

Richmond air quality
monitoring of borough-wide
20 mph speed limit

July 2021

Quality information

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1. Introduction

AECOM was commissioned by London Borough of Richmond-upon-Thames (LBRuT) to undertake continuous monitoring of nitrogen dioxide (NO₂) using low-cost continuous air quality sensors (AQ Mesh pods). The aim of the study was to investigate the potential impacts on local air quality due to the roll-out of the borough wide 20 mph speed limit initiative. The study focused on the impacts at selected roads throughout the Borough.

NO₂ monitoring was carried out at three locations across the Borough in two 3-month phases. The first phase during December 2019 – May 2020 aimed to establish baseline NO₂ concentrations before the introduction of the 20 mph scheme, with the second phase during January 2021 – April 2021 to determine concentrations once the scheme was in place.

2. Monitoring Methodology

AQ Mesh continuous monitors (pods) are small, relatively low-cost, multi-sensor units capable of measuring concentrations of gases and particulate matter at up to 5-minute resolution. Pods measuring NO₂ using electrochemical sensors, and particulate matter fractions using optical particle counters, powered by solar panels with attached battery packs, were used for the project. The pods measured concentrations at up to 15-minute resolution.

Table 1 presents details for each of the three monitoring locations and the approximate date the 20 mph speed limits were introduced at these locations.

Table 1 AQ Mesh Monitoring Locations

Location	Address	Lamppost number	Approximate date of 20 mph roll-out
St Margaret's Road	359 St Margaret's Road, Twickenham	058	March 2020
Queen's Road	139 Queen's Road, Richmond	043	December 2019
Petersham Road	Rose of York Pub, Petersham Road, Richmond	125	January 2020

The AQ Mesh pods at each location were installed on roadside or kerbside lampposts, with solar panels set up to face south where possible with a relatively unimpeded view of the sky to allow for maximum power generation. For the first phase, monitoring was carried out from 20th December 2019 until 19th May 2020, and from 22nd January 2021 until 29th April 2021 for the second phase. When switched on and monitoring, the pods frequently transmit pod status updates and monitoring data to a remote web server. The remote server was interrogated regularly during the monitoring to check the pods were functioning correctly and data was being collected as expected, and raw data was periodically downloaded for ongoing data checks and quality assurance/quality control procedures.

3. Results

Overall Summary

A comparison of the January – April period mean NO₂ concentrations in 2021 versus the data collected in 2020 for the same period is presented in Table 2 for all three monitoring locations. The three locations were found to experience year-on-year (YoY) decreases in NO₂ concentrations of between 13% and 21% in 2021.

Table 2 Comparison of 2020 and 2021 Period Mean NO₂ concentration at all AQ Mesh monitoring locations

Monitoring Location	Period Mean (Jan – Apr)	
	2020	2021 (YoY Change)
Queen's Road	28.7	23.2 (-19.4%)
St Margaret's Road	30.3	23.9 (-21.1%)
Petersham Road	28.2	24.5 (-13.0%)

Detailed Summary

Monthly Averages

Table 3 breaks down this analysis for the three AQ Mesh locations into monthly average NO₂ concentrations, with the respective 2020 and 2021 monthly concentrations presented side-by-side. In each month between January and March inclusive, the 2021 concentrations are notably lower than 2020 for all locations. In April in 2021 there is a slight increase at Petersham Road relative to April 2020, whilst the reductions in concentration for the other locations is less evident in April 2021.

Table 3 Comparison of 2020 and 2021 monthly average NO₂ concentration at monitoring locations

Monitoring Location	January		February		March		April	
	2020	2021	2020	2021	2020	2021	2020	2021
Queen's Road	30.5	21.4	28.1	23.4	30.5	24.1	25.7	22.4
St Margaret's Road	33.7	24.7	30.8	23.9	30.0	24.4	26.7	23.3
Petersham Road	29.1	24.7	28.0	23.9	30.1	24.5	25.5	25.9

Table 4 presents NO₂ concentrations for the same periods in 2020 and 2021 from two nearby reference continuous monitoring sites in Putney – High Street Façade (WA8; Roadside site) and Felsham Road (WA9; Urban Background site). Again, the roadside site shows a decrease (16%) in NO₂ concentrations in 2021 relative to 2020, whereas the urban background site shows a reversal of this trend with an increase in background NO₂ concentrations across the period. These observations might indicate that regional background concentrations in 2021 are higher than 2020 as a result of meteorological factors, partially offsetting the reduction in roadside NO₂ concentrations caused by COVID-19 lockdown measures.

