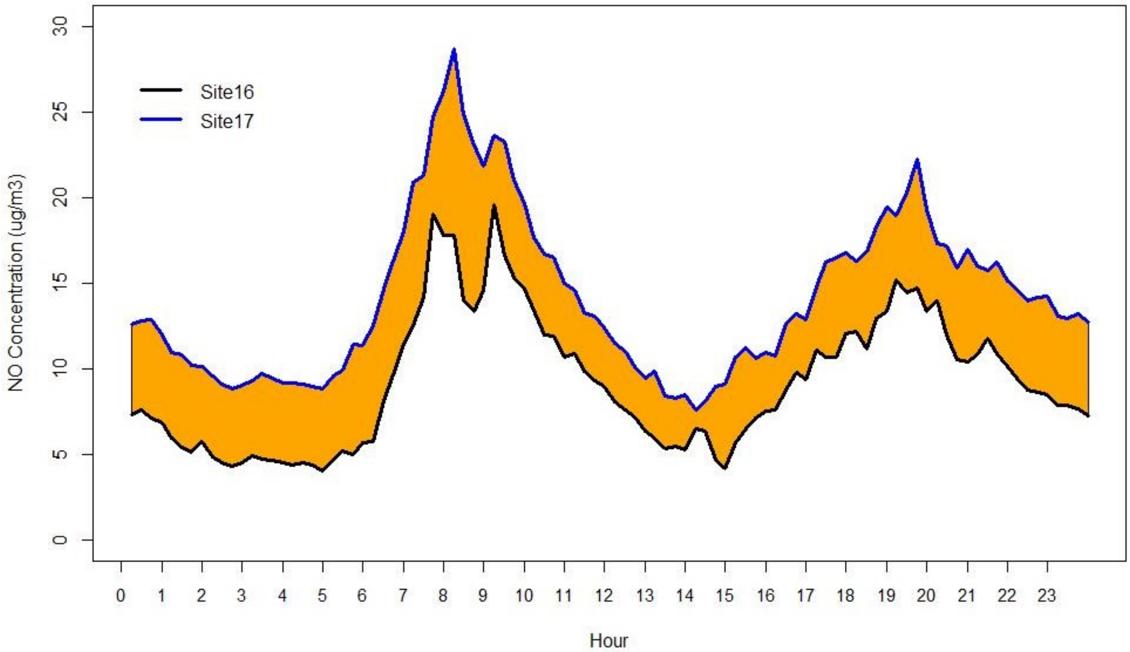


Figure 47: Average Diurnal Profile of NO Concentrations at Sites 16 and 17 (µg/m³)

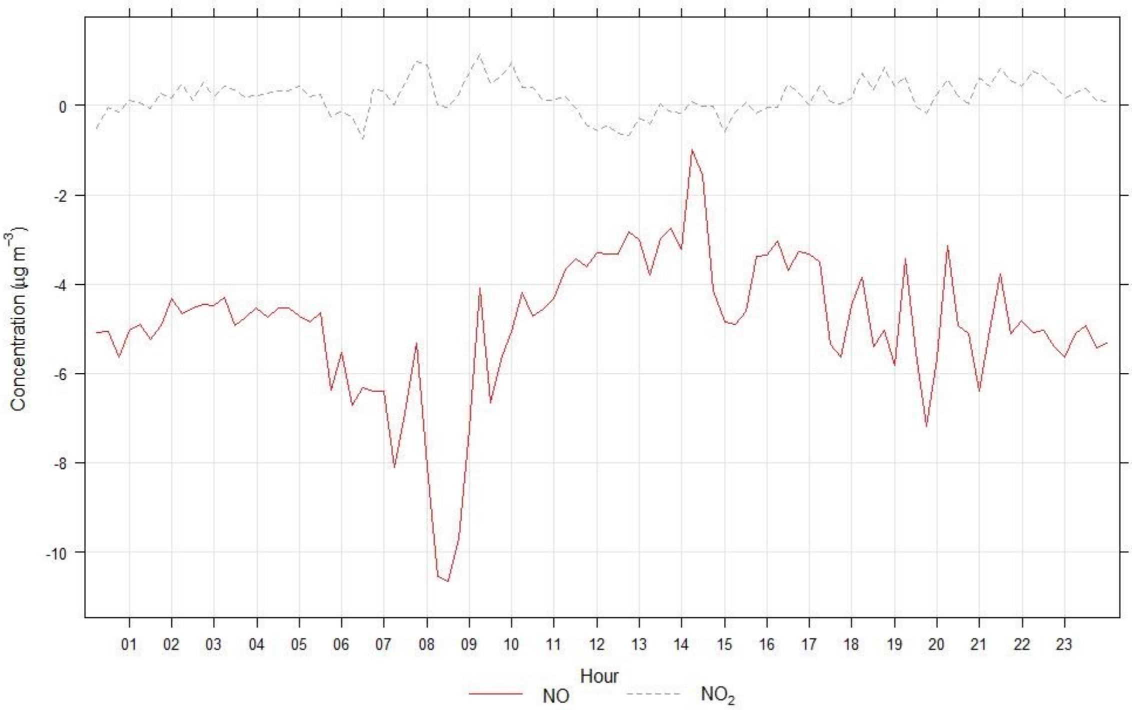


Figure 48: Average Diurnal Profile of NO Concentrations at Site 16 with Concentrations at Site 17 Subtracted (µg/m³)

5.16 Figure 49 presents the week-by-week time series of concentrations at Site 16 with those at Site 17 subtracted. Negative spikes in concentrations do occur around the times of the morning School Streets interventions, but less frequently than for the previous two comparisons, suggesting a less systematic effect.

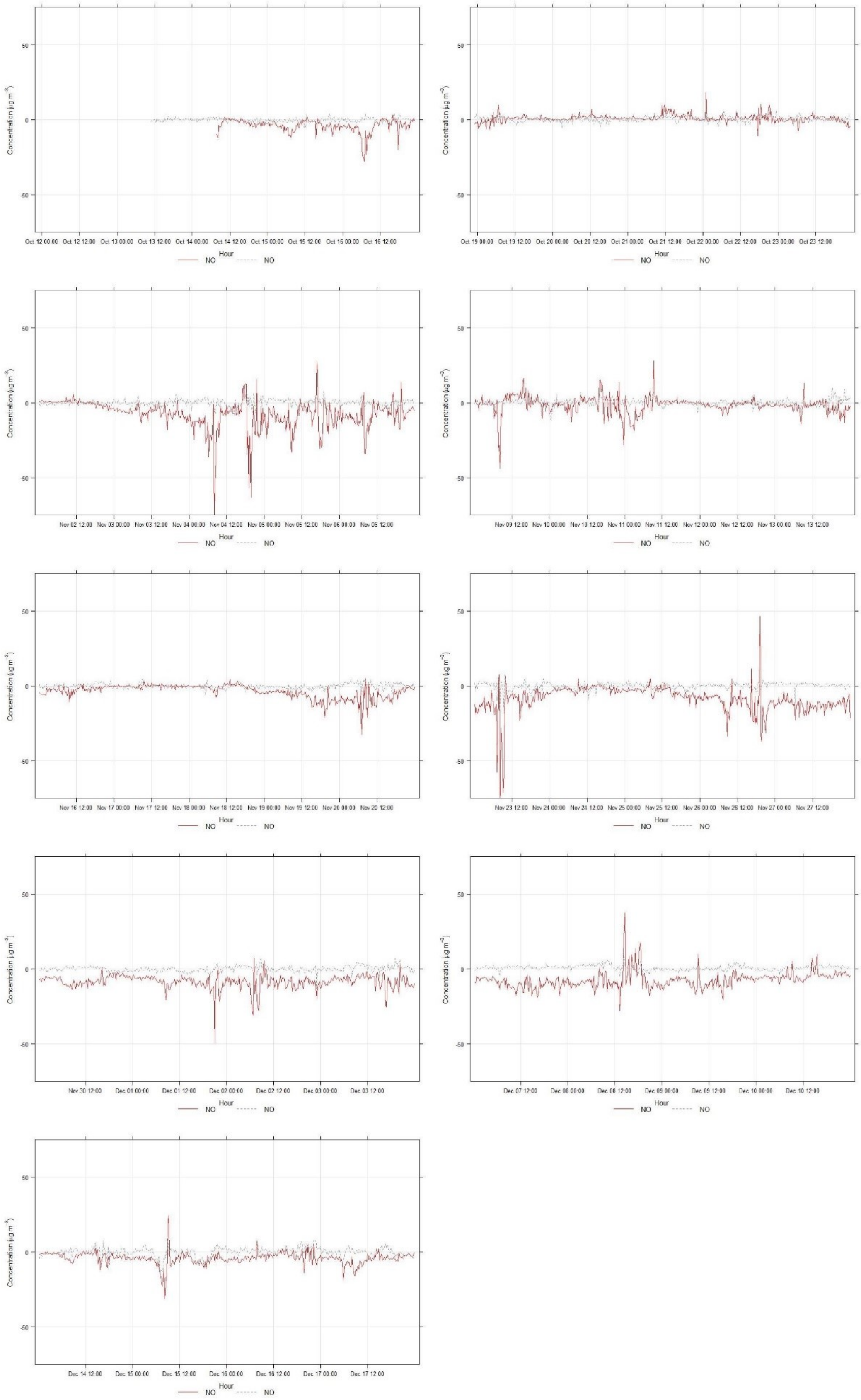


Figure 49: Measured School Day Concentrations at Site 16 with Concentrations at Site 17 Subtracted (µg/m^3)

5.17 This is tested further in Figure 50, which shows the frequency distribution of 15-minute NO concentrations expressed as the difference in concentration between the sites relative to the concentration at Site 17. Again, this shows that the reductions in concentration are systematic and prolonged, rather than caused by isolated events.

