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Correlation between NO and NO_2 roadside concentrations, traffic volumes and local meteorology at a major London route

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Abstract

The main source of air pollution in London is now road vehicle emissions. In addition to meteorological conditions, traffic volume is an important factor which influences the local air pollutant concentrations to which pedestrians and road users are exposed.

This paper discusses the relationship of local meteorology, traffic volumes and roadside air quality. Data from the London Borough of Southwark's roadside monitoring station, situated at a major London route (A2), has been analyzed for traffic volumes and nitrogen oxides. Data sets for the months of February and March 1995 have been employed for this study. The data analysis indicates a measurable correlation between the levels of NO and NO_2, traffic volumes and wind speed.

1 Introduction

The monitoring of pollutants in London has historically been associated with stack emissions from industry and residential sources. However, as a result of the combination of legislation and a decline in urban based industries over the last few decades, the main source of air pollution in London is now road vehicle emissions. In London road vehicles are responsible for 98% of all carbon monoxide, 74% of nitrogen oxides and the majority of fine particulates and hydrocarbon emissions [1]. Similar findings have also been reported in other references [2,3].

Over the last decade research interest into the sources and fate of atmospheric nitrogen oxides has increased considerably [4,5]. This research activity stems not only from the need to understand their general impact on the environment but also because they have been associated with a variety of respiratory effects over short and long term exposures [3, 6].

Anthropogenic emissions of nitrogen oxides are mainly due to fuel combustion and as mentioned above transport is a major contributor. Once NO is emitted into the atmosphere it is rapidly oxidised into NO_2 by oxidants, such as, ozone (O_3). Other complex reactions may also take place in contaminated air depending on the pollutants present [3]. NO_2 can then undergo a photochemical reaction to form NO and O. The oxygen atom resulting form the photodissociation of NO_2 can subsequently react with O_2 to form O_3 [7].

As most of the air pollution in urban regions is due to road traffic it is essential that monitoring of the air quality should take place near roadsides to estimate realistically the local pollutant concentrations. Although meteorological conditions have an important influence over the transport, deposition and dispersion of pollutants, near roadsides the volume of traffic is a major factor that determines the air pollutant concentrations to which pedestrians and road users are exposed. In order to understand the relationship between the air pollutant concentrations and local traffic volumes, therefore, real-time roadside ambient air quality, meteorological and traffic monitoring is required. Such detailed measurements permit relationships between traffic volumes, meteorology and urban air quality to be studied in order to establish local pollution trends.

This paper reports on the relationships between the measured roadside concentrations of nitrogen oxides (NO and NO_2), traffic volumes and local wind speeds. The measurements reported in this study were conducted at a major route (A2, the Old Kent Road) in the London Borough of Southwark, shown in Figure 1. The general aim of the study is to improve the understanding of how the traffic flow patterns and meteorology influences the local air quality.

2 Monitoring of traffic flows, air quality and meteorological parameters

The following data sets from the London Borough of Southwark's permanent roadside monitoring station were employed for this work:

(i) roadside concentrations of the nitrogen oxides (NO and NO_2);
(ii) wind speeds and
(iii) traffic volumes along the Old Kent Road (A2).

2.1 Description of the site

The monitoring station, which is housed in a museum building, is located along the major London A2 route (Old Kent Road), approximately 4.8km south-east of central London (see Figure 1). The section of the A2 where the