Table 4 Comparison of 2020 and 2021 Period Mean NO₂ concentration at nearby reference monitoring stations

Reference Monitoring Location	Period Mean (Jan – Apr)	
	2020	2021 (YoY Change)
Putney High Street Façade Roadside (WA8)	55.9	47.0 (–16.0%)
Putney Felsham Road Urban Background (WA9)	25.8	29.4 (+14.0%)

Temporal variation in NO₂ concentrations at AQ Mesh monitoring locations

Figures 1 to 3 present the temporal variations in hourly NO₂ concentrations for Queen’s Road, St Margaret’s Road and Petersham Road respectively, comparing the 2020 monitoring data (shown in red) with the 2021 monitoring data (in blue). The lines show the mean NO₂ concentrations, with 95% confidence intervals shown by the bars or shading on the plots. These plots were created using the R programming language “Openair” package¹. For each figure, the uppermost plot shows the variation in NO₂ concentrations by hour-of-day and day-of-week. The bottom-left plot shows the variation in NO₂ concentration by hour-of-day only, and the bottom-right plot is by day-of-week only. The bottom-centre plot shows the monthly average NO₂ concentrations.

In all three figures, as seen in Table 2, NO₂ concentrations are shown to be lower on average in 2021 than in 2020 across all three locations, which as previously discussed is likely to have been caused at least in part by the impact of the COVID-19 pandemic on traffic flows and consequent pollutant emissions. This difference between 2020 and 2021 is most clear for the Queen’s Road and St Margaret’s Road locations, although the difference is also evident at Petersham Road.

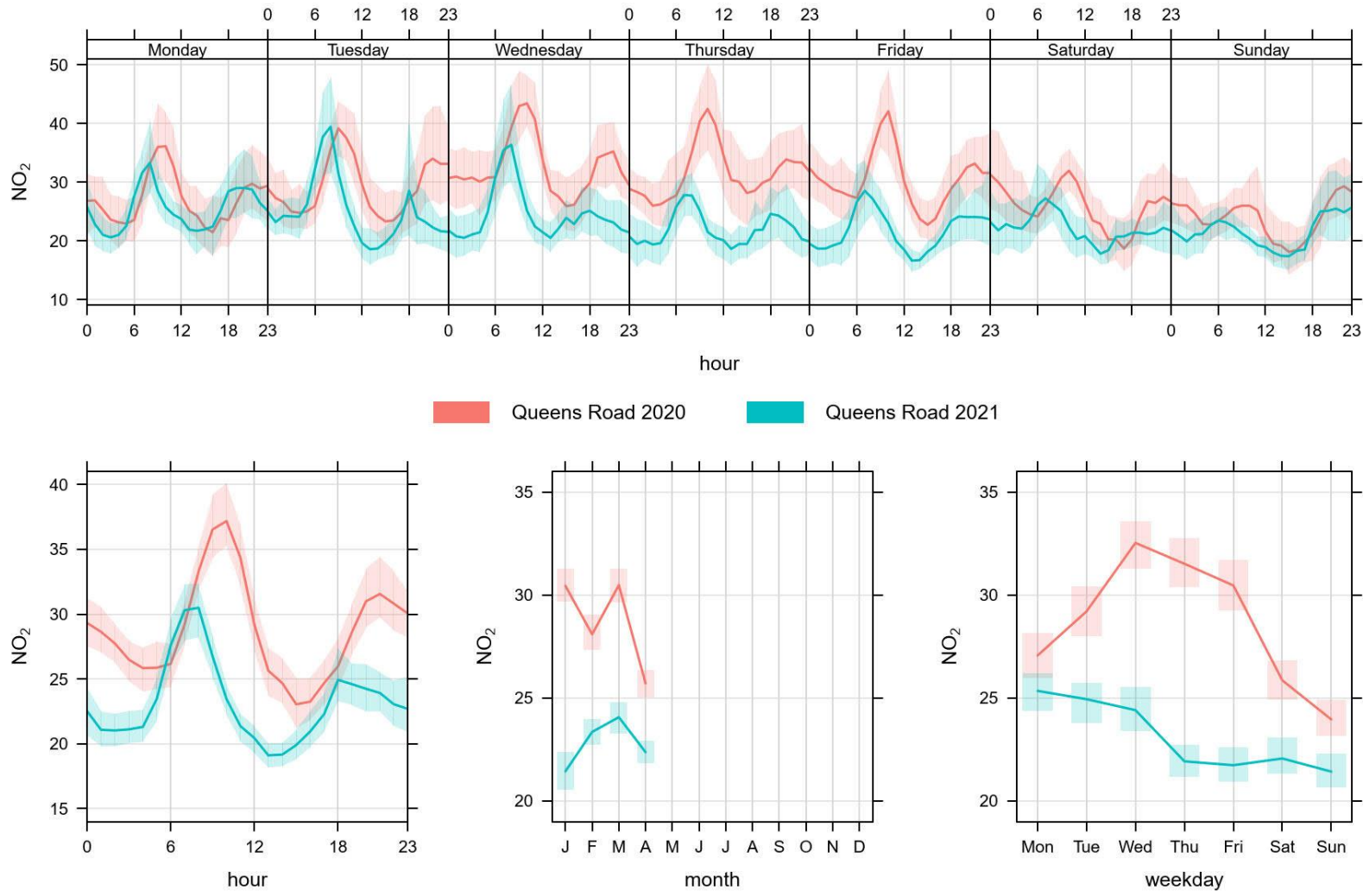
At each site, Figures 1 to 3 show that the NO₂ concentrations in 2021 were lower for almost every hour of the day (bottom-left plot), except during the early morning rush-hour at Queen’s Road and Petersham Road, where the peaks in NO₂ concentrations during the morning rush-hour traffic appear to occur earlier in the day in 2021 than in 2020. The cause of this shift in the morning peak concentrations is unclear, although it may be related to post-pandemic shifts in daily routines and the knock-on effects on traffic patterns. Evidence of a decrease in the *amplitude* of the morning peak in NO₂ concentrations, at Queen’s Road and St Margaret’s Road in particular, could have resulted from smoother traffic flows and lower congestion during the 2021 period as compared with 2020, and this could have been influenced by a reduction in traffic speeds brought about by the 20 mph speed limit introduction. Again, the influence of the pandemic cannot be ruled out in being a factor here.