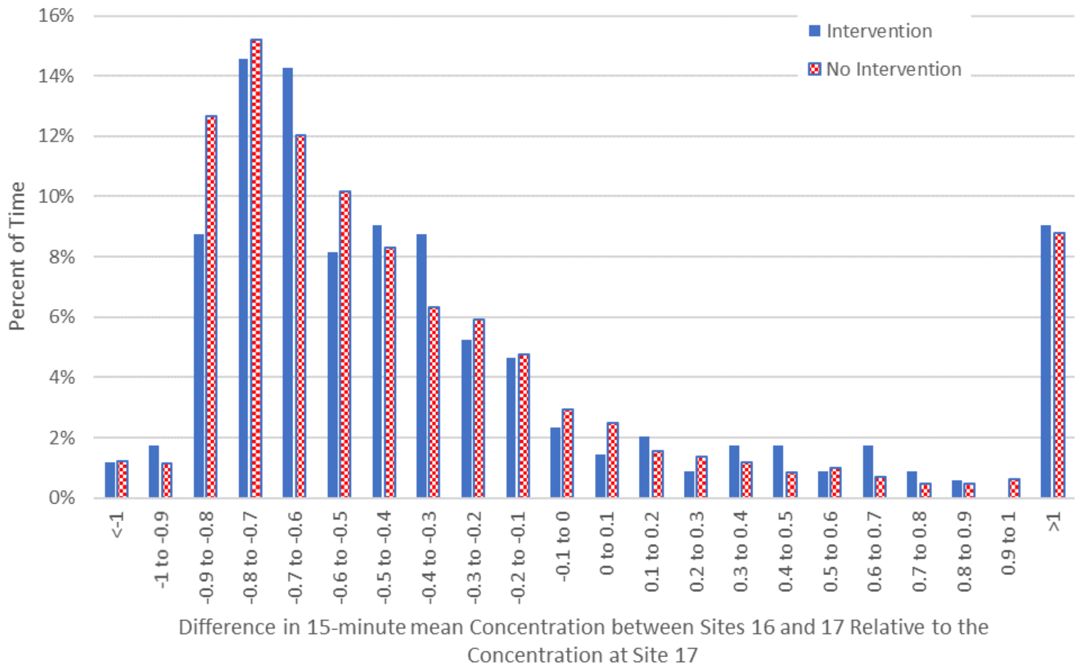


Figure 50: Difference in 15-Minute Mean NO Concentrations at Site 16 and Site 17 Relative to the Concentration at Site 17, Showing Frequency of Different Values

5.18 The comparison of Site 16 with Site 14 better isolates the effect of the School Streets intervention than using Site 15. It is again not judged relevant to reproduce the analysis described in Paragraph 5.8 for this pairing.

Site 17

5.19 Figure 51 presents the average diurnal profile of NO concentrations at Sites 17 and 14. The plot highlights that concentrations at Site 17 are usually higher than at Site 14, the only exception being between about 8.15-9.15am, which coincides with the School Streets road closure period.

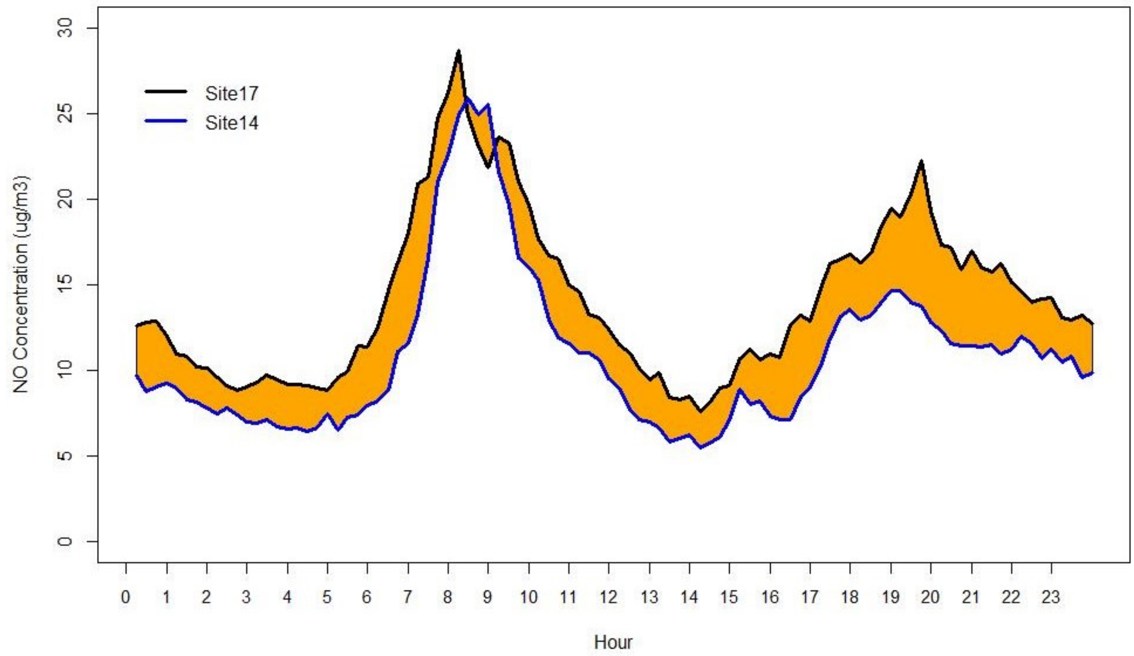


Figure 51: Average Diurnal Profile of NO Concentrations at Sites 17 and 14 (µg/m³)

5.20 Figure 52 presents the average diurnal profile of concentrations at Site 17 with those at Site 14 subtracted. The dip in concentrations between about 8.15-9.15am is evident, especially in the NO profile, with concentrations more than 5 µg/m³ lower during this period. It is reasonable to conclude that the road closure implemented as part of the School Streets programme will have been a key driver in this reduction in concentrations.

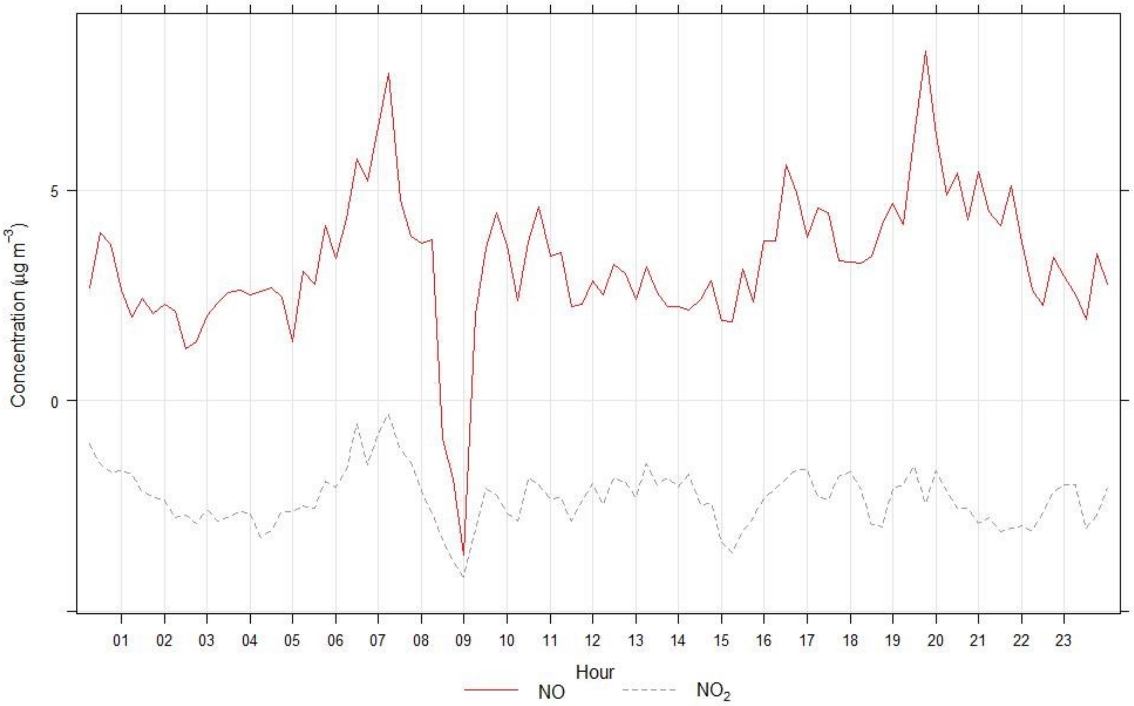


Figure 52: Average Diurnal Profile of NO and NO_2 Concentrations at Site 17 with Concentrations at Site 14 Subtracted (µg/m^3)

5.21 Figure 53 presents the week-by-week time series of concentrations at Site 17 with those at Site 14 subtracted. Negative spikes in concentrations do occur around the times of the morning School Streets interventions, but less frequently than for the comparison on Sites 16 and 14.

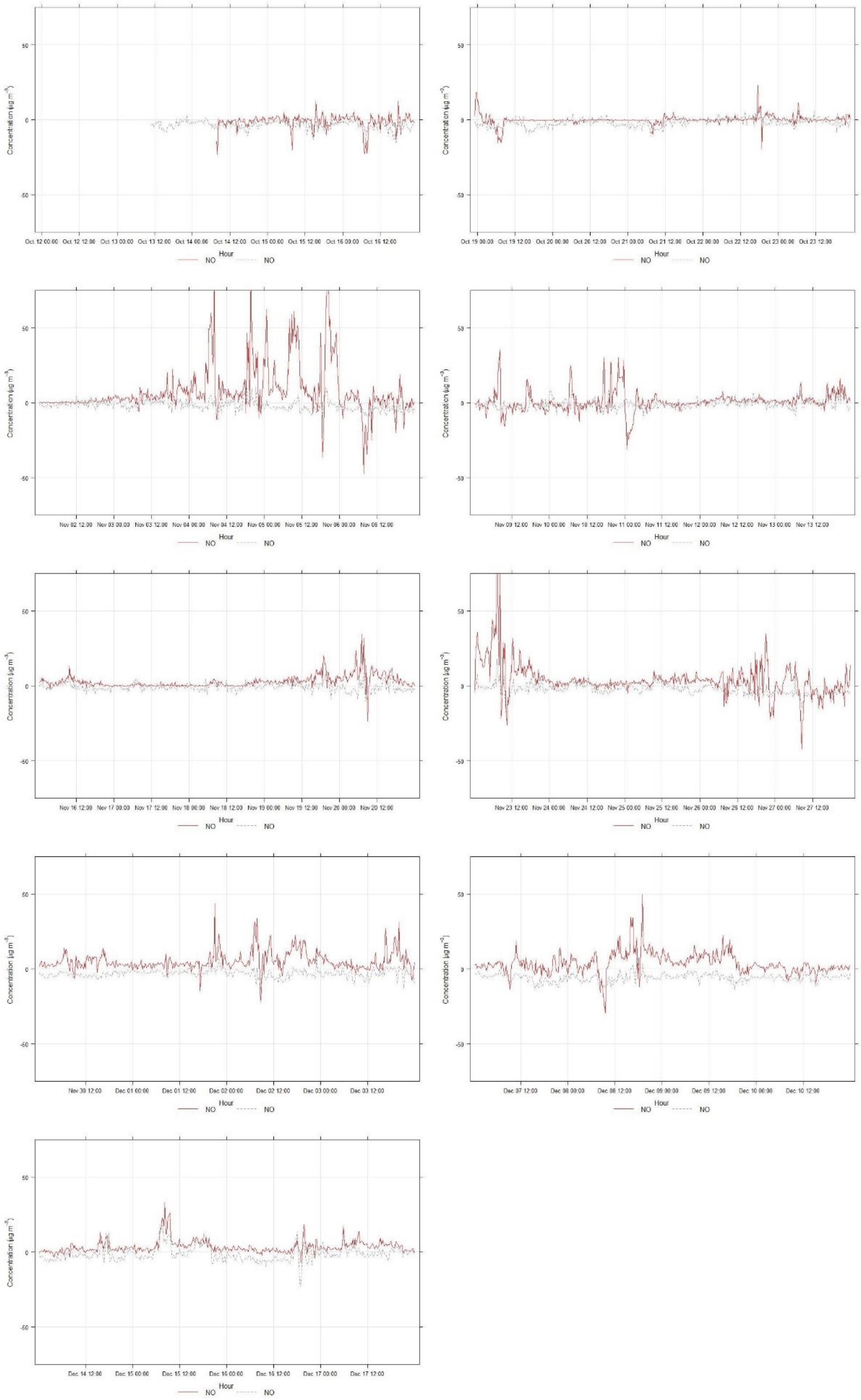


Figure 53: Measured School Day Concentrations at Site 17 with Concentrations at Site 14 Subtracted (µg/m^3)

5.22 Figure 54 shows the frequency distribution of 15-minute NO concentrations expressed as the difference in concentration between the sites relative to the concentration at Site 14. Similar to Figure 42, there is a clear systematic tendency for lower concentrations during the road closures, suggesting that the morning dip in Figure 52 can probably be attributed to the School Streets interventions.

