AIR QUALITY AT ROADSIDE AND URBAN CENTRE LOCATIONS IN LEICESTER

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ABSTRACT

This paper presents the results of a comprehensive statistical analysis of roadside and urban background air quality data in Leicester as part of an ongoing study on Reducing Urban Pollution Exposure from Road Transport (RUPERT). The main aim of this project is to develop a new modelling framework for nitrogen dioxide (NO_2), carbon monoxide (CO) and particulate matters to simulate personal exposures of different population groups across a city, and to assess the impact of roadside concentrations on these exposures. This is achieved by modelling the frequency distribution of personal exposures as a function of urban background and roadside concentrations under different traffic conditions.

A comprehensive statistical analysis of roadside and urban background data has been completed for this project. Roadside air quality is monitored at 13 locations within Leicester city using Roadside Pollution Monitors (RPM). Data collected every minute throughout each day of year 2001 forms the basic dataset for the research. Urban background air quality data was available from the Leicester Automated Urban and Rural Network (AURN) station classified as an 'Urban Centre' monitoring site. RPM and AURN data have been averaged for 15 minutes and statistically analysed for temporal and seasonal variability including diurnal, day-of-week and seasonal concentration distributions. These data form the basis of enhanced exposure and health models to better inform traffic management and policy decisions that aim to reduce traffic related air pollutant emissions.

1. INTRODUCTION

Air quality is a significant environmental problem in most major cities, largely due to its impact on public health. It has been estimated, for example, that in UK urban areas, 24 000 premature deaths occur each year due to poor air quality [1]. Exceedance of health based air quality standards is common throughout European cities [2]; hence the air quality framework directive (96/62/EC) requires member states to eliminate standard exceedances for a range of pollutants by defined target dates, most in 2005.

Road transport is a major source of atmospheric emissions affecting air quality in the UK. National policies and local actions to improve air quality require accurate monitoring and projections of major air pollutants from road vehicles in order to evaluate their effectiveness.

The nature of the air pollution problems relating to vehicle use varies widely from country to country and from one town or city to another and is dictated not just by the volume of the traffic, but also by the prevailing weather conditions. Also the range of pollutant types emitted is wide, although the oxides of nitrogen, ozone, carbon monoxide, polyaromatic hydrocarbons and particulates appear to be the most important. In order to understand the impact of air pollution on health it is important to have estimates of air pollutant concentrations at strategic locations in an urban area. This can be achieved by direct measurement or by numerical modelling. As monitoring systems tend to be expensive both to purchase and maintain, it is impossible to have a large number of installations in a city or urban area. Therefore, it is common practice to employ a combination of monitoring and modelling to assess urban air quality. The introduction of new methods of detecting and quantifying these pollutants and establishing rural and urban air pollution monitoring networks has helped to investigate regional and local patterns and to build up a profile of air pollution problems [3].

This paper presents the results of a comprehensive statistical analysis of roadside and urban background air quality data in Leicester as a part of an ongoing study on Reducing Urban Pollution Exposure from Road Transport (RUPERT) [4].

2. MONITORING ROADSIDE AND URBAN BACKGROUND AIR QUALITY

The objectives of a study usually govern which types of monitoring systems are deployed for measurements. For example, precision systems such as those employed in the UK AURN (Automatic Urban and Rural Network) are used to assess short-term objectives and the impact of policy set by the Department for Environment Food and Rural Affairs (DEFRA) to achieve targets and assess health risk. The less accurate, portable Roadside Pollution Monitoring (RPM) units use inexpensive electrochemical sensors and are used to study medium-term trends and to evaluate traffic demand management schemes. The passive monitoring systems such as diffusion tubes give data aggregated over a period of time, typically a month and hence are used to study long-term trends and assess the impact of policy.

There are several air quality monitoring schemes running in parallel in Leicester. Firstly, the AURN site maintained and run by DEFRA measures levels of O_3, CO, SO_2, PM_{10} and NO_x. Leicester AURN site is classified as Urban Centre. Urban Centre sites are non-kerbside sites located in an area representative of typical population exposure in town or city centre areas e.g. pedestrian precincts and shopping areas. Sampling heights are typically within 2-3m [5]. Secondly, Leicester City Council (LCC) monitor air quality at roadside mainly using RPMs and at other specific locations, regular monitoring is carried out at various locations for short-term periods of typically one month using a mobile van.