The variation in NO₂ concentrations with day of the week (bottom-right plot) also shows dramatic and significant differences between 2020 and 2021 across all three locations. Whereas in 2020, NO₂ concentrations were highest during Wednesday to Friday, 2021 concentrations were generally lower, and were highest on Monday and Tuesday before decreasing during the rest of the week and into the weekend. Again, this could be a manifestation of a post-pandemic shift in routine, however it is also important to consider that meteorological influences cannot be ruled out, since weather patterns are inherently cyclical in nature, and the same weeks and months in different years can present very contrasting weather conditions.

As seen in Table 3, the monthly average NO₂ concentrations in all three figures (bottom-centre plot) show the decrease in NO₂ concentrations between 2020 and 2021 most clearly, with January to April reporting a significantly lower NO₂ concentration in 2021 than in 2020 at all sites. The exception to this pattern is Petersham Road in April where April 2021 concentrations are higher than April 2020. The impact of the first nationwide lockdown at end of March 2020 can be clearly seen with a sharp decline in NO₂ concentrations across all sites due to much lower traffic volumes.

¹ Openair: Open Source Tools for Air Quality Data Analysis: <https://www.rdocumentation.org/packages/openair/versions/2.8-3>

Figure 1 Temporal variation of NO₂ concentrations in 2021 compared to 2020 at Queen's Road AQ Mesh location



mean and 95% confidence interval in mean

Figure 2 Temporal variation of NO₂ concentrations in 2021 compared to 2020 at St Margaret's Road AQ Mesh location

