Air Quality Geographic Pilot Study
M1 Tinsley

Non-technical Summary

May 2018
1. Introduction

Purpose of the Study
The M1 motorway, as it passes Sheffield, runs close to the urban areas of Blackburn, Tinsley and Brinsworth, as shown in Figure 1. Air quality measurements in these areas show that long-term concentrations of nitrogen dioxide (NO$_2$) exceed the objective set by the UK Government in order to protect public health (i.e. an annual average concentration of 40 µg/m$^3$).

The purpose of this study was to develop a deep understanding of the causes of these local air quality problems, with the intention being that these findings would provide a direction for the development of mitigation strategies to improve air quality.

![Figure 1: Study Area, Highlighting Key Urban Areas that are Close to the Motorway](image)

General Approach
This study has taken a forensic approach to analysing the available information and goes well beyond the level of detail typically found in a standard air quality assessment. The results obtained have allowed a comprehensive picture of the air quality conditions in the area to be developed, and the principal factors which influence these concentrations to be understood in more detail.
The study considers concentrations of both NO₂ and total nitrogen oxides (NOx). NOx is the sum of nitric oxides (NO) and NO₂. Both NO and NO₂ are emitted from engines and combustion, but NO subsequently forms NO₂ in the atmosphere. When describing emissions, it is therefore convenient to refer to NOx rather than NO₂.

For this study, road traffic data from a number of sources has been collected and analysed. This includes real-time information collected by Highways England as part of its motorway incident detection system (MIDAS), as well as anonymised information collected by a commercial vehicle tracking system (Trafficmaster). In order to understand how differences in the types of vehicle using different roads might be affecting air quality, a network of Automatic Number Plate Recognition (ANPR) cameras was installed by Highways England. These cameras detect vehicle number plates as they drive past, and the type and age of that vehicle is then determined from a large database.

The study has also considered air quality measurements made within the study area by Highways England and local councils, using two different methods. The first, more detailed, method pumps air continuously through a sampler that measures concentrations each hour of the year. Measurements from four of these instruments were used. The second, more simple, method uses small plastic tubes containing a special absorbent. These devices are small and so can be affixed to lamp-posts in areas of key concern. One of these samplers is shown in Figure 2. Measurements from more than 100 of these samplers have been considered.

Various other sources of information have also been considered, including databases of industrial emissions held by the Department of Environment Food and Rural Affairs (Defra) and the Environment Agency, information on terrain and meteorology, and detailed maps and photographs of the area.

2. Study Area

The study has focused on identifying the cause of high measured NO₂ concentrations at the urban areas beside the motorway (see Figure 1). In Blackburn and Brinsworth, measurements made within approximately 25 m of the motorway have exceeded the Government’s objective for annual mean NO₂ concentrations in some years, but measurements further than this from the motorway have achieved the objective. For Tinsley, recent measurements are summarised in Figure 3, which
indicates NO₂ concentrations in Tinsley have exceeded the objective at a large number of sites during all four years shown, with the highest concentrations measured alongside Tinsley Roundabout.

Figure 3: Measured Annual Mean NO₂ Concentrations at the Diffusion Tube Sites Close to Tinsley Roundabout (µg/m³)
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3. Background Concentrations

Background concentrations are the air quality levels experienced well away (i.e. >200 m or more) from individual emission sources. They form a spatially consistent baseline to which localised contributions can be added. Background concentrations can be further divided into ‘rural’ and ‘local’ components. The rural background in Tinsley has been taken to be the same as that measured at Ladybower Reservoir in the Peak District. This ‘rural’ background contribution comes from regional transport and emissions from across the UK and Europe and contributes around 10 µg/m³ to annual mean NO₂ concentrations in the study area.

The ‘local’ background represents the effect that emissions from across the wider study area and beyond have on concentrations over and above that measured at Ladybower Reservoir. While

Figure 4: Approximate Spatial Pattern in Local Background NO₂ Concentration (2014)
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the rural background concentration does not vary across the study area, the local background concentration is higher in those locations where there are more emissions, owing to the density of the road network, and areas of industrialisation and urbanisation. In particular, the large number of emission sources running through the Don Valley between the centres of Sheffield and Rotherham leads to elevated local concentrations in the Tinsley area when compared with those to the northwest and southeast of Tinsley where such sources are less prevalent. This spatial pattern is illustrated in Figure 4, which indicates that the local background NO$_2$ concentration in Tinsley is double that experienced elsewhere in the wider study area.

These local background concentrations are made up from emissions from many different sources, which in Tinsley are estimated to be broken down as shown in Figure 5. Industrial emissions comprise 5 µg/m$^3$ of the local background NO$_2$ concentration around Tinsley, with this being the combined influence of very many industrial premises over the wider area. Emissions from more distant road traffic also make up approximately 4 µg/m$^3$ of the annual mean background NO$_2$ concentration; with 1 µg/m$^3$ of this representing motorway emissions and 3 µg/m$^3$ representing emissions from local roads. 1 µg/m$^3$ of the local background at Tinsley comes from railway emissions, 1 µg/m$^3$ from commercial, institutional and domestic emissions, and 2 µg/m$^3$ from other sources.