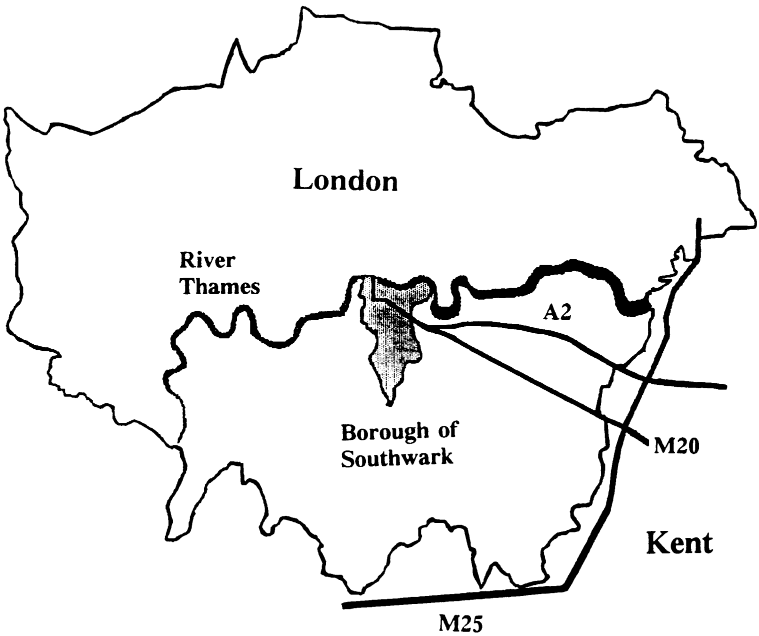

Figure 1: Map of London showing the location of the Borough of Southwark and the major traffic routes.

monitoring takes place consists of a four lane carriage way, with two lanes south-east bound towards Kent and two lanes north-west bound into London. In each direction there is one bus lane which limits access only to buses, taxis and cycles during morning and afternoon rush hours; 07:00 - 10:00 hrs into London and 16:00-18:00 hrs out of London.

2.2 Air quality monitoring

The monitoring intake is located above the pavement, 4m above the ground level, and is located on the south-eastern side of the road nearest the London bound traffic. The museum and the adjacent buildings tend to reduce the influences on the monitoring intake from traffic at other streets and from non-local stationary emission sources. The air quality measured is thus only representative of the local environment. Air quality was monitored with an automatic Daisibi system 1000 consisting of rack mounted pollutant analyzers, data acquisition systems, programmable multi-gas calibrators and modem to facilitate data transfer for subsequent analysis. Nitrogen oxides, NO and NO_2, in the urban air were measured with chemiluminescence monitors (model 2108) giving ten minute averaged concentrations. Conventional spreadsheet software (MS EXCEL) was used to analyse the data and present it for various averaging times.

2.3 Meteorological monitoring

A meteorological station is also housed at the site and consists of a rotating cup wind speed detector, a wind direction sensor and solar radiation detector. The road at the monitoring site cuts through urban topography consisting of non-residential premises such as two to three storey buildings, shops and a museum. Consequently, this topography will have local influences on the wind directions and speeds, which will therefore differ from the regional meteorology. Although regionally the predominant wind direction is south-westerly, the monitoring has shown that winds from south-easterly are more influential to the dispersion of the pollutants. North-westerly winds are the next most influential direction but are less significant.

2.4 Traffic Flow Monitoring

The traffic monitors consist of two sets of loops or sensor cables which were imbedded in the surface of each lane of the carriage way. As described in section 2.1 the traffic volumes that pass the monitoring site consist of flows of traffic into and out of London. Week day total average volumes consist of 45000 to 52000, with daily volumes into London consisting of 25000 to 28000 and out of London ranging from 20000 to 24000.

3. Results and Discussion

Air quality, meterological and traffic flow data for the months of February and March 1995 are discussed in this paper. Hourly averages of NO and NO_2, total traffic volumes travelling towards London and wind speed for a typical week day are shown in figure 2. The levels of NO_2 mimic those of NO as expected. Figure 2 also show how the concentrations of the nitrogen oxides vary with traffic volumes and local wind speed. The expected variations would be that the concentrations should be:

(i) proportional to traffic volume which is proportional to NO emissions and;

(ii) inversely proportional to the wind speed which is proportional to the magnitude of dispersion.