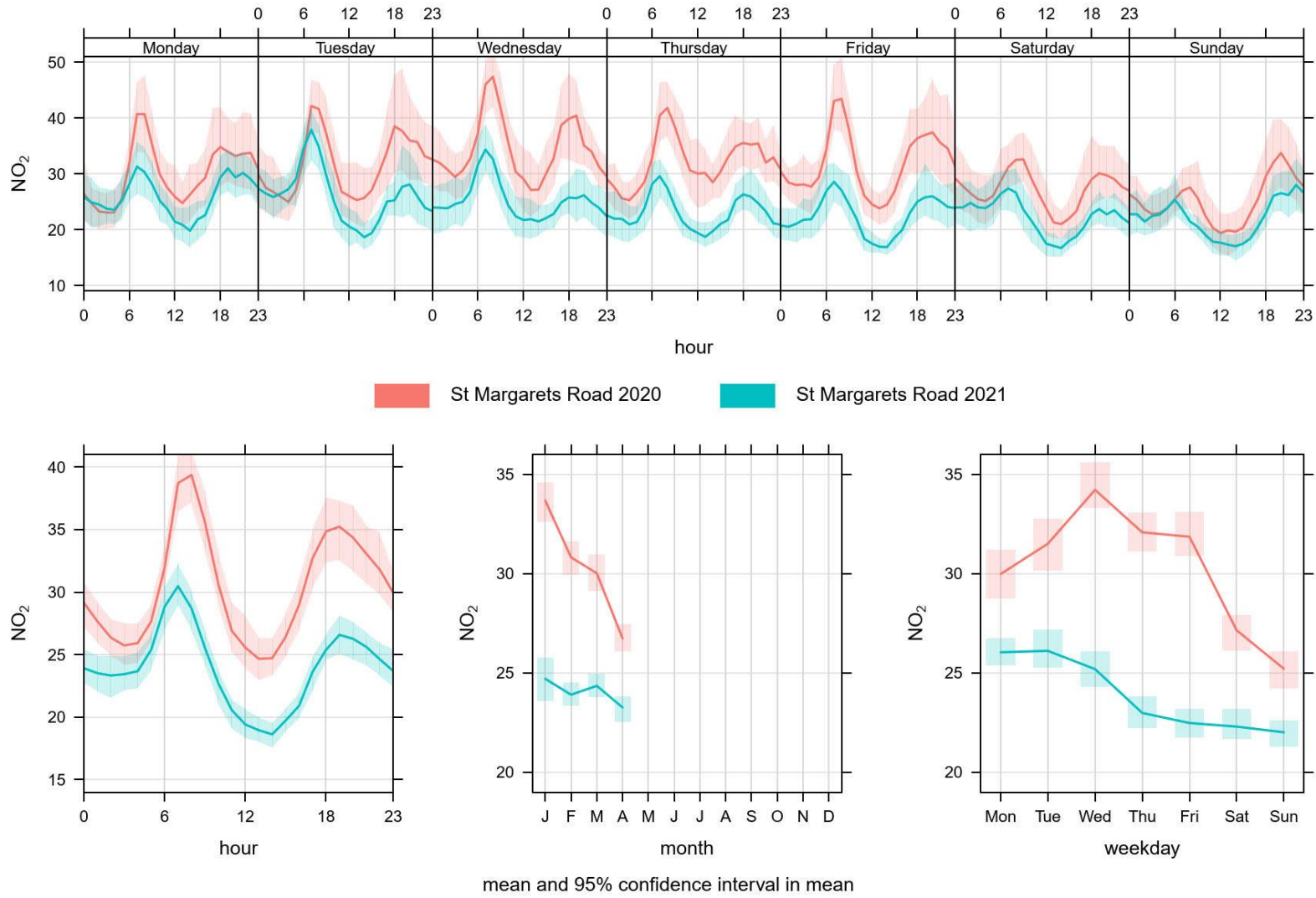
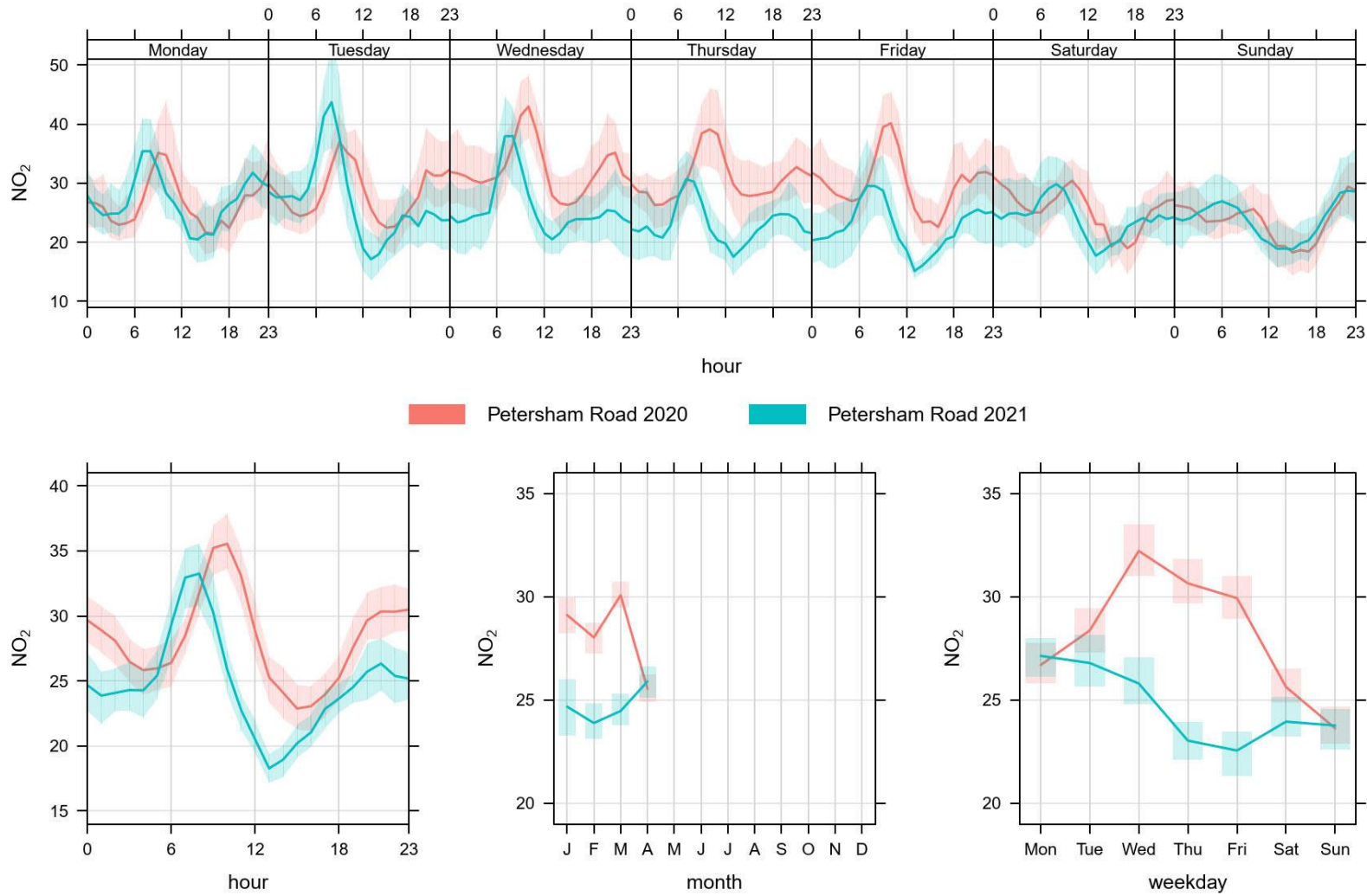