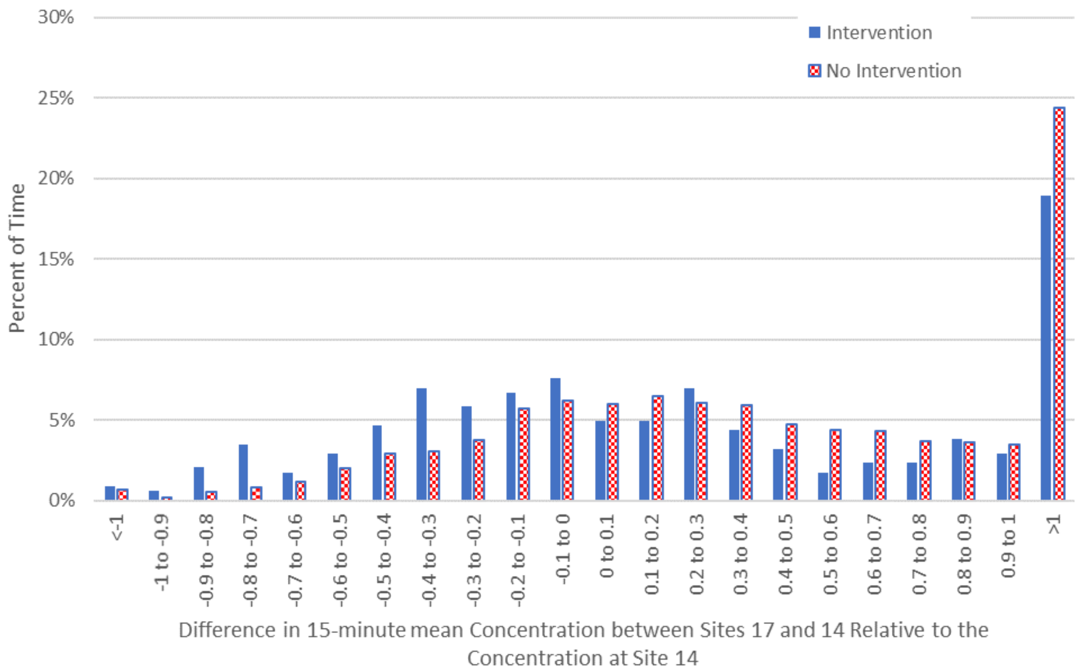


Figure 54: Difference in 15-Minute Mean NO Concentrations at Site 17 and Site 14 Relative to the Concentration at Site 14, Showing Frequency of Different Values

5.23 Applying the same approach as described in Paragraph 5.8, a School Streets-related reduction of 4.69 µg/m^3 is calculated when comparing the average difference in concentrations between Sites 17 and 14 during the morning intervention to those over the rest of the day (excluding the afternoon intervention period). This represents a 17% reduction in the NO concentration which would otherwise have been recorded during the drop-off period. The daily average (school day) concentration is predicted to have been 0.31 µg/m3 (2.2%) lower than it would have been without the intervention. Applying the same approach for NO_2 as described in Paragraph 5.9, the corresponding reductions in NO_2 are 3.6 µg/m^3 (16%) during the intervention, and 0.24 µg/m^3 (1.2%) as a daily mean.

Site 18

Comparison to Site 14

5.24 Figure 55 presents the average diurnal profile of NO concentrations at Sites 18 and 14. Concentrations are consistently higher at Site 18 than they are at Site 14, with the exception of the period 8-9am, when concentrations at Site 18 dip substantially.

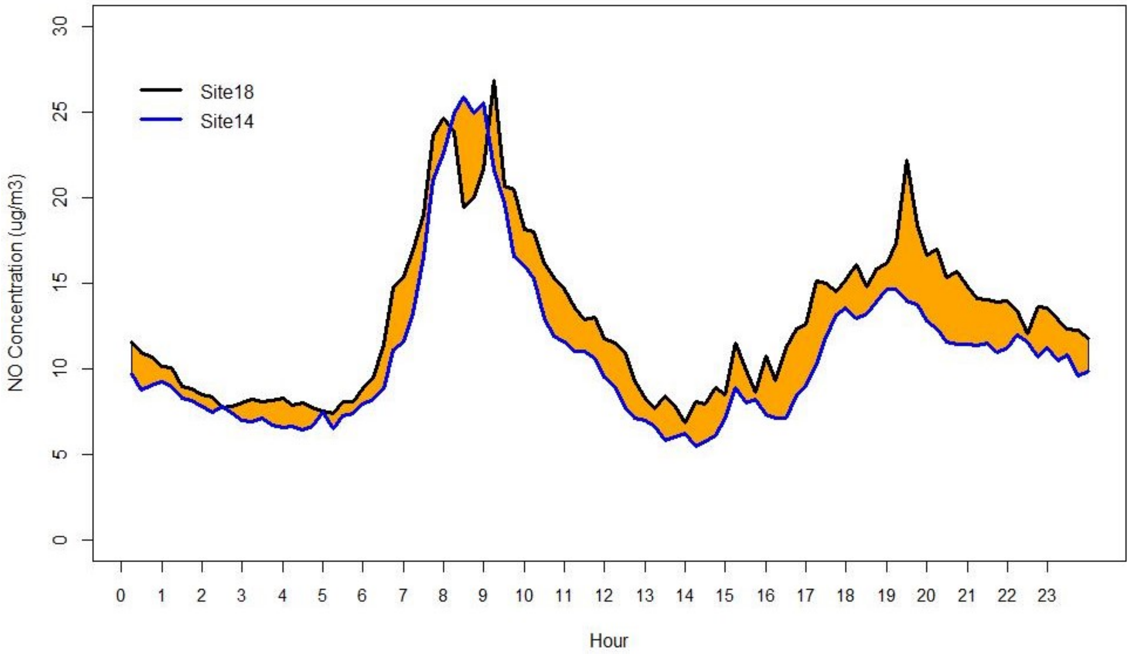


Figure 55: Average Diurnal Profile of NO Concentrations at Sites 18 and 14 (µg/m^3)

5.25 Figure 56 presents the average diurnal profile of concentrations at Site 18 with those at Site 14 subtracted. The dip in concentrations between about 8.15-9.15am stands out in the NO profile, with concentrations more than 5 µg/m^3 lower during this period. It is reasonable to conclude that the road closure implemented as part of the School Streets programme will have been a key driver of this reduction in concentrations.

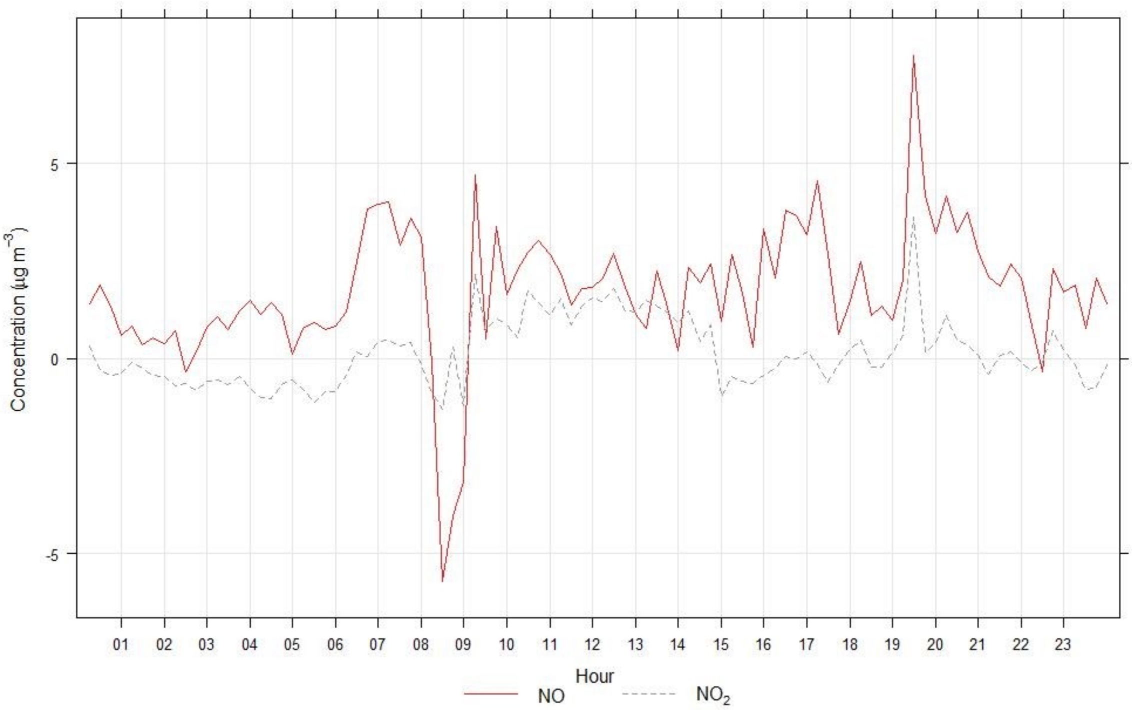


Figure 56: Average Diurnal Profile of NO Concentrations at Site 18 with Concentrations at Site 14 Subtracted (µg/m^3)

5.26 Figure 57 presents the week-by-week time series of concentrations at Site 18 with those at Site 14 subtracted. Negative spikes in concentrations appear common around the times of the morning School Streets interventions.