The RPM units were developed as a result of the work carried out by Bell and Reynolds [6] to continuously monitor gases over a sufficiently long time to ensure statistically significant results. These monitors were developed as part of a joint project between the University of Nottingham, Siemens Environmental Systems Ltd. (SESL), Siemens Traffic Control Ltd., and Leicestershire and Nottinghamshire County Councils [7]. These systems can monitor CO and NO_2 along with temperature. The range of CO and NO_2 measured is between 0 to 120ppm and 0 to 200ppb respectively. SESL first manufactured these systems quoting an accuracy of ±0.5ppm or 10% of the reading whichever is greater for CO, and the same for NO_2 being ±10ppb or 10% of the reading. Also, the reason why the units record the cell temperature is to correct the temperature dependency of the CO and NO_2 levels using an empirically derived relationship.

Around 20 local authorities in UK use these systems. The advantage of these systems is that they can be either integrated with existing monitoring systems for on-line automatic data capture and storage centrally or the data can be logged locally. Although the prototype systems could be powered by battery increased sophistication requires that the RPMs are powered by the mains and therefore are permanently sited. The accuracy of data from these units was verified by surveys carried out at two sites in Leicester using the Instrumented City (*i*C) mobile precision monitoring system [8]. In the verification surveys the RPM measurements of CO and NO_2 were compared with those obtained from a precision system. In both cases the sample of air drawn across the sensors was the same. The analysis of data showed that for both pollutants at both sites there was a statistically significant correlation between the high precision system measurements (tow-a-van) and those of the RPM. However, the accuracy of the system was found to be ±1ppm or 10% of the reading whichever is greater for CO and ±20ppb or 10% of the reading whichever is greater for NO_2.

LCC have installed 13 RPMs in Leicester, 10 of which are within the city limits, as shown in Figure 1. The RPMs are classified according to their locations namely Category 2 and Category 5 as shown in Table 1. Category 2 is described as 'Urban Roads with High HGV Fractions' whereas Category 5 is described as 'Urban Roads with Medium HGV Fractions'.

3. ANALYSIS OF ROADSIDE POLLUTION CONCENTRATIONS

For the RUPERT project, data from the ten monitors listed in Table 1 were collected at one minute interval for the year 2001. CO and NO_2 data were collected and then analysed using specially written Visual Basic and C++ scripts to produce five and 15 minute profiles. Data were segregated and averaged to produce yearly, seasonal and weekday/weekend profiles. Geometric means and geometric standard deviations have been used in developing a statistical description of these profiles as the data generally follow a geometric distribution.

Yearly profiles of CO and NO_2 are shown in Figures 2 and 3. These profiles represent average pollution over the year and therefore, without the day-to-day variation, help to illustrate the underlying relationships between roadside pollution and traffic conditions. CO profiles clearly show a diurnal variation consistent with traffic flow profiles indicating a strong relationship with the amount of traffic activity. The profiles are seen to fall into different categories, those displaying a dominant morning (W0625) or evening (W0158) peak or both, with profile W0552 being more pronounced than W1032. The profiles reflect not only the volume (W0158 has higher levels of CO throughout the day compared to W2626) but also the nature of traffic on the road. For example, a one-way street (W0158), a two-way radial with a dominant flow into (W0625) or out of city (W0948) or with busy commuter traffic at peak times in both directions (W0914). NO_2 profiles are slightly different; they show that evening peaks are higher than morning peaks. NO_2 levels rise gradually during the day and peak in the late afternoons indicating the influence of sunshine and ozone on the level of roadside NO_2 concentrations.

Figures 4 and 5 show the seasonal and weekday/weekend variation in CO concentrations. Winter concentrations are higher than summer concentrations. Similarly, weekday levels are higher than weekend levels as would be expected at roadside stations.

4. CONCLUSION

This paper presents a statistical analysis of comprehensive data sets of measured roadside pollutant concentrations of CO and NO_2. This has produced the profiles of diurnal and seasonal variation in concentrations. While CO profiles show marked morning and evening peaks consistent with traffic density, NO_2 profiles show a gradual build-up resulting in higher evening peaks. Weekday CO levels, as expected are higher than weekend levels again showing the influence of traffic patterns. The results presented in this paper are part of a bigger study which has studied the shape of these profiles in the context of a statistical analysis of traffic data including volume of traffic in peaks and off-peaks, proportion of HGV and speeds. The results of the latter study are to be published elsewhere. Roads with high proportion of HGV and lower travel speeds show highest concentrations compared to high speed medium HGV proportion roads.