Figure 3 Temporal variation of NO₂ concentrations in 2021 compared to 2020 at Petersham Road AQ Mesh location



mean and 95% confidence interval in mean

Temporal variation in NO₂ concentrations at nearby continuous monitoring locations

Figure 4 shows the results of time variation analysis of NO₂ concentrations for the roadside reference continuous monitor located on Putney High Street façade (WA8). Consistent with the AQ Mesh monitoring data, a sharp decrease in NO₂ concentrations is seen in April 2020 relative to the January – March 2020 period, which is very likely to be as a result of the first national lockdown causing traffic flows to decrease significantly. This reduction in concentration is again also seen more generally for the whole January to March period in 2021 versus 2020, however April 2021 concentrations are higher than in 2020, in line with the ease of lockdown and changes in travel patterns.

In terms of the hourly distribution of NO₂ concentrations, there is evidence for less amplified morning and evening peaks in NO₂ concentrations, while early morning concentrations are very similar between 2020 and 2021.

Due to the similarities in the patterns of NO₂ concentrations recorded by the AQ Mesh monitors and the nearby reference monitor, it would seem more likely that the observed differences in concentrations are due to impacts stemming from the COVID-19 pandemic, and potentially also meteorological factors. The influence of the general slowing of traffic due to the introduction of 20 mph speed limits cannot be ruled out, but further work would be needed to establish a larger dataset to analyse and control for the effects of the global pandemic.

Figure 5 shows the same analysis for the Felsham Road reference continuous monitor (WA9) located very close to the Putney High Street monitor. This site is an urban background and is therefore not representative of a heavily trafficked environment. In a reversal of trend at roadside sites, NO₂ concentrations are greater in 2021 than in 2020 at this location. As traffic emissions are less of a strong influence on background concentrations, such as those measured here, the implication is that meteorological influences are more likely to cause this result and suggest that the January – April 2021 period was meteorologically more favourable to conditions that reduce the dispersion of pollution (e.g. colder weather and higher surface pressure / atmospheric stability, lower wind speeds). This also implies that the true impact of the pandemic on NO₂ concentrations, as seen from the AQ Mesh locations, may have been masked or partially offset by meteorological differences between the two years, suggesting the potential impact from the pandemic (and also the 20 mph speed limit roll-out) could have been larger than that shown by the data.

Figure 4 Temporal variation of NO₂ concentrations in 2021 compared to 2020 at Putney High Street Façade reference location