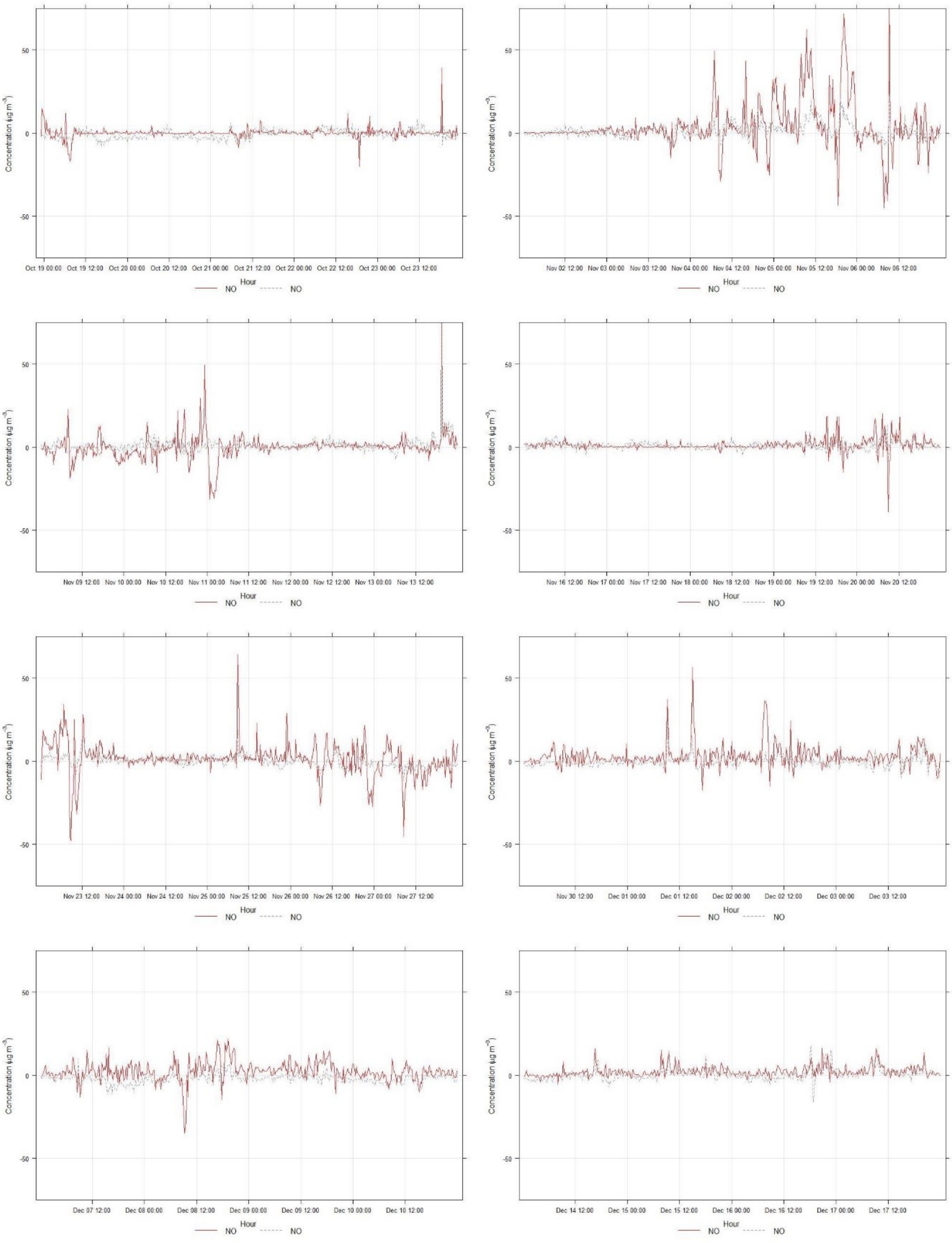


Figure 57: Measured School Day Concentrations at Site 18 with Concentrations at Site 14 Subtracted (µg/m^3)

5.27 Figure 58 shows the frequency distribution of 15-minute NO concentrations expressed as the difference in concentration between the sites relative to the concentration at Site 14. There is a very clear systematic tendency for lower concentrations during the road closure periods, suggesting that the morning dip in Figure 56 can be attributed to the School Streets interventions.

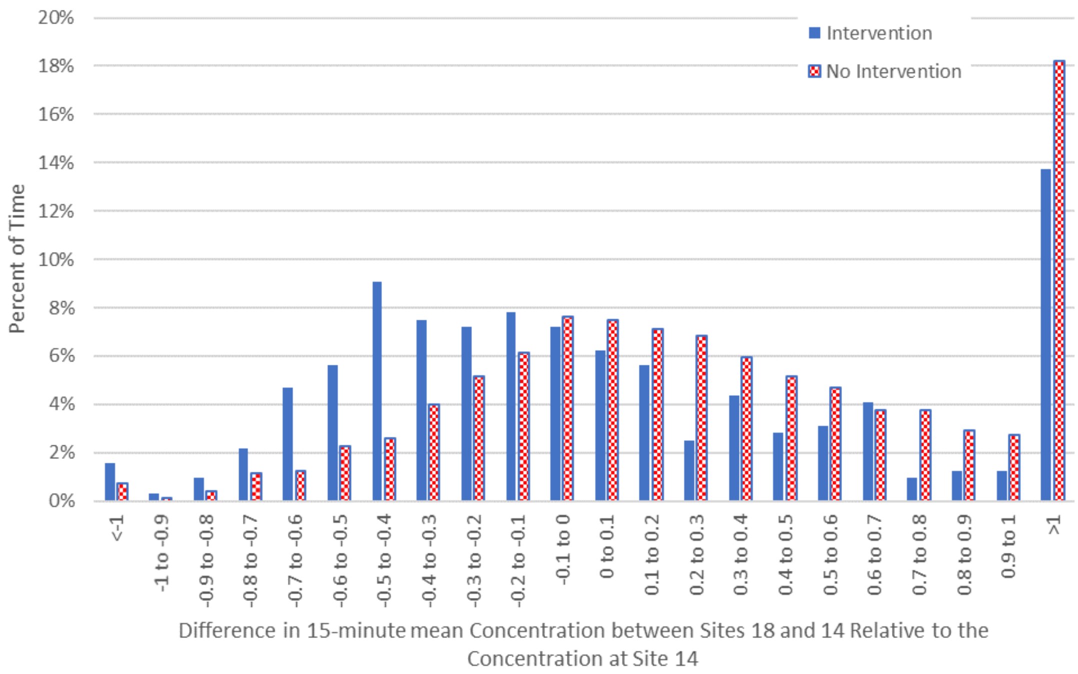


Figure 58: Difference in 15-Minute Mean NO Concentrations at Site 18 and Site 14 Relative to the Concentration at Site 14, Showing Frequency of Different Values

5.28 Applying the same approach as described in Paragraph 5.8, a School Streets-related reduction of 4.73 µg/m^3 is calculated when comparing the average difference in concentrations between Sites 18 and 14 during the morning intervention to those over the rest of the day (excluding the afternoon intervention period). This represents an 18% reduction in the NO concentration which would otherwise have been recorded during the drop-off period. The daily average (school day) concentration is predicted to have been 0.32 µg/m^3 (2.4%) lower than it would have been without the intervention. Applying the approach described in Paragraph 5.9, the corresponding reductions in NO_2 are 3.6 µg/m^3 (14%) during the intervention and 0.24 µg/m^3 (1.1%) as a daily mean.

Comparison to Site 22

5.29 Figure 59 presents the average diurnal profile of NO concentrations at Sites 21 and 22. Figure 10 shows that both of these sites are on the same School Streets road, but that while Site 21 is in the centre of the closed section of road, Site 22 is at the end of the closed section and also adjacent to Hillyard Street/Durand Gardens. The plot highlights that the concentrations, and the profile of concentrations, at the two sites are very similar. The only noteworthy difference is the spike at Site 22 around 9am that is not reflected at Site 21. This may reflect the use of Hillyard Street and Durand Gardens by vehicles during the morning rush hour.

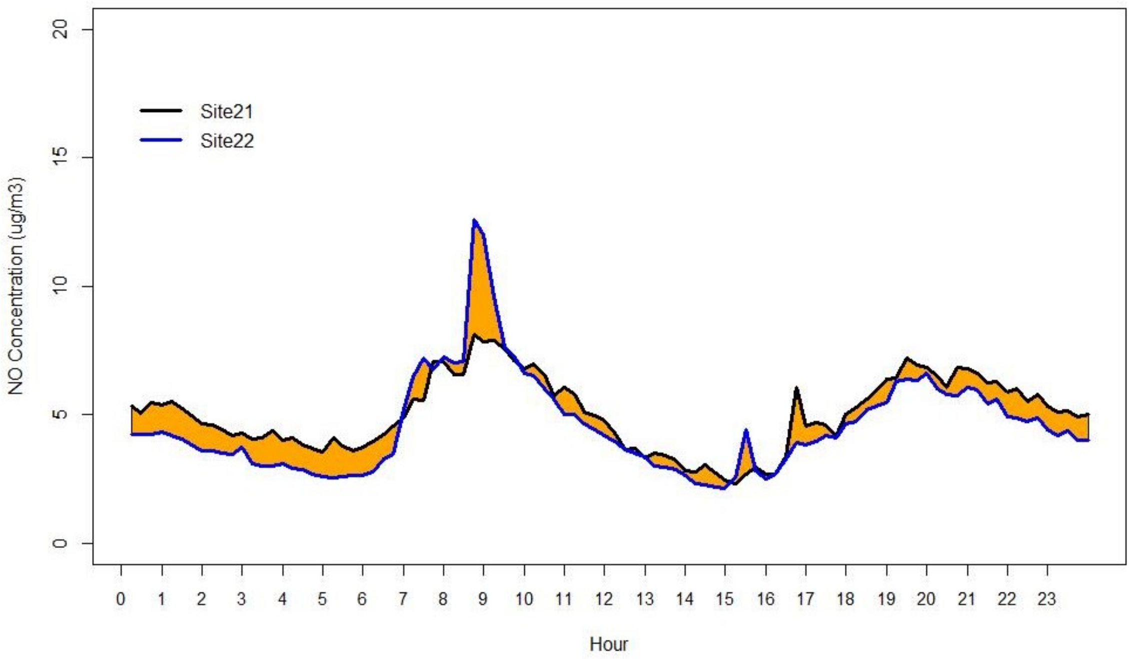


Figure 59: Average Diurnal Profile of NO Concentrations at Sites 21 and 22 (µg/m^3)

5.30 Figure 60 presents the average diurnal profile of concentrations at Site 21 with those at Site 22 subtracted. The plots appear to show a dip in concentrations of both pollutants during the morning and afternoon closure periods; however, these may reflect Site 22 being located adjacent to roads which see more through traffic during the morning.

