Imperial College London Projects

Environmental Research Group

Air quality effects of the implementation and removal of zero emission street restrictions at Beech Street in the City of London

Summary prepared for Clean Cities Campaign.

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1 Introduction

An experimental traffic order for a zero emission street, restricting the use of Beech Street in the City of London to zero emission vehicles, was introduced on 19th March 2020 for a period of 18 months. The restrictions were applicable 24 hours a day with exceptions only for emergency vehicles, access to the car parks off Beech Street and for refuse collection and deliveries. Initially restrictions were implemented using signs and road markings. From 27th July 2020 restrictions were enforced using automatic number plate recognition cameras with a penalty charge notice issued for contraventions of the traffic order. The scheme was introduced with a view to extension, subject to consultation. However, this was not agreed by the end of the period and the restrictions ended on 18th September 2021.

This summary examines the air quality effects of the scheme and subsequent removal of restrictions. The analysis focuses on nitrogen oxides, particularly nitrogen dioxide (NO₂), the main source of which in London is road traffic and is therefore the most likely pollutant to be affected by the implementation of the zero emission street. NO₂ is also the pollutant which most commonly breaches the UK Air Quality Strategy Objectives in London and elsewhere in the UK, currently representing the biggest challenge for local and national government in meeting these objectives.

1.1 Air Quality measurements

This analysis uses measurements from the Beech Street roadside and The Aldgate School urban background air quality monitoring sites, operated by the City of London Corporation. Their location is shown in Figure 1. The sites are part of the London Air Quality Network (LAQN), with data management and ratification carried out by the Environmental Research Group at Imperial College London. In addition, mean concentrations from roadside LAQN sites are included for comparison.



Figure 1: Location map of Beech Street and The Aldgate School measurement sites

All of the sites included in the analysis measure nitrogen oxides (NO_x) by chemiluminescence which is the method specified in the EU Air Quality Directive 2008/50/EC (EC, 2008). The equipment is calibrated fortnightly and is operated and maintained in accordance with the requirements of

Directive 2008/50/EC, including UKAS accredited audits. These procedures also meet the requirements of LAQM TG16 (Defra, 2018).

In order to include as much data as possible since the re-opening of Beech Street to all traffic, some of the measurements included in the analysis are not fully ratified. However, they have been subject to daily validity checks.

2 Results and analysis

Air quality measurements were examined for four periods, defined according to the traffic restrictions in place at the time. The periods and dates are shown in Table 1. The pre-restrictions period was defined as one calendar year before the closure to include seasonal variations but reduce the effect of longer-term pollution trends. The end date of the re-opening period was set to 28th February, in order to avoid changes to the results during the analysis as further data was collected.

Dates				
18-Mar-2019 to 17-Mar-2020				
18-Mar-2020 to 26-Jul-2020				
27-Jul-2020 to 17-Sep-2021				
number plate recognition and penalties)				
18-Sep-2021 to 28-Feb-2022				

Table 1: Analysis periods and dates

2.1 Mean Concentrations

Mean NO₂ concentrations at the Beech Street measurement site during each of the defined periods are shown in Table 2, along with the percentage change after the implementation of the zero emission street, compared to the pre-restrictions period. Mean NO₂ concentrations from The Aldgate School site and the London Roadside Mean for each period are shown for comparison.

There was a 67% reduction in the mean NO₂ concentration at Beech Street during the initial introduction of restrictions compared to the pre-restrictions period. However, the introduction of the zero emission street coincided almost exactly with the start of restrictions due to the COVID-19 pandemic. Therefore, it is important to consider the change in the context of other sites. The reduction in NO₂ concentrations was greater at Beech Street than at The Aldgate School urban background site where there was a 49% reduction in the mean NO₂ concentration. The reduction in NO₂ concentrations at Beech Street was also greater than the reduction in the London Roadside Mean concentration which fell by 38% during the same period.