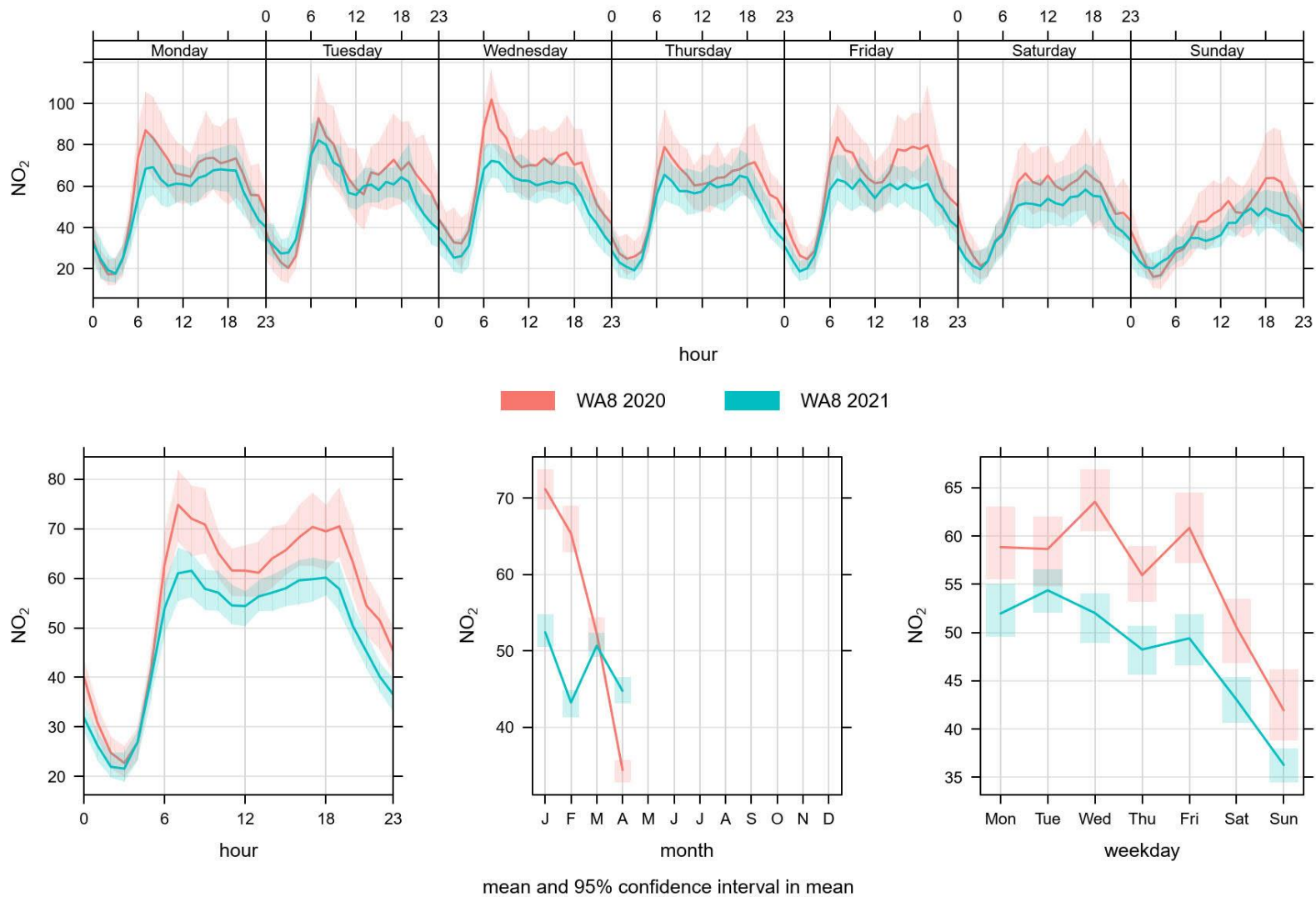
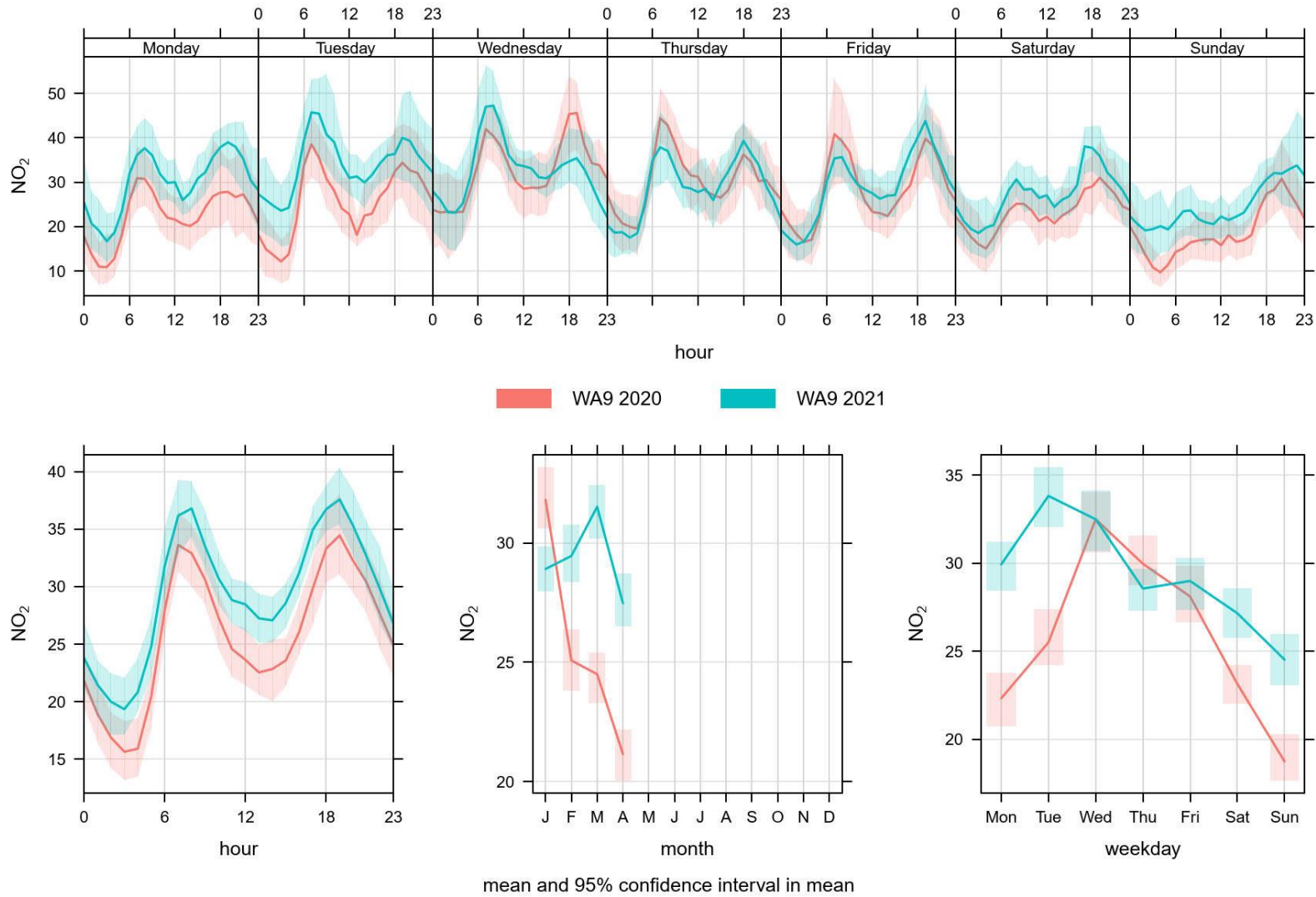