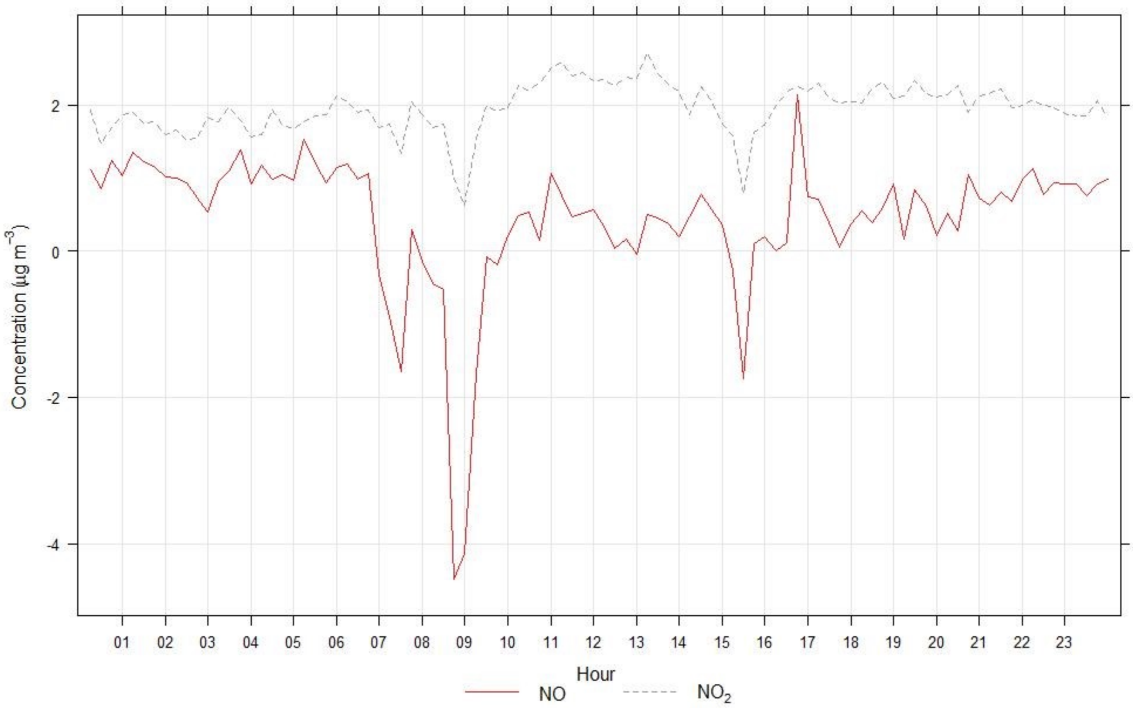


Figure 60: Average Diurnal Profile of NO and NO_2 Concentrations at Site 21 with Concentrations at Site 22 Subtracted (µg/m^3)

5.31 Figure 61 and Figure 62 present the week-by-week time series of concentrations at Site 21 with those at Site 22 subtracted. There are frequent negative spikes in concentrations common around the times of the morning School Streets interventions.

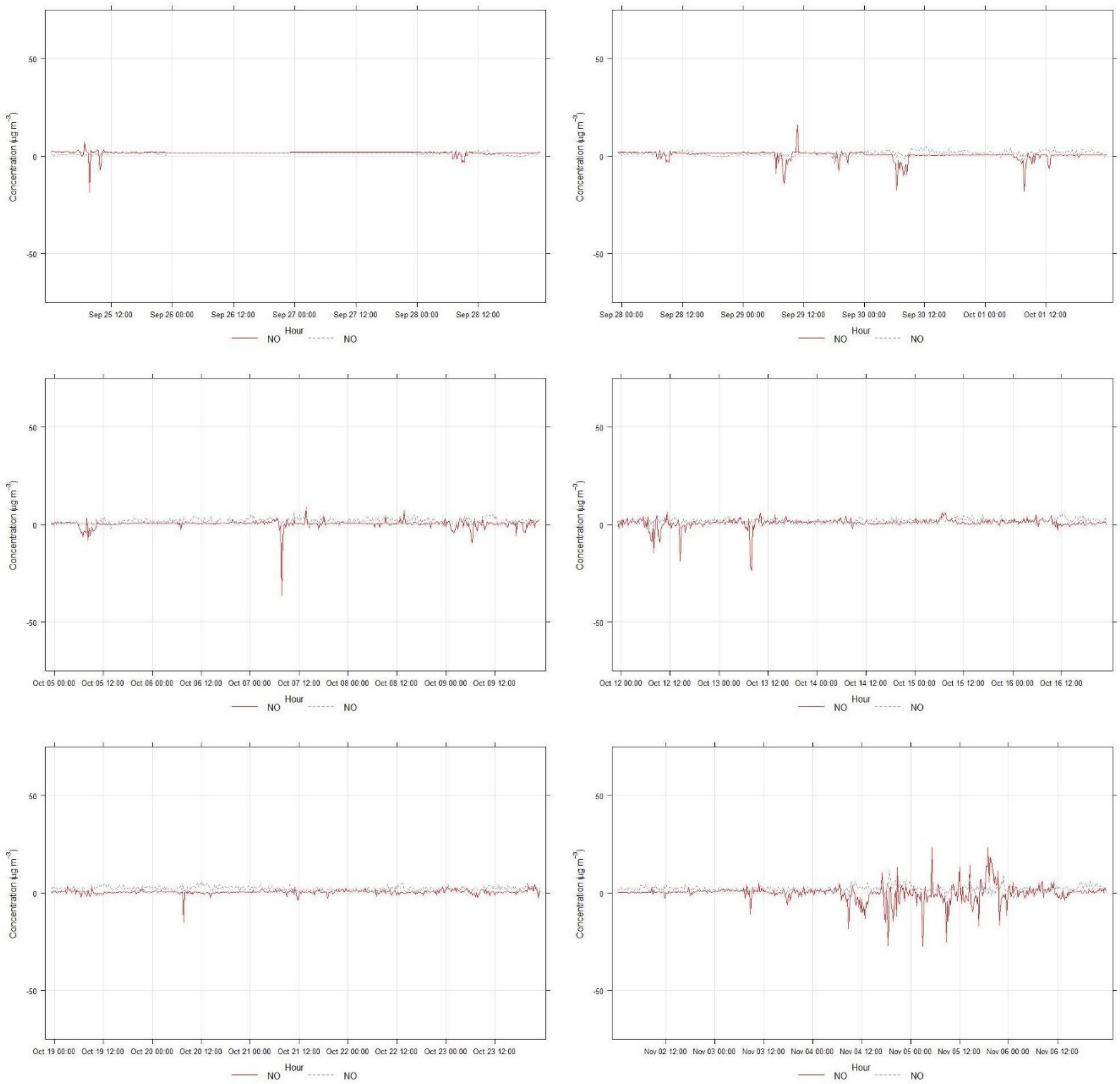


Figure 61: Measured School Day Concentrations at Site 21 with Concentrations at Site 22 Subtracted – First Six Weeks (µg/m³)

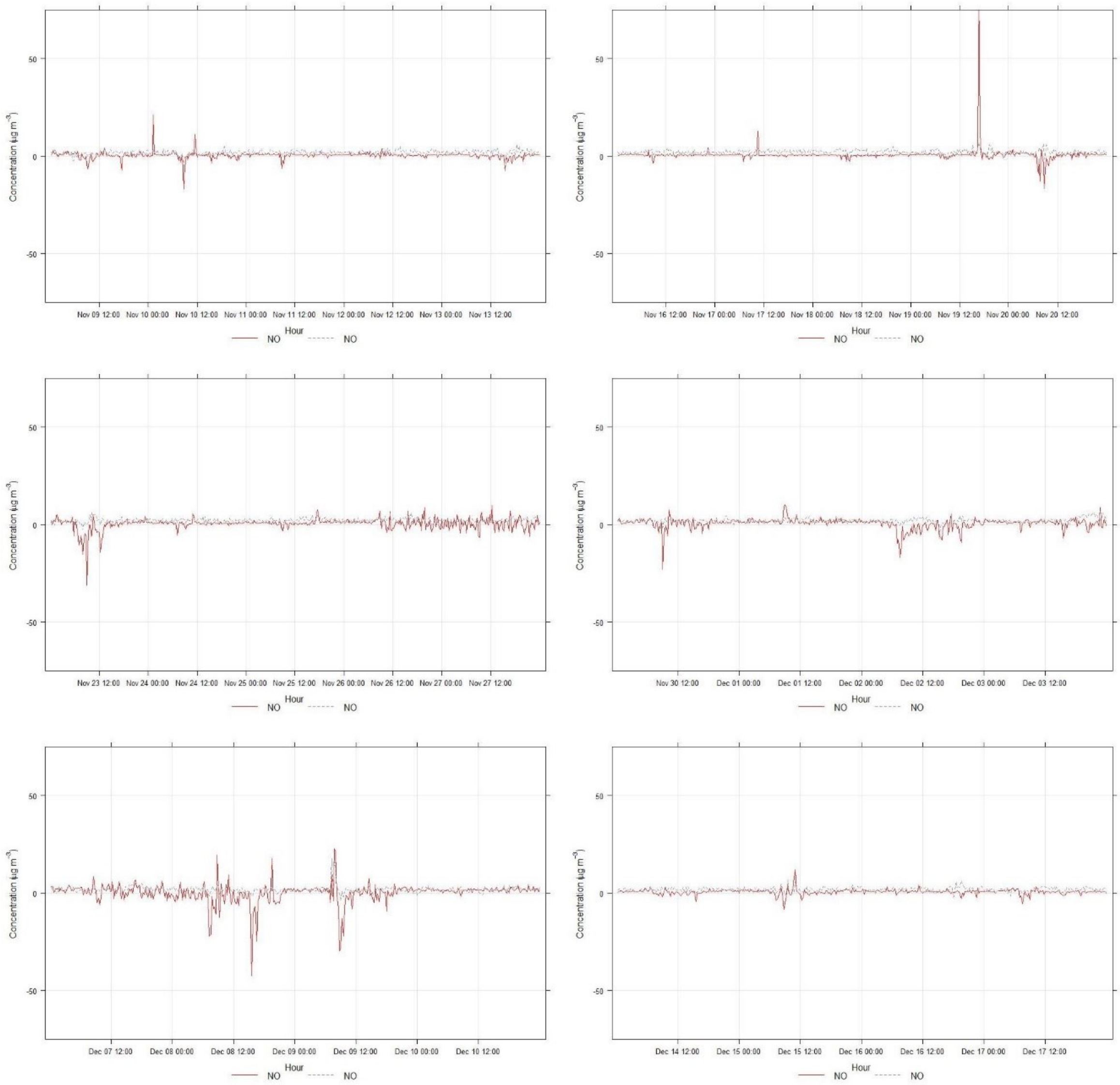


Figure 62: Measured School Day Concentrations at Site 21 with Concentrations at Site 22 Subtracted – Last Six Weeks (µg/m^3)

5.32 Figure 63 shows the frequency distribution of 15-minute NO concentrations expressed as the difference in concentration between the sites relative to the concentration at Site 22. The histogram highlights that there are far more similarities in measured concentrations at Sites 21 and 22 than in the previous analyses for sites in Enfield. The reductions observed are clearly systematic, as opposed to driven by isolated events, but it is possible that the differences are unrelated to the School Streets interventions.