5. REFERENCES

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ID	Station Name	Category
W0158	Newarke Street	2
W0552	Melton Rd	2
W0625	Uppingham Rd	2
W0914	Welford Rd	2
W0948	Soar Valley Way	2
W1032	Narborough Rd	5
W1156	Hinckley Rd	5
W1253	A50 New Parks	5
W2626	Norman/Wilton	5
W4126	A6 Ashtree Rd	5
Category 2 = Urban Road with High HGV		
Category 5 = Urban Road with Medium HGV		

Table 1: Roadside Pollution Monitors and their classification by road type

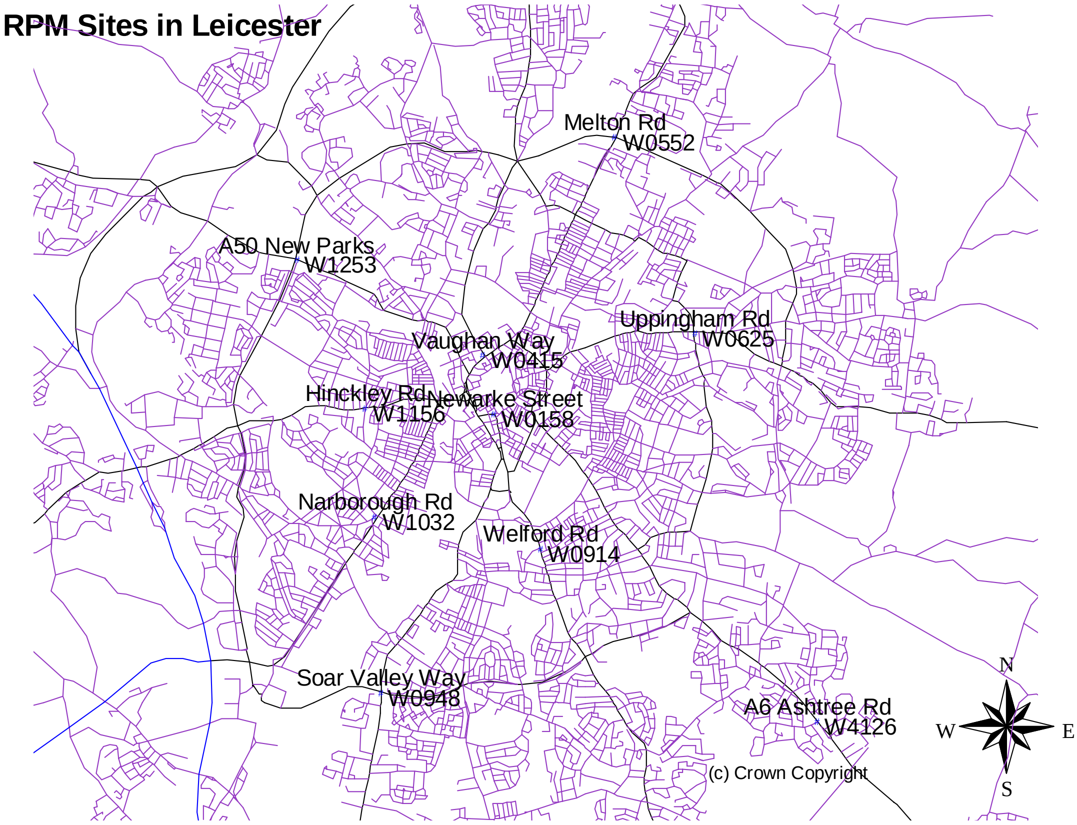