Figure 5 Temporal variation of NO₂ concentrations in 2021 compared to 2020 at Felsham Road, Putney urban background reference location



Traffic count data

Bi-directional traffic counts were conducted near to the three AQ Mesh monitoring locations before (September/October 2018) and after (September/October 2020) the introduction of the 20 mph speed limit, in order to determine and compare the vehicle fleet average speed, flow and composition. The counts took place for approximately 1 week's duration. Table 5 shows the average daily traffic flows and average vehicle speed in 2018 and 2020, with the percentage change given in brackets

Table 5 Comparison of pre-20mph (2018) and post-20mph (2020) traffic data near all AQ Mesh locations

Site	Average Daily Traffic Flows		Average Speed (mph)	
	2018	2020 (Change)	2018	2020 (Change)
Queen's Road	11,132	12,011 (+7.9%)	26.0	22.7 (-12.5%)
St Margaret's Road	9,407	10,271 (+9.2%)	23.8	21.8 (-8.4%)
Petersham Road	11,060	9,391 (-15.1%)	25.8	24.0 (-7.0%)

The table shows that average speeds across all sites decreased by between 7% at Petersham Road and 12.5% at Queen's Road, which could play a minor role in reducing traffic emissions through lower levels of braking/accelerating and less congestion, although this cannot be directly inferred from the traffic data shown above or the NO₂ concentrations.

Although the average daily traffic flows increase at both Queen's Road and St Margaret's Road in 2020 relative to 2018, the 2020 traffic count was undertaken during one of the busier periods for traffic during the first year of the COVID-19 pandemic, and the increase seen at these sites could potentially also be attributed to general expected year-on-year growth in traffic. We can be confident that traffic flows would have dropped significantly during the first national lockdown of the COVID-19 pandemic, in particular. Along Petersham Road, the reverse is seen with a sharp decrease in average daily traffic flows in 2020 compared to 2018, for reasons not known.

4. Summary and Conclusions

AECOM carried out monitoring of NO₂ using AQ Mesh sensors at three roadside locations before and after the introduction of the borough 20 mph speed limit to determine if there were air quality impacts due to the scheme.

The main conclusions from the AQ Mesh monitoring undertaken are summarised below.

- All three AQ Mesh monitoring locations showed a substantial (up to 20%) decrease in period mean NO₂ concentration for the January – April period in 2021 (post-scheme), relative to the same period of 2020 (pre-scheme).
- A sharp decrease in NO₂ concentration at these locations was also seen in April 2020 relative to January – March 2020.
- The combination of the sharp decrease in April 2020 and the subsequent lower concentrations in the 2021 period compared to 2020 is likely to have been at least partly due to the impacts of the COVID-19 pandemic on traffic flows and emissions, particularly with regard to the first national lockdown but then also subsequent longer term changes to working patterns and general decreases in rush-hour traffic from reductions in commuting and greater home-working.
- While impacts on air quality from the introduction of the 20 mph speed limits cannot be ruled out, they are likely to be minor relative to impacts from the pandemic, and difficult to identify or isolate without further study and a larger dataset. Other effects, such as meteorological variability from year to year and month to month, are also likely to have played a greater role in affecting concentrations, and further effects such as the gradual improvement of the vehicle fleet through hybridisation/electrification could also have played a role.
- Traffic counts conducted before and after the roll-out of the 20 mph speed limit show a marked decrease in average vehicle speeds after the roll-out, and while daily vehicle flows were higher at Queen's Road and St Margaret's Road after the roll-out, it is likely that daily vehicle flows were much lower in April 2020 than when the traffic count took place. Additionally, traffic flows may have then reduced again during January and February 2021 when the impact of the COVID-19 pandemic on the country was greatest, and so the lower NO₂ concentrations monitored during 2021 are more likely to have been a result of pandemic influenced reduced traffic flows.