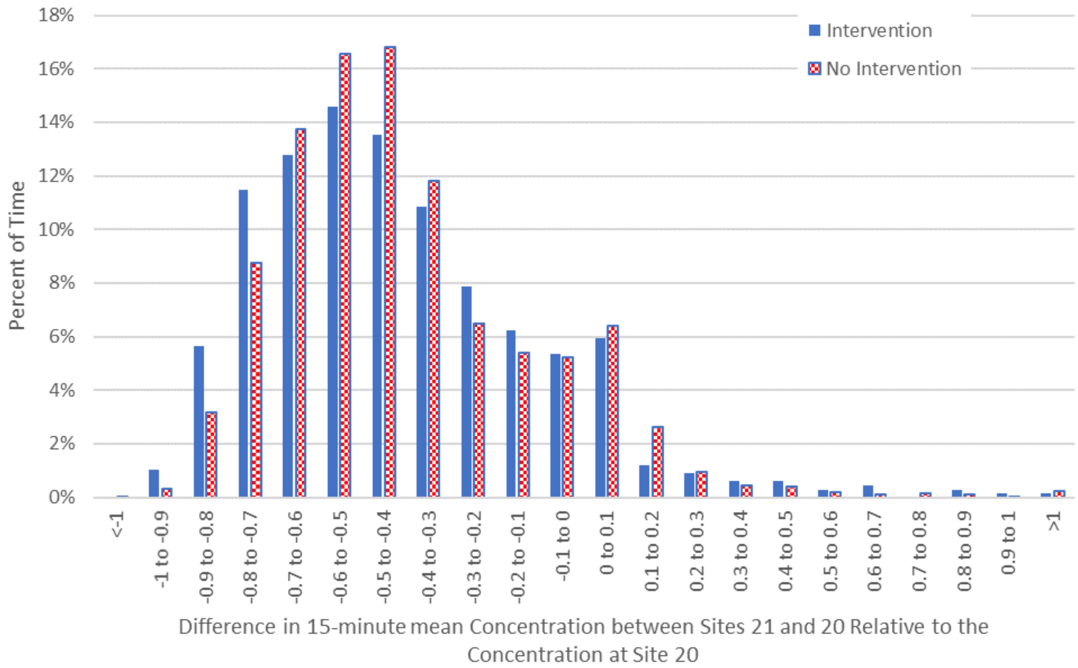


Figure 63: Difference in 15-Minute Mean NO Concentrations at Site 21 and Site 22 Relative to the Concentration at Site 22, Showing Frequency of Different Values

5.33 Applying the same approach as described in Paragraph 5.8, a School Streets-related reduction of 2.56 μg/m^3 is calculated when comparing the average difference in concentrations between Sites 21 and 22 during the morning intervention to those over the rest of the day (excluding the afternoon intervention period). This represents a 26% reduction in the NO concentration which would otherwise have been recorded during the drop-off period. The daily average (school day) concentration is predicted to have been 0.17 μg/m^3 (3.3%) lower than it would have been without the intervention. Applying the same approach for NO_2 as described in Paragraph 5.9, the corresponding reductions in NO_2 are 1.9 μg/m^3 (10%) during the intervention and 0.13 μg/m^3 (0.8%) as a daily mean.

Comparison to Site 20

5.34 Figure 64 presents the average diurnal profile of NO concentrations at Sites 21 and 20. Figure 10 shows that both of these sites are on the same road, with Site 20 being at the end of the closed section while Site 21 is at the centre. Concentrations, and the profile of concentrations, at the two sites are very similar, albeit with concentrations at Site 20 being consistently higher than those at Site 21. Both profiles show a dip in concentrations around 8-8:45am. It is likely that the same factors which cause the dip in morning-peak concentrations at Site 20 also caused the dip at Site 21. This means that subtracting concentrations at Site 20 from those at Site 21 is likely to underestimate the effect of the intervention, but is still a worthwhile exercise.

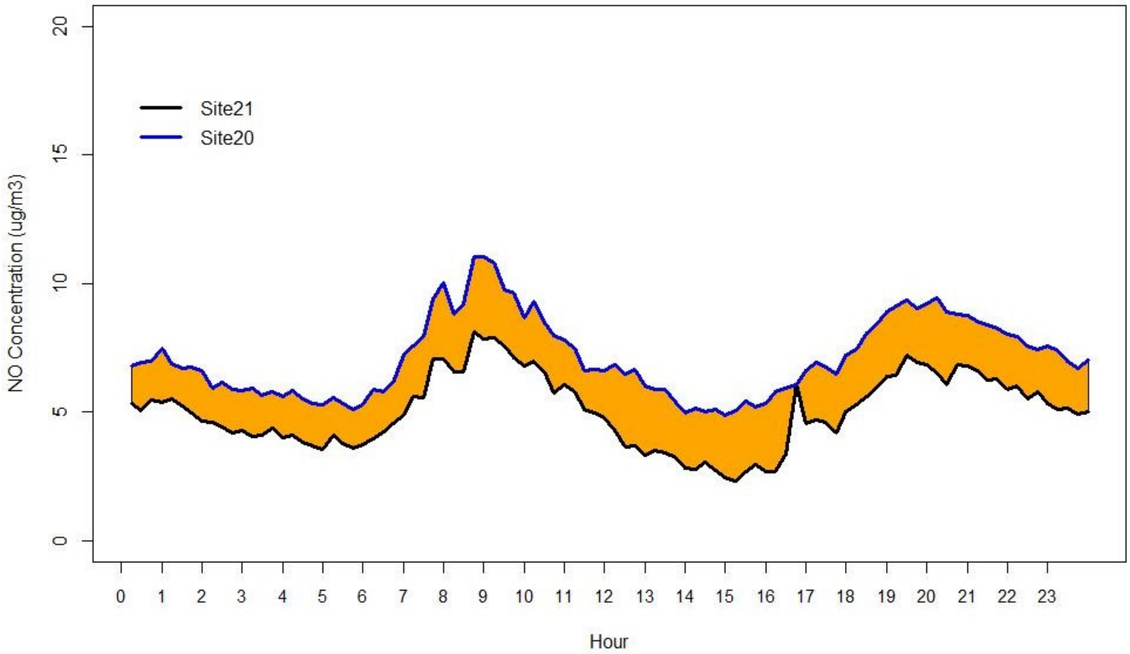


Figure 64: Average Diurnal Profile of NO Concentrations at Sites 21 and 20 (µg/m^3)

5.35 Figure 65 and Figure 66 present the week-by-week time series of concentrations at Site 21 with those at Site 20 subtracted. There are some negative spikes in concentrations common around the times of the morning School Streets interventions, but these are less frequent than when using Site 22 as the comparison site, suggesting a less robust observation.

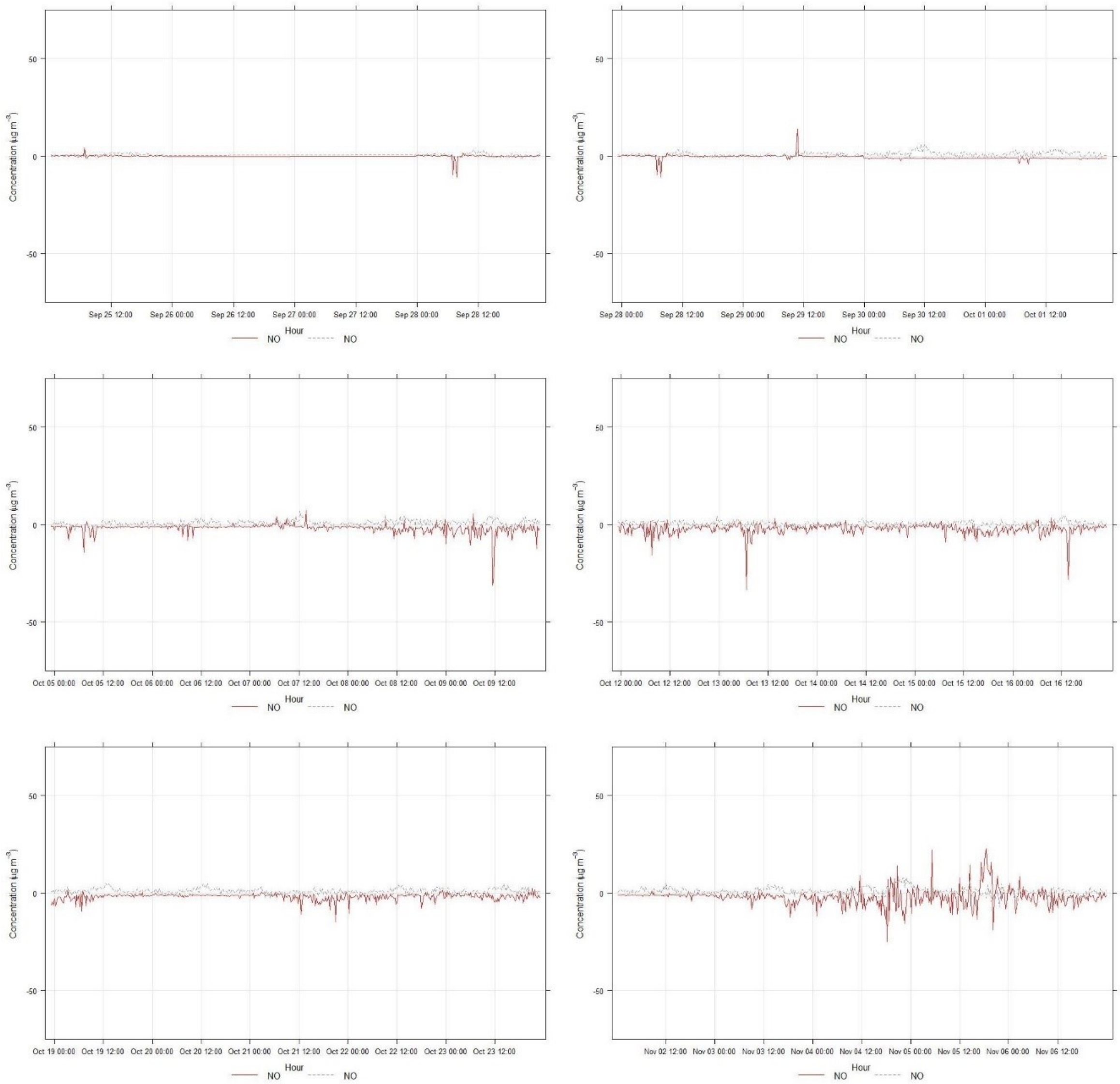


Figure 65: Measured School Day Concentrations at Site 21 with Concentrations at Site 20 Subtracted – First Six Weeks (µg/m^3)