The maximum concentrations, therefore, should be observed when traffic volumes are high and wind speeds are low. As figure 2 confirms the maximum concentrations were actually observed when the traffic volumes were high and wind speeds were low which occurred during 07.00 and 12.00 hours of that day. The maximum at 8-9 O'clock corresponds to the usual week day traffic flow peak. The second maximum in the concentrations of the nitrogen oxides during a typical week day would be expected around 18.00-19.00 hours when traffic again peaks. However, because of the higher wind speed, causing greater dispersion of pollutants, the expected peak was not observed.

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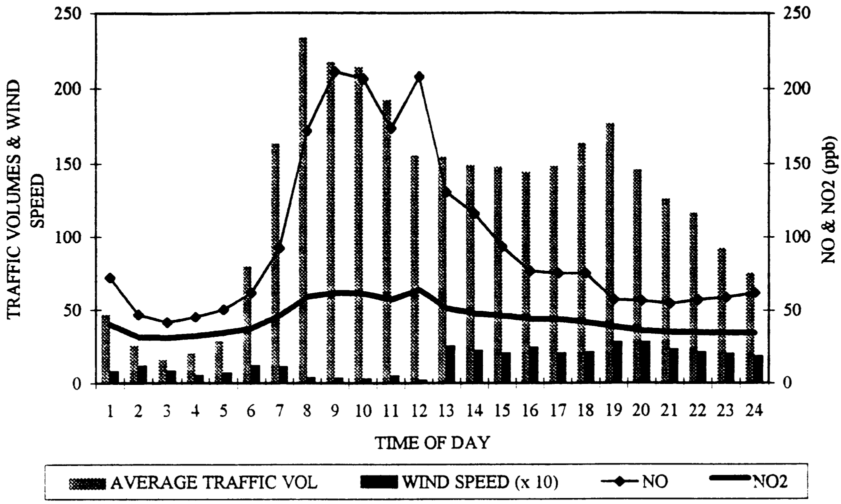

Figure 2: Diurnal variations of traffic volumes (towards London), wind speed (m/s) and concentrations of NO and NO_2 (ppb).

Figures 3 and 4 show the daily averages for NO, NO_2, total traffic volumes and wind speeds for the months of February and March 1995. The gap in the air quality and wind speed data for February was due to equipment failure. Although large variations in the traffic volumes are observed over a period of a day (figure 2) when daily averages are considered the fluctuations over a month are greatly reduced (figures 3 and 4). The variation that is seen in the monthly data is primarily due to the different traffic volumes experienced during week days (high volumes) and week ends (low volumes) although less fluctuations were observed for the month of February. The influence of wind speed on the local concentrations of the pollutants is clearly illustrated in figure 3 where the daily averages of the traffic volumes were generally constant throughout the month. For example, lower concentrations were measured on 3 and 12-16 February when the wind speeds were generally higher and increased levels of NO and NO_2 were observed during the periods 4th and 23rd of the month when wind speed was lower. Similar trends were observed for March although the traffic volumes were slightly more variable.

The combined influence of traffic and local wind speed on the air quality can be observed by expressing the NO and NO_2 concentrations as a function of the ratio of the traffic volumes to wind speeds. This is shown in figures 5 and 6 which includes hourly averaged data for the month of February. Although there is considerable scatter in the data a general direct correlation can be observed for both pollutants. A linear regression equation has been fitted to