Period	Mean NO₂ (µgm⁻³)		
	Beech Street	The Aldgate	London
		School	Roadside Mean
Pre-restrictions	58.8	30.7	41.0
Zero emission street (signs, markings)	19.5 (-67%)	15.6 (-47%)	25.5 (-38%)
Zero emission street (enforcement)	24.7 (-58%)	22.0 (-28%)	31.2 (-24%)
Re-opening	39.9 (-32%)	26.6 (-13%)	34.1 (-17%)

Table 2: Mean of NO₂ concentrations at Beech Street, The Aldgate School and the London Roadside mean during the defined analysis periods. Percentage change compared to the pre-restrictions period is shown in brackets.

When enforcement of the zero emission street began at the end of July 2020, some of the pandemic restrictions had started to be lifted and activity gradually began to return towards more normal levels for the remainder of the zero emission restrictions. The mean NO₂ concentration at Beech Street remained 58% lower than the pre-restrictions period during the enforcement period,

compared to 28% lower at The Aldgate School and the London Roadside mean which was 24% lower. During the zero emission street restrictions, the mean NO₂ concentration at Beech Street was lower than the London Roadside mean.

When the zero emission restrictions were removed in September 2021, NO_2 concentrations at Beech Street increased. The mean NO_2 concentration at Beech Street in the re-opening period was 39.9 μ gm⁻³, compared to 58.8 μ gm⁻³ pre-restrictions. Although still 32% lower than the pre-restrictions period, the mean concentration at Beech Street increased above the London Roadside mean concentration. The variation in mean concentrations at each site is illustrated in Figure 2. The mean concentration at Beech Street was much closer to the mean concentrations measured at The Aldgate School urban background site during the zero emission street restrictions. The increase in NO_2 concentrations seen during the re-opening period is similar at Beech Street and the London Roadside mean, suggesting that this is influenced by other factors, such as weather conditions and increases in activity as a result of the improving situation with the COVID-19 pandemic.



Figure 2: NO_2 mean concentrations for Beech Street, The Aldgate School and the London Roadside mean during the prerestrictions, zero emission street, and re-opening periods.

Beech Street NO₂ measurements were paired with those from The Aldgate School and the London Roadside mean and the difference calculated. The mean of this difference for each period is shown in Table 3. This shows a small difference between the Beech Street measurements and the background measurements from The Aldgate School during the zero emission street restrictions. During the pre and post restrictions periods, the difference is greater.

The difference between the Beech Street NO₂ measurements and the London Roadside Mean shows the lower concentrations at Beech Street than the London Roadside mean during the zero emission street restrictions. The difference between Beech Street and the London Roadside mean after the restrictions were removed is smaller than before the zero emissions street was implemented.

Period	Mean NO ₂ (µgm ⁻³)		
	Beech Street-The Aldgate	Beech Street-London	
	School	Roadside mean	
Pre-restrictions	28.1	17.7	
Zero emission street (signs, markings)	3.7	-6.0	
Zero emission street (enforcement)	2.4	-6.5	
Re-opening	12.5	4.8	

Table 3: Mean difference in NO₂ concentrations between Beech Street and The Aldgate School and Beech Street and the London Roadside mean during the defined analysis periods

2.2 Time series analysis

Time series of the NO₂ and NO_x weekly mean measurements from Beech Street and The Aldgate School are shown in Figure 3 and Figure 4, respectively. This clearly illustrates the reduction in concentrations when the zero emission street was implemented and the much closer concentrations at the roadside and background site. The increase in concentrations when the road was re-opened to all traffic is also evident. It is not clear from this whether the concentrations at Beech Street are increasing with increasing time from the removal of restrictions. The increase in NO₂ seen at both sites in January 2022 is due to a more widespread episode of increased concentrations due to settled weather conditions.



Figure 3: Weekly mean NO_2 concentrations at Beech Street and The Aldgate School during the analysis period. Blue dotted lines mark the boundaries between the periods defined in Table 1.



Figure 4: Weekly mean NO_x concentrations at Beech Street and The Aldgate School during the analysis period. Blue dotted lines mark the boundaries between the periods defined in Table 1.