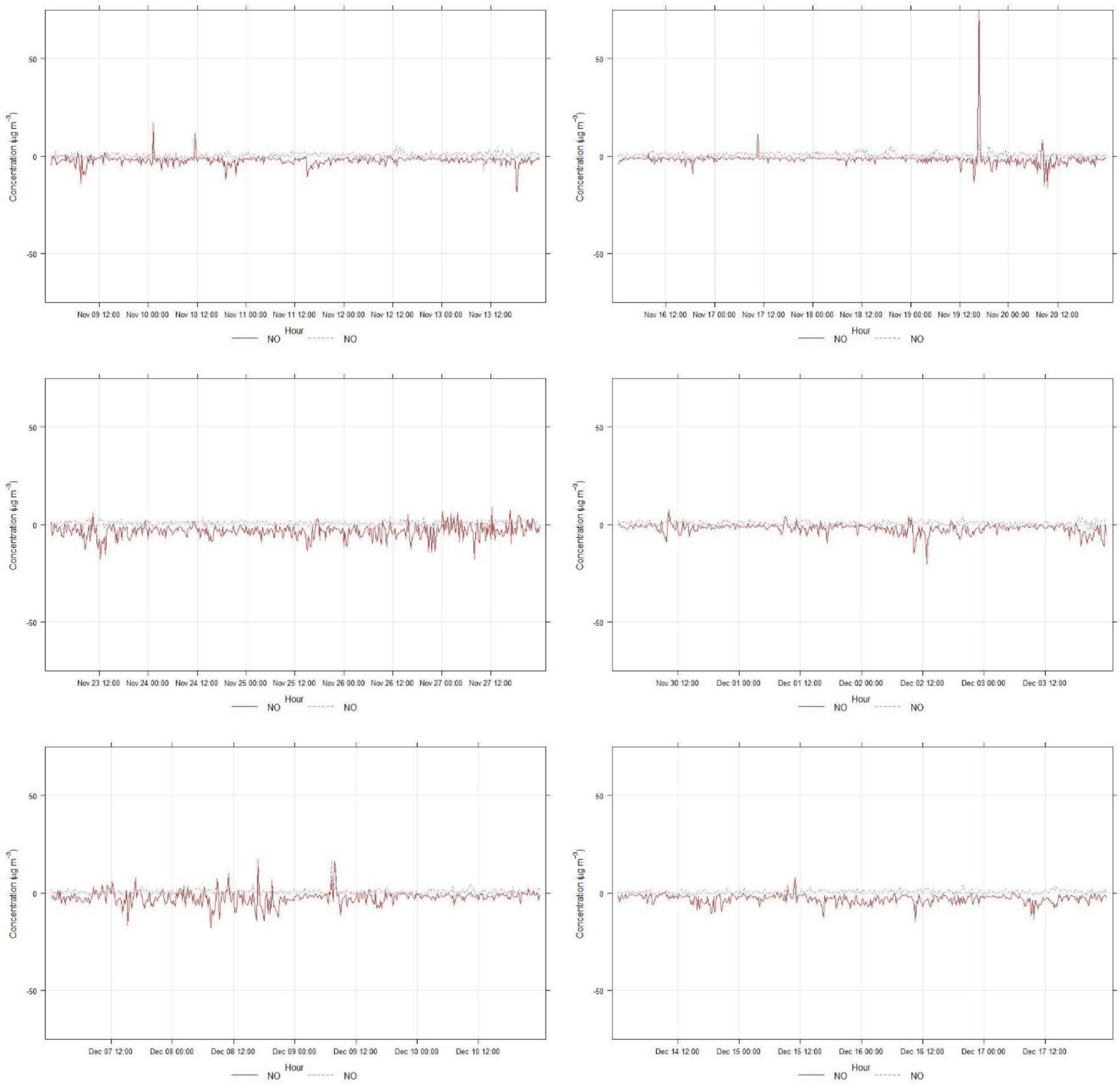


Figure 66: Measured School Day Concentrations at Site 21 with Concentrations at Site 20 Subtracted – Last Six Weeks (µg/m^3)

5.36 Figure 67 shows the frequency distribution of 15-minute NO concentrations expressed as the difference in concentration between the sites relative to the concentration at Site 20; showing that this comparison is not being driven by isolated events.

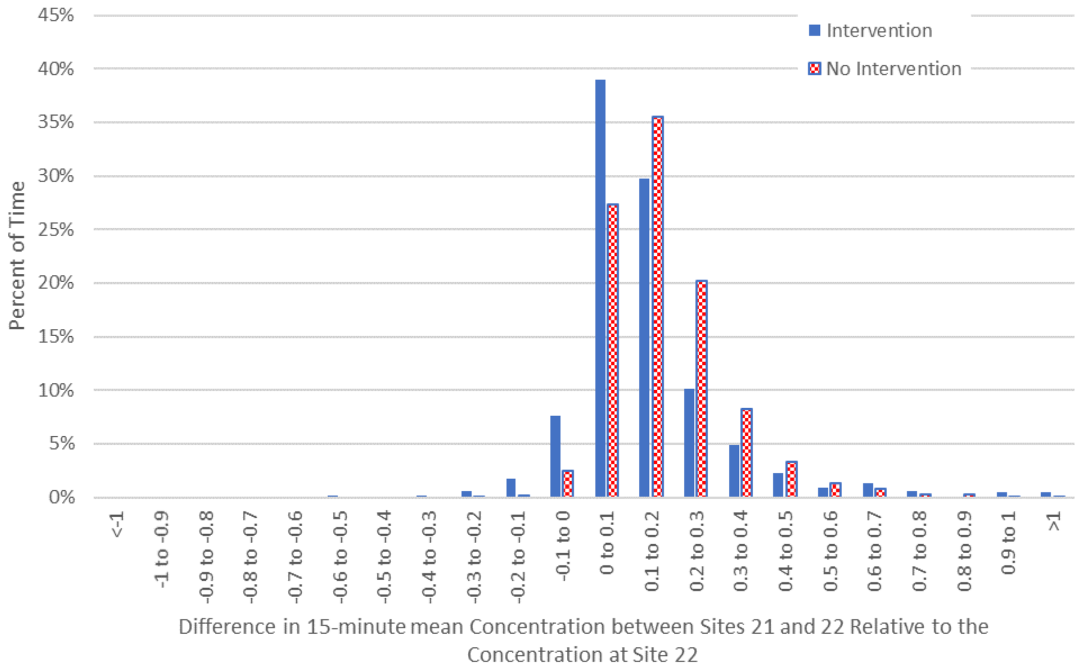


Figure 67: Difference in 15-Minute Mean NO Concentrations at Site 21 and Site 20 Relative to the Concentration at Site 20, Showing Frequency of Different Values

5.37 The comparison of Site 21 with Site 22 better isolates the effect of the School Streets intervention than using Site 20. It is not relevant to reproduce the analysis described in Paragraph 5.8 for this pairing.

Other Sites

5.38 A number of other comparisons have been carried out, but the resulting plots were all noisy and have not been presented.

Meteorological Variation

5.39 As noted in Paragraph 4.1, meteorological and seasonal factors are key drivers of pollutant concentrations, and could mask other patterns in the measured data. As such, further analysis has been carried out, seeking to incorporate the removal of such meteorological effects, using the ‘deweather’ function in the openair software package (Carslaw DC, Ropkins K, 2012) alongside meteorological data from Heathrow Airport. Only hourly metrological data were available, thus it was necessary to average the measured concentrations to hourly averaging periods, which may have masked some of the potential effects of the School Street interventions. The analysis is also limited by the short period of dataset; the deweather package works best with datasets that include several years data or more.

5.40 The measured pollutant concentrations at each site have been entered into the deweather model together the concurrent meteorological data and a specific parameter flagging whether or not an intervention was in place during each hour. The resultant partial dependencies (which show the relationship between the pollutant of interest and the covariates used in the model while holding the value of other covariates at their mean level) have then been analysed to identify whether there is an apparent influence that could be attributable to the interventions, either an obvious dip in concentrations at the relevant times in the ‘hour of the day’ partial dependency, or a clear inverse relationship between concentrations and interventions being in place.

5.41 No such obvious effects were apparent at any site. Even with meteorological and seasonal parameters averaged out, concentrations were still generally relatively high during the intervention periods, with no obvious dips in concentrations.

6 School Streets Attitudinal Survey

6.1 As part of the Streetspace for London and School Streets programme, TfL commissioned research to explore parents' awareness, attitudes and any changes to their travel behaviour as a result of School Streets delivered by Boroughs across London.

6.2 The study was an attitudinal survey to provide insight into awareness and attitudes towards School Streets, among parents/carers of children who attend a Primary School where a School Street was implemented (Intervention) and those without a School Street (Control). This was to understand (amongst other things) the impact on travel behaviour.

6.3 The results are summarised below, insofar as they are relevant to air quality.

Question 1: Parents/carers were asked how their children usually travelled to school before the pandemic, and how they usually travel now

6.4 The responses to Question 1 are summarised in Figure 68 and below:

- The way that children usually travel to school since before the pandemic is relatively unchanged.
- Walking continues to be the most popular mode of travel to and from school for children attending intervention (75% before Covid -79% nowadays December 2020) and control schools (71%) both before the Covid-19 pandemic and nowadays.
- The only significant difference in the main mode of transport used between pre pandemic and December 2020 was a 6% decrease in children traveling to school by Public Transport at Control Schools.
- Compared to before the Pandemic, there was a slight increase (4%) in the number of children walking to school and a slight decrease (4%) in the number of children being driven to school at Intervention Schools. This compares to a small increase (3%) in the number of children being driven to school at control schools. However, none of these findings are large enough to be significant.