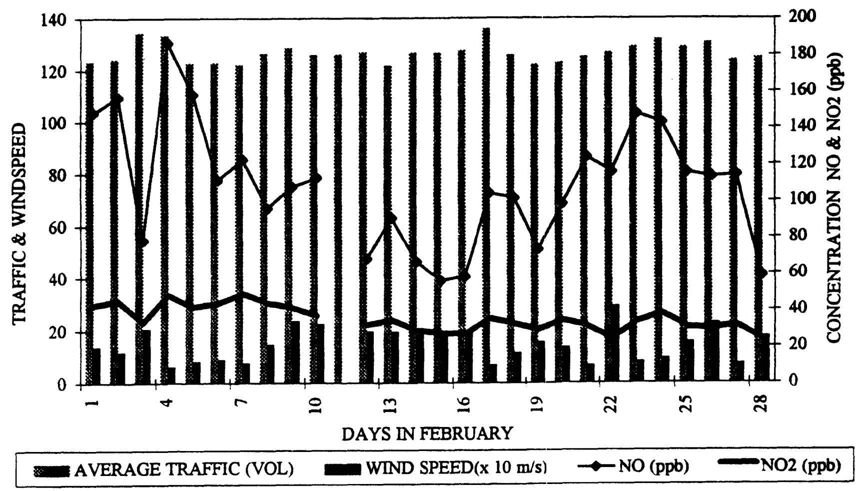

Figure 3: Daily averages of NO and NO_2 concentrations (ppb), total traffic volumes and wind speed (m/s) for the month of February.

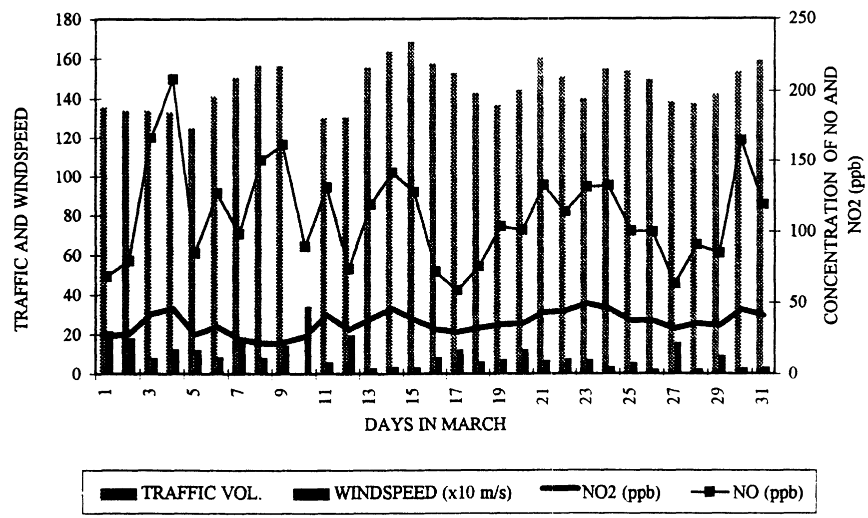

Figure 4: Daily averages of NO and NO_2 concentrations (ppb), total traffic volumes and wind speed (m/s) for the month of March

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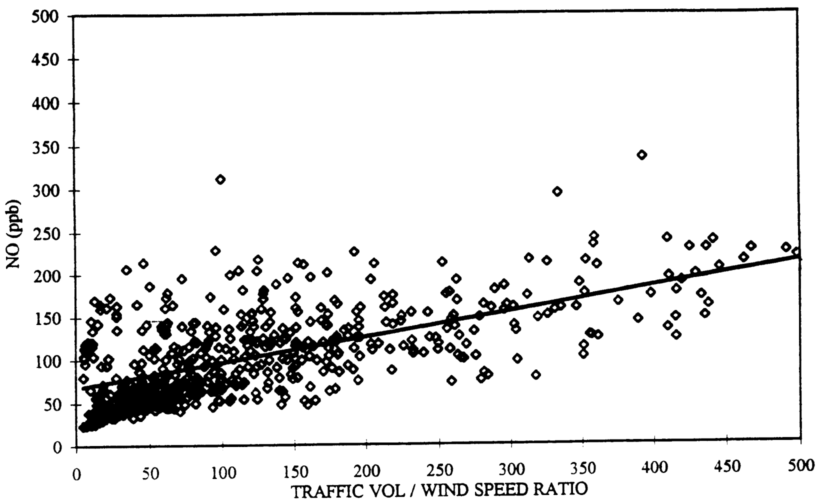

Figure 5: Hourly concentrations (C) of NO plotted versus the ratio (R) of traffic volumes/wind speed (number of vehicles.s/m). The regression equation is C = 0.29R + 67, correlation coefficient = 0.38).