Figure 1: Location of Roadside Pollution Monitors in Leicester

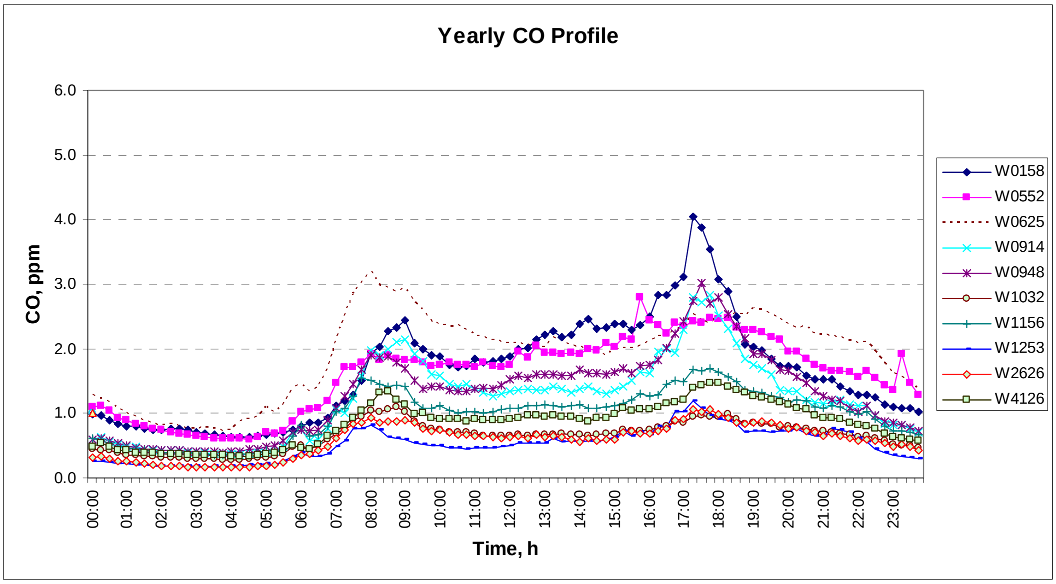

Figure 2: Yearly profile of CO concentrations

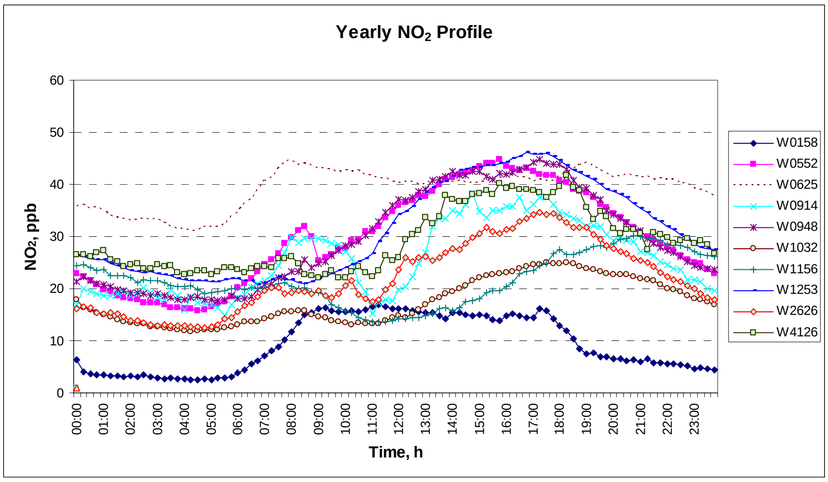

Figure 3: Yearly profile of NO_2 concentrations

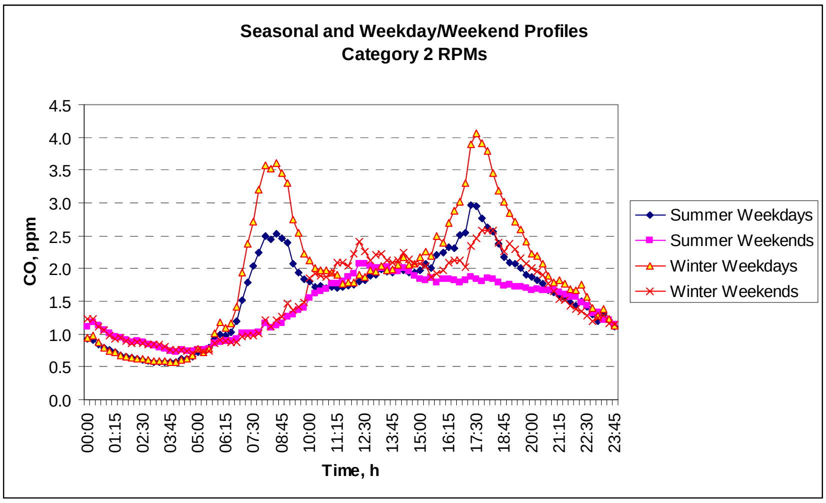

Figure 4: Seasonal and Weekday/Weekend Profiles of CO for Category 2 RPMs

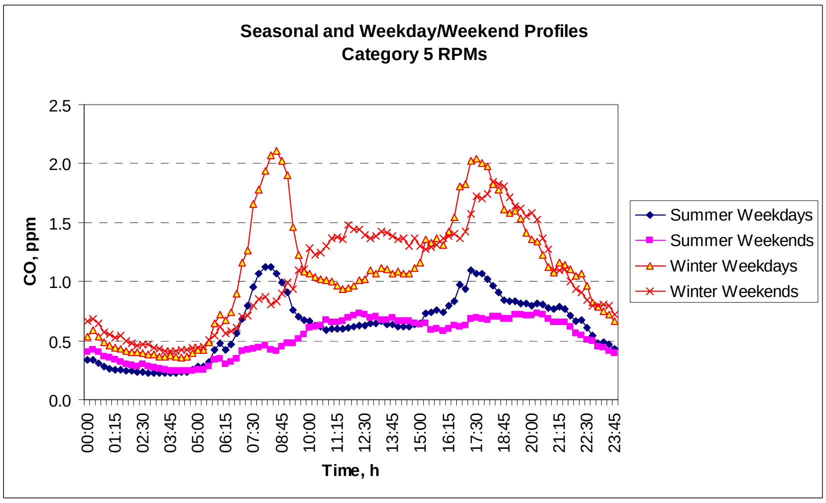

Figure 5: Yearly Seasonal and Weekday/Weekend Profiles of CO for Category 5 RPMs