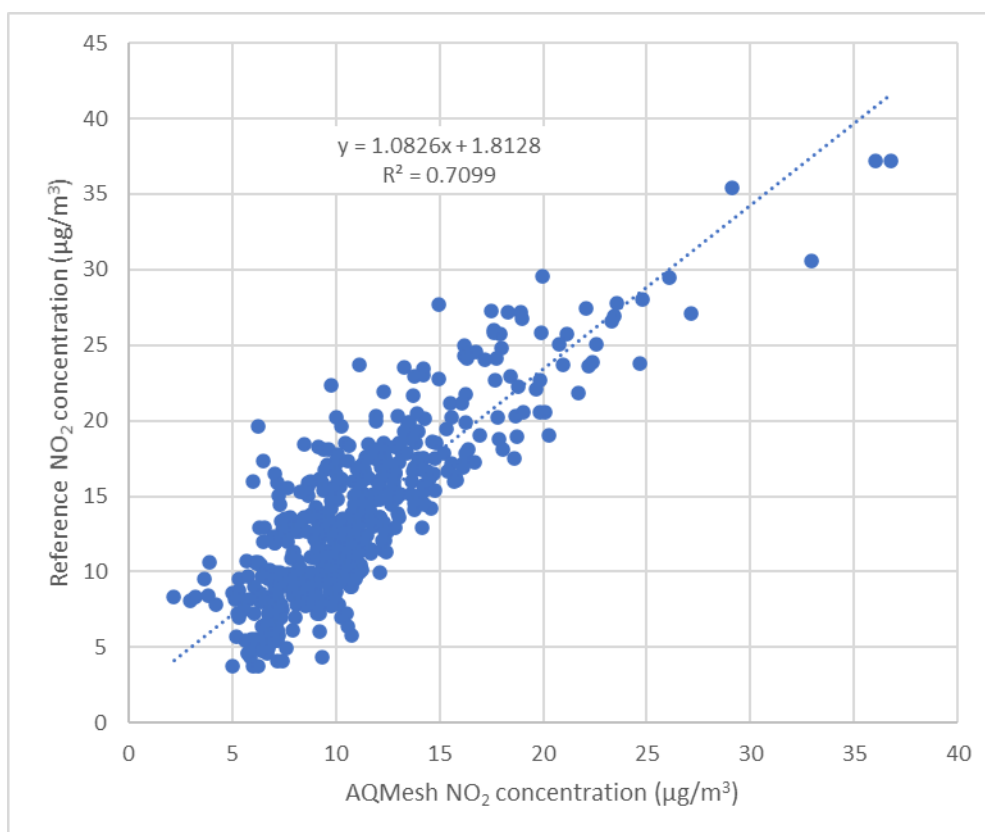
Appendix A AQ Mesh Scaling method

The raw NO₂ concentrations from the AQ Mesh pods were scaled to data collected at a reference monitor, i.e. a continuous NO_x analyser within one of the Council's air quality monitoring stations. This was carried out using a separate AQ mesh "gold pod", which was co-located for a period of time with a reference monitor and "scaled" to this monitor. The gold pod was also co-located with the AQ mesh pods that were monitoring at the three designated monitoring locations. These pods were then scaled to the gold pod, which was already scaled to the reference monitor. The process for scaling the gold pod to the reference monitor is summarised below.

1. Hourly data from the reference monitoring station was downloaded from the London Air Quality Network (LAQN²) portal, and the AQ Mesh gold pod was obtained from the remote server.
2. The coincident hourly averaged NO₂ concentrations for all available hours that the units were co-located for were plotted on separate axes, and a linear regression between the reference monitor and the gold pod was performed.
3. The gold pod data was "scaled" to the reference monitor by the factors obtained in the regression, such that the best fit line observed approximately "y = x" relationship – at this point the AQ Mesh scaled data was essentially measuring the equivalent NO₂ concentration as the reference monitor.
4. The gold pod with scaling factors was co-located with the other AQ Mesh pods. Hourly NO₂ concentrations monitored by the gold pod at the three long-term monitoring locations, when scaled using the derived scaling factors, were effectively then measuring the same NO₂ concentration that a reference monitoring station would measure if it were at the same location.
5. The AQ Mesh pods at the long-term monitoring locations were then scaled in the same way to the gold pod.

Figure A.1 below shows an example of a co-location scatterplot and derived scaling factors, with the slope factor equal to 1.0826 and the offset equal to 1.8128. Therefore, to scale the raw hourly NO₂ concentrations from the AQ Mesh pod, the raw concentrations would need to be multiplied by 1.0826 and then have 1.8128 added.

Figure A.1 Example scatterplot of hourly AQ Mesh NO₂ concentrations against hourly reference monitor concentrations



² London Air Quality Network (LAQN): <https://londonair.org.uk/LondonAir/Default.aspx>

