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Classification of road traffic and roadside pollution concentrations for assessment of personal exposure

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Abstract

Nowadays urban pollution exposure from road transport has become a great concern in major cities throughout the world. A modelling framework has been developed to simulate Personal Exposure Frequency Distributions (PEFDs) as a function of urban background and roadside pollutant concentrations, under different traffic conditions. In this paper, we present a technique for classifying roads, according to their traffic conditions, using the traffic characteristics and fleet compositions. The pollutant concentrations data for 2001 from 10 Roadside Pollution Monitoring (RPM) units in the city of Leicester were analysed to understand the spatial and temporal variability of the pollutant concentrations patterns. It was found that variability of pollutants during the day can be associated with specific road traffic conditions. Statistical analysis of two urban and two rural Automated Urban and Rural Network (AURN) background sites for particulates suggests that $PM_{2.5}$ and PM_{10} are closely related at urban sites but not at rural sites. The ratio of the two pollutants observed at Marylebone was found to be 0.748, which was applied to Leicester PM_{10} data to obtain $PM_{2.5}$ profiles. These results are being used as an element in the PEFDs model to estimate the impact of urban traffic on exposure.

Keywords: Traffic classifications; Roadside pollution concentrations; PEFD; k-Means algorithm; RPM and AURN

1. Introduction

Urban air pollution is one of several major atmospheric pollution problems currently confronting the world's population. The problem is growing because of rapidly increasing urban populations, unchecked urban and industrial expansion, and the phenomenal surge in the number and use of motor vehicles. Examining air quality information is important in understanding possible human exposure and potential impacts in health and welfare. The UK National Atmospheric Emissions Inventory (NAEI) report shows that road traffic is the largest emission source of many health-related air pollutants (AEAT/NETC, 2004) such as carbon monoxide (CO, 59%), nitrogen oxides (NOx, 45%), benzene (32%), 1,3-butadiene (75%) and primary PM_{10} (25%), some of which contribute to the formation of ozone and secondary particles. Road traffic becomes an increasingly important sector as the particle size decreases. In 2002, it accounts 38% and 52% of $PM_{1.0}$ and $PM_{0.1}$ emissions, respectively. With road traffic emissions accounted for such a high proportion of the pollutants, and with the forecast of constantly growing traffic volume resulting in congestion and in turn exacerbating vehicle emissions (DoT, 1997), further refinement of the associations between air pollution, and in particular that related to traffic, and health is needed. A theoretical modelling exercise on a study of the relationship between industrial and traffic sources contributing to air quality objective exceedences in the UK was carried out, which showed that traffic emissions make a greater contribution to ground level concentrations of NO_2 than industrial sources per unit emission, and that street canyon conditions

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gives rise to higher NO_2 concentrations than an open road (Leksmono et al., 2006). Farias and ApSimon studied the temporal and spatial contributions to NOx concentrations from aircraft and traffic around Heathrow airport in West London (Farias and ApSimon, 2006). Their analysis showed that in the areas where people are exposed to air pollution, the impact of traffic emissions is larger than that of aircraft emissions.

Indeed, air quality problems experienced today in the UK are caused by pollution from road transport which is being addressed by the UK National Air Quality Strategy (DETR, 2000). Information about pollution may be obtained from two sources, namely monitoring sites (field data) and simulation (modelled data). A number of air quality simulation models have been developed, including two widely used models in the UK, namely ADMS-Urban (Carruthers and McHugh, 1996) and Airviro (SMHI, 2002), taking into account the whole range of relevant emission sources such as traffic, industrial, commercial, domestic and other less well-defined sources. When calibrated appropriately, these mesoscopic (or regional) models can be served as a useful tool for indirect estimation of air pollution levels and hence human exposure. Since a significant part of exposure of the population in many cities is caused by emissions from traffic in urban streets, the development of street pollution models has been a focus in exposure assessment. Examples of such models are STREET (Johnson et al., 1973), CPBM (Yamartino and Wiegand, 1986), OSPM (Hertel and Berkowicz, 1989; Berkowicz et al., 2006), CAR (Den Boeft et al., 1996), PANACHE (Tripathi, 1996), SPRAY (Tinarelli et al., 1994; Calori et al., 2006), Neural Network Models (Agirre-Basurko et al., 2006; Zito et al., 2007), and statistical distribution models (Gokhale and Khare, 2007). As the dispersion of street pollution is highly influenced by many factors such as the topology of the streets (street orientation, street width, height of buildings, etc.) and local wind turbulences, the calibration of these models to achieve accurate estimation is time-consuming and difficult. Geographic information systems (GIS) have been increasingly becoming a useful tool for the automatic map interpretation and representation of the street configuration in the assessment of air pollution exposure (Jensen et al., 2001; Beyea and Hatch, 1999).

The AURN sites serve as important sources of information about field pollution concentrations and hence indirect estimation of exposure at these fixed locations. Although there are over 1500 sites across the UK which monitor air quality, such coverage is not sufficient for the monitoring and modelling of street pollution. In Leicester, the local authority has installed 10 air quality units near the busy roads to measure the roadside pollution. Data from these units were used in this study.

Another serious limitation of the current air quality assessments of air pollution control policies is that they rely on estimates of outdoor concentrations rather than personal exposures (DoH, 1998). In our recent study on Reducing Urban Pollution Exposure from Road Transport (RUPERT), a modelling framework has been developed to simulate PEFDs of four pollutants (i.e. NO_2