4. Meteorology
Analysis of meteorological data in this area has shown that the strongest and most frequent winds originate from the southwest. This will mean that, for most of the time, air pollutant emissions will be carried north-eastwards. It is, however, important to note that less frequent winds still have the potential to result in high pollutant concentrations at certain locations and that lower wind speeds can result in less dilution and dispersion and, therefore, higher pollutant concentrations.

5. Industrial Sources

No individual industrial emission sources have been identified which are thought likely to contribute significantly to measured concentrations in Tinsley or Blackburn, but there may be a significant industrial contribution to concentrations at Brinsworth. It has not been possible to determine the source of these emissions with any certainty, but it is possible that emissions related to the Sheffield International Rail Freight Terminal, or the nearby Aggregate Industries facility are affecting NO$_2$ concentrations in Brinsworth.

6. Motorway Traffic

Traffic Flows

The study has shown that traffic flows for different types of vehicle show different temporal patterns. Goods vehicles, for example, show a very different diurnal pattern to that of cars, reflecting the different purposes of these journeys. In general, motorway traffic speeds tend to be slower in the vicinity of Junction 34 than they are elsewhere on the M1, particularly during the morning and evening rush hours. The ANPR survey results show that the vehicle fleet using the motorway network is relatively new, with a proportionately larger number of vehicles meeting newer, cleaner vehicle emissions standards, than on local roads. This perhaps reflects the fact that vehicles used more frequently on longer journeys (e.g. HGVs) are replaced more frequently.

Emissions from Free-flowing Traffic on the Motorway

In order to determine the effect that free-flowing sections of the motorway are having on annual mean NOx concentrations, the analysis has considered traffic flows and speeds, as well as the spatial pattern in roadside measurements made at Blackburn and Brinsworth. The line shown in Figure 6 has been inferred from the measurements made alongside the motorway at Blackburn, but the results for
Brinsworth were almost identical. It shows that the motorway has a very large effect on concentrations very close to the motorway, but this effect diminishes rapidly with distance so that, at distances of 100 m or more, motorway traffic has only a relatively modest effect on NOx, and by extension NO2, concentrations. Bawtry Road is more than 100 m from the mainline of the motorway and thus, while motorway traffic dominates measured concentrations at some properties in Blackburn and Brinsworth, it does not dominate concentrations along Bawtry Road.

**Congestion on the Motorway at Tinsley**

The detailed traffic data collected for this study show that traffic speeds on the motorway close to Tinsley are often lower than those at Blackburn and Brinsworth during peak traffic periods presumably as a result of increased congestion. Comparing hour-by-hour NO2 measurements made to the east of the motorway at Tinsley with those made at a background site to the west of the motorway suggests that the influence of congestion and driving behaviour on motorway traffic emissions at Tinsley, together with the effect of other emission sources in the vicinity, adds up to 8 µg/m³ to annual mean NO2 concentrations 100 m from the motorway, compared to the more free flowing sections of motorway at Blackburn and Brinsworth. The analysis does, however, suggest that at least some of this 8 µg/m³ has nothing to do with emissions from the motorway and is the confounding influence of other emission sources (e.g. the southbound on-slip at M1 J34). Thus, any effects from congestion on the motorway at Tinsley are likely to add less than 8 µg/m³ to the concentrations that would be recorded if flow patterns were the same as those at Blackburn and Brinsworth.
Contribution by Vehicle Type

Figure 7 shows how different vehicle types are estimated to contribute to NOx emissions from the M1 as it passes Tinsley. It shows that emissions from diesel vehicles, particularly cars and vans (LGVs), dominate the motorway emissions.

Slip-Roads

Figure 8 shows the indicative additional contribution – over and above that of all vehicles on the mainline of the motorway as a whole – that the southbound on-slip at M1 J34 is causing along the two cul-de-sacs which abut the slip-road. The lines shown in Figure 8 describe the average contribution made by the slip road to NOx concentrations along these two streets, based on all of the measurements made along these cul-de-sacs.

At the western end of both Siemens Close and Newburn Drive, emissions from the slip-road have a significant effect on annual mean NO\textsubscript{2} concentrations, but this effect diminishes very rapidly on moving away from the slip-road. The slip-road effect is therefore very localised.

7. Urban Roads

Traffic Flows

The same detailed traffic information described above has also, where available, been investigated for the local roads in the study area. This has shown a number of important features. In particular, the vehicles using Bawtry Road tend to be much older than those on the motorway and several other roads in the area. Since older vehicles do not conform with the latest controls on vehicle emissions, they may emit more NOx than newer vehicles. It was also observed that buses serving
Meadowhall shopping centre are much newer than those on other roads in the area. The observed urban traffic volumes tend to be cyclical, with two defined peaks corresponding with the morning and evening rush-hours. Unsurprisingly, recorded traffic speeds tend to follow the opposite pattern, with slower speeds occurring during the rush hours close to junctions. Away from junctions, traffic flows on most roads indicate free-flowing traffic throughout most of the day.