2.3 Daily and hourly plots



Figure 5: Hourly variation in NO₂ concentrations for the defined periods at Beech Street and the London Roadside mean

Figure 5 shows the hourly variation in NO₂ concentrations during the defined periods at Beech Street compared to the London Roadside mean. In both cases, NO₂ concentrations reduced during the initial implementation of the zero emission street. This is likely to include a large effect of COVID-19 restrictions which were also implemented at this time. However, at Beech Street, NO₂ concentrations remained relatively low for the remainder of the period when the zero emission street was in place. The London Roadside mean NO₂ concentrations returned closer to the concentrations measured in the pre-restrictions period. When the zero emission street restrictions were removed, there was a larger increase in NO₂ concentrations at Beech Street compared to the increase in the London Roadside mean concentrations. There was a small increase in London Roadside mean NO₂ concentrations restrictions ended at Beech Street. This is likely related to increasing traffic as the COVID-19 situation improved.



The same pattern can be observed in the daily mean NO₂ concentrations at Beech Street and the London Roadside mean, in Figure 6.

Figure 6: Daily variation in NO₂ concentrations for the defined periods at Beech Street and the London Roadside mean

The difference between paired NO₂ measurements from Beech Street and The Aldgate School was used to give a local NO₂ concentration. The resulting measurements were examined for the defined restriction periods. The diurnal pattern is shown in Figure 7. This shows a large reduction in local NO₂ concentrations during the period when the zero emission street was in operation, compared to the pre-restrictions period. There was a clear increase in local NO₂ concentrations when the road was reopened to all traffic. However, similarly to the earlier analysis, the concentrations were lower than the pre-restrictions period. The same pattern is evident in the daily means for each period, shown in Figure 8.



Figure 7: Hourly variation in local NO₂ concentrations (Beech Street – The Aldgate School) for the defined periods



Figure 8: Daily variation in local NO₂ concentrations (Beech Street – The Aldgate School) for the defined periods

3 Summary and conclusions

- The mean NO₂ concentration at Beech Street was 67% lower when the zero emission street restrictions were first implemented, without enforcement, compared to before the restrictions. This period was also affected by the introduction of restrictions due to the COVID-19 pandemic. However, the reduction in NO₂ at Beech Street was greater than the 38% reduction in mean London Roadside NO₂ concentration and a 47% reduction at The Aldgate School urban background site during the same period.
- The mean NO₂ concentration at Beech Street remained 58% lower for the remainder of the zero emission street restrictions when enforced by automatic number plate recognition and penalty charges. This is a much greater reduction than the 24% reduction in mean London Roadside NO₂ concentration and 28% reduction at The Aldgate School during the same period. The mean NO₂ concentration during this period was lower than the London Roadside mean and the difference compared to The Aldgate School urban background site was just 2.4 µgm⁻³.
- When the zero emission street restrictions were removed, the mean Beech Street NO₂ concentration increased and was higher than the London Roadside mean NO₂ concentration at 39.9 μgm⁻³ compared to 34.1 μgm⁻³. The difference compared to The Aldgate School urban background site increased to 12.5 μgm⁻³.
- NO₂ concentrations at Beech Street, the London Roadside mean and The Aldgate School were lower in the period after the zero emission restrictions were removed than those measured during the period before they were introduced. This could be a result of the overall downward trend in NO₂ concentrations in London in recent years and the effect of the COVID-19 pandemic.
- The difference between the NO₂ concentrations after the zero emission restrictions were removed compared to before the zero emission restrictions were in place was greater at Beech Street than the London Roadside mean or The Aldgate School. This suggests a possible residual effect of the restrictions where drivers may not know that the restrictions were removed or they were using an alternative route. This residual effect may reduce as the time from the re-opening increases.
- Importantly, the increase in NO₂ concentrations when Beech Street re-opened to all vehicles brings the mean concentration very close to the annual mean Air Quality Strategy Objective for NO₂ of 40 µgm⁻³. Although it is not appropriate to apply the objective to this period of data since it is not a full year and covers part of two calendar years, it raises concerns that should traffic continue to increase as the pandemic situation improves, it is more likely that this objective would be exceeded whereas it may have been met with the zero emissions restrictions in place.

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