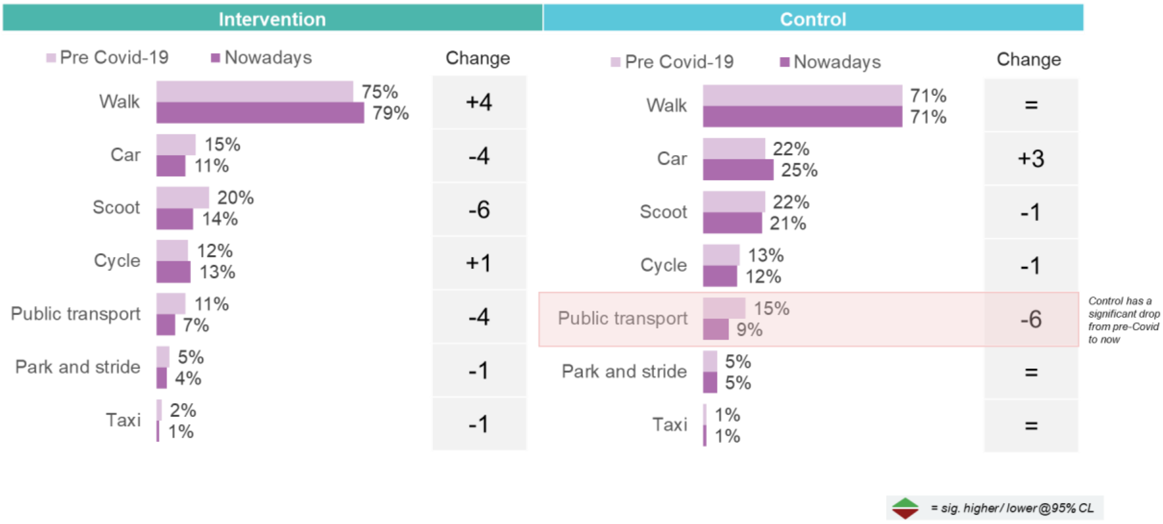


Figure 68: Responses to Attitudinal Survey Question 1

Question 2: Parents/Carers at intervention and control schools were asked whether they used each mode of transport more or less, as a result of the COVID-19 Pandemic

6.5 The responses to Question 2 are summarised in Figure 69 and below:

- Significantly more respondents (+5%) reported cycling more as a result of the COVID-19 pandemic at School Street schools than at control schools, where there was only a marginal increase (+1%).
- Furthermore, there was a larger decrease in parents / carers driving to or from school as a result of the COVID-19 pandemic at School Street schools (-12%), as compared to the slight fall at control schools (-2%).
- Among the minority of parents / carers using Park and Stride to get to and from school, there were falls for both intervention and control schools. However, the decrease was greater (-9%) in reported use of park and stride at control schools, than at intervention schools (-4%).
- Parents report walking more frequently and using public transport less frequently at school street and control schools, however there was no significant difference between the two groups.

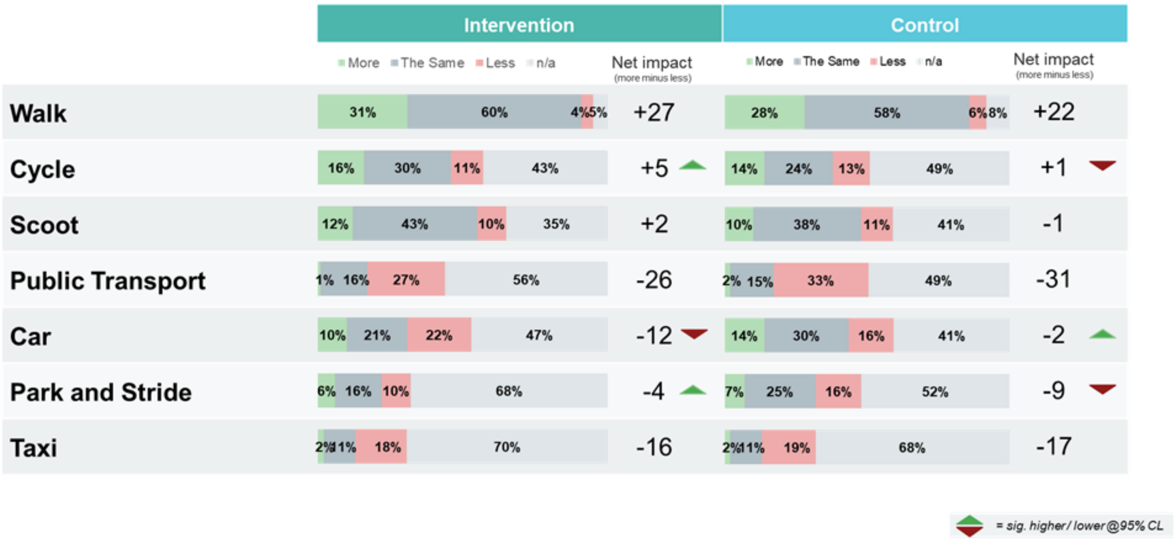


Figure 69: Responses to Attitudinal Survey Question 2

Question 3: Parents at intervention and control schools were asked whether they use each mode of transport more or less, as a result of the School Street

6.6 The responses to Question 3 are summarised in Figure 70 and below:

- At School Street schools, parents were asked whether they used each mode of transport more or less due to the COVID-19 pandemic and again due to the School Street.
- Parents reported driving to school less as a result of the COVID-19 pandemic and also driving to school less as a result of the School Street. However, the School Street had a significantly greater impact (-18%) on reducing car travel to school than the impact of COVID19 (-12%).
- 27% of parents reported walking to school more as a result of the pandemic and the same proportion (27%) reported walking more as a result of the School Street. Similarly, 5% of parents reported cycling more as a result of the pandemic and 6% reported cycling more as a result of the School Street. This suggests that COVID-19 and the implementation of the School Street had an equal impact on encouraging more walking and cycling to school at School Street schools.

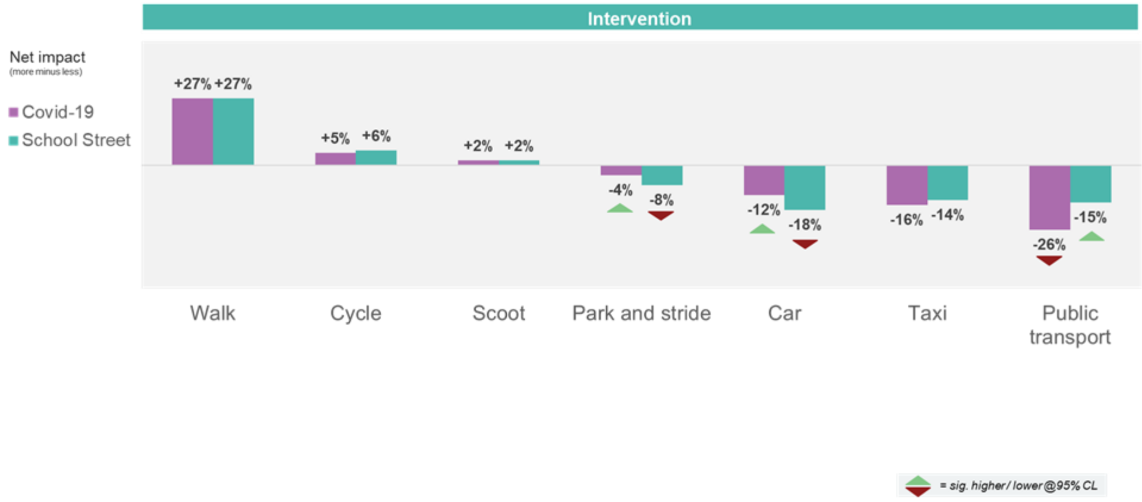


Figure 70: Responses to Attitudinal Survey Question 3

Implications for Air Quality (AQC Appraisal)

6.7 A modal shift towards active means of travel, such as walking, cycling or scooting has many benefits to parents and children alike. In terms of specific benefits to air quality, it is the reduction in the use of the private car for drop-off and pick-up that is most relevant. The data available from the survey do not allow any analysis of how this reduction might affect pollutant concentrations in absolute terms, but some general conclusions can be drawn. The survey found that 18% of parents/carers at School Street schools reported driving less as a result of the School Street. However, there are no data to quantify what reduction in car trips this led to, and, therefore, the associated reduction in pollutant emissions, i.e. If parents reduced the number of weekly car trips from ten to four, this would lead to a greater reduction in emissions than if parents made a smaller reduction in weekly car trips e.g. from two to one. Nonetheless, there must have been some reduction in both emissions and pollutant concentrations associated with fewer parent/carer trips to the schools.

7 Summary and Conclusions

7.1 An air quality monitoring study has been carried out utilising 30 AQMesh sensors installed near to schools in the London Boroughs of Brent, Enfield and Lambeth to investigate the air quality benefits of School Streets. Sensors were installed adjacent to, and at the ends of, sections of road that would be closed at certain times of the day on school days as part of the School Streets initiative. Comparator sites were also installed adjacent to schools where no interventions were implemented, i.e. schools that were not in in the School Streets initiative.

7.2 A range of approaches has been used to attempt to identify the influence of the road closures on measured pollutant concentrations. The confounding effects of COVID-related travel restrictions and day-to-day changes to the weather have made it difficult to identify the precise effect of many of the individual interventions on air quality, but, as explained in paragraph 2.22, isolating the benefits of individual interventions is never straightforward even utilising the most sophisticated techniques; it is important to note, however, that simply because the air quality benefits at some sites could not be identified from an analysis of the monitoring data, this does not mean that benefits did not occur (see paragraph 7.4 below).

7.3 However, at some sites, a clear effect has been seen. The comparison of concentration profiles at similar sites (typically one with a School Street intervention and one without), has identified average reductions in NO concentrations of up to 8 $\mu g/m^3$ (34%) during the morning intervention period, which equates to a reduction in daily average (school day) concentration of approximately 5%. The resultant reduction in NO_2 during the school drop-off period has been estimated as being up to 6 $\mu g/m^3$ (23%). The morning intervention alone is thus expected to have reduced daily average NO_2 by up to 0.4 $\mu g/m^3$, or 2%. It is unsurprising that the morning interventions had a much more obvious effect, given that they coincide with the morning peak traffic period, whereas the afternoon interventions occurred well before the evening traffic peak.

7.4 Attitudinal Surveys carried out by TfL have highlighted that 18% of parents/carers reported driving less as a result of School Street interventions. This can reasonably be expected to have reduced pollutant emissions (NOx and Particulate Matter) and carbon dioxide emissions associated with car trips for school drop-off and pick-up, but the precise level cannot be quantified as the actual change in car trips is not known.

8 References

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9 Glossary

AQC	Air Quality Consultants
CERC	Cambridge Environmental Research Consultants
COVID	Coronavirus Disease
Defra	Department for Environment, Food and Rural Affairs
GLA	Greater London Authority
FIA	Fédération Internationale de l'Automobile
µg/m^3	Microgrammes per cubic metre
NCM	Network Calibration Method
NO	Nitric oxide
NO_2	Nitrogen dioxide
NOx	Nitrogen oxides (taken to be NO_2 + NO)
TfL	Transport for London