**Area-wide Analysis**

An analysis of measurements made close to urban roads across the study area has shown that differences in measured concentrations can largely be explained in terms of:

- distance of the monitor from the road;
- road width; and
- traffic volume, fleet composition, and speed.

In particular, the analysis has shown that the relationship between traffic movements and measured concentrations on Bawtry Road is similar to that on many other roads in the study area. The key factor which drives the high NO₂ concentrations measured on Bawtry Road is the close proximity of the monitors to Bawtry Road itself.

**Bawtry Road**

**Emissions from Free-flowing Traffic**

By investigating the measured patterns at those monitoring sites close to sections of Bawtry Road which are well away from Tinsley Junction, and by then subtracting the influence of the motorway from these measured concentrations, it has been possible to determine the ‘base’ effect of traffic using Bawtry Road. This is the effect that traffic would have along the entire road if all issues relating to congestion and parked cars etc. were removed. This ‘base’ concentration reduces with increasing distance from the road, but at a distance of 1.6 m from the edge of the road, it contributes 13 µg/m³ to annual mean NO₂ concentrations.

**Effects of Additional Features**

Measured concentrations tend to be higher toward the northern end of Bawtry Road. The main reason for this is that the residential properties and monitoring sites at the northern end of the road are closer to Bawtry Road than the properties and monitoring sites further south and west.
Traffic queuing to access Tinsley junction, as well as navigating vehicles stopped and parked in the road will, however, also add to measured concentrations. A further factor is the confinement caused by the buildings on either side of Bawtry Road, which is much more enclosed at its northern end. These buildings are likely to inhibit the flow of air and thus effectively trap air pollution close to the road. All of these factors, when taken on aggregate, do appear to add to measured concentrations, but not significantly. At a distance of 1.6 m from the road, these features only add around 3 µg/m³ to total measured concentrations at the northern end of Bawtry Road.

**Contribution by Vehicle Type**

Figure 9 shows how different vehicle types contribute to NOx emissions from Bawtry Road. Diesel cars contribute 52% while diesel LGVs contribute 16%. Buses on Bawtry Road contribute 9% of the total emissions from this road.

![Figure 9: Indicative Composition of the Local Road Component of NOx Concentration on Bawtry Road by Vehicle](image)

**8. Conclusions**

NO₂ concentrations across the study area can be understood in terms of a background component and a road component. The background component is around 6 µg/m³ higher in Tinsley than it is further north and east along the M1, but this variation is the combined effect of emissions from very many sources spread along the Don Valley. There are no individual emission sources which contribute significantly to the background concentration such that their removal would, on its own, have a large effect on local pollution concentrations.

It is emissions from road traffic which, when added to the background component, causes the air quality objective for annual mean NO₂ concentrations to be exceeded at locations along the M1 corridor. Traffic on the M1 is not, however, the principal cause of the air quality problems in the majority of urban locations.

At locations which are very close to the mainline of the motorway, emissions from the motorway itself are likely to contribute significantly to measured concentrations. For example at 5 m from the motorway, the motorway has been calculated to add 52 µg/m³ to annual mean NO₂ concentrations. However, such a strong influence is highly localised. At the distance of Bawtry Road from the motorway (>100m) the motorway itself is likely to contribute between 4 and 11 µg/m³. Thus, proximity to the mainline of the motorway gives rise to high concentrations, but with the
exception of a few residential properties in Blackburn and Brinsworth, none of the residential properties in the study area are sufficiently close to the motorway that this, on its own, could cause an exceedence of the annual mean NO$_2$ objective.

Proximity to the southbound on-slip-road at Junction 34 is a significant cause of local air quality problems for the relatively small number of properties which are very close to it. The influence of the slip-road is, however, even more limited in its spatial extent than the mainline motorway. Toward the eastern ends of Siemens Close and Newburn Drive, the effect of the slip-road falls so low as to be negligible in comparison to the contribution from other sources (e.g. Bawtry Road).

Emissions from traffic on Bawtry Road dominate the high concentrations measured on Bawtry Road. This is despite the fact that traffic volumes on Bawtry Road are so much lower than those on the motorway, and the explanation for this is simply proximity. The monitoring sites on Bawtry Road, particularly those at its northern end, are very close to the kerb and this has a significant effect on the measured concentrations. The effects of slower speeds and inhibited dispersion at the northern end of Bawtry Road also contribute to the poor air quality in this area, but it is proximity to the road which is the main cause.

Traffic using Tinsley Roundabout also has a significant effect on concentrations, but only in the immediate vicinity of the roundabout. As with the other localised sources described above, the effect of roundabout traffic on local concentrations falls off very rapidly with distance from the roundabout.

The air quality problem at some houses in Blackburn and Brinsworth is dominated by emissions from the motorway, but the issues in Tinsley are more complex; with different sources being significant in different places. Reducing emissions from the southbound on-slip would do very little to reduce concentrations on Bawtry Road, just as reducing emissions from Bawtry Road would do little to reduce concentrations at the western end of Siemens Close. Reducing emissions from through-traffic on the M1 mainline would have only a modest effect on concentrations along Bawtry Road or around Tinsley Roundabout.