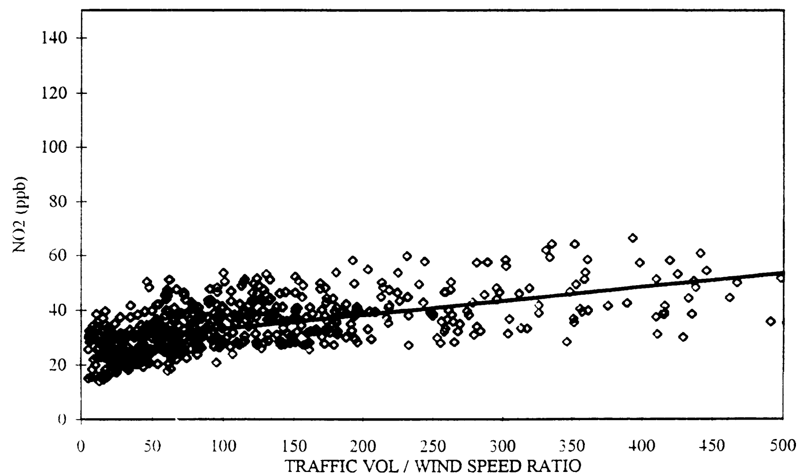

Figure 6: Hourly concentrations (C) of NO_2 plotted versus the ratio (R) of traffic volume/wind speed (number of vehicles.s/m). The regression equation is C = 0.051R + 28, correlation coefficient = 0.32).

the data and is also plotted on the same figures. The background levels of NO and NO_2, that is, the concentrations due to natural sources and anthropogenic sources other than road traffic, have been estimated from the linear regression equations and are 67ppb for NO and 28ppb for NO_2 giving a ratio for NO:NO_2 of 1:0.42.

4. Conclusions

This study has illustrated the critical dependence of roadside air quality on traffic volumes and local meteorology. The temporal variations in the roadside concentrations of nitrogen oxides can be explained in terms of local wind speeds and traffic volume fluctuations. There is a measurable direct correlation between the levels of the nitrogen oxides and the ratio of traffic volumes to wind speed. This has significant implications for local air quality management and modelling. If these trends can be further substantiated then monitoring road traffic and local meteorology can also be used to infer the quality of the roadside air without necessarily reverting to direct routine monitoring of air pollution. If air pollution monitoring is to be undertaken to estimate the quality of urban air then it is important to site the station where it can measure the contribution of traffic emissions which are often the most important source of pollution. Furthermore, this study suggests that the use of local meteorological data and detailed traffic flow patterns, if incorporated into mathematical models, would provide more representative predictions of the urban air quality.

References

1. London energy survey, London Research Centre, UK, 1992.
2. Digest of environmental protection and water statistics No 14 1991, Department of the Environment, UK, HMSO, London, 1992.
3. Urban air quality in the United Kingdom. First report of the Quality of Urban Air Review Group, Department of the Environment, UK, 1993.
4. Lenner, M., Lindqvist, O. and Rosen, A. The NO_2/NO_x ratio in emissions from gasoline-powered cars: high NO_2 percentage in idle engine measurements, *Atmospheric Environment*, 1983, 17, 13595-1398.
5. Atkins, D. H. F. and Lee, D. S. Spatial and temporal variation of rural nitrogen dioxide concentrations across the United Kingdom, *Atmospheric Environment*, 1995, 29, 223-239.
6. Walters, S. What are the respiratory health effects of vehicle pollution?, in *How Vehicle Pollution Affects Our Health*, ed C. Read, pp9-11, The Ashden Trust, London, 1994.
7. Brimblecombe, P. *AIR composition and chemistry*, Cambridge University Press, Cambridge and London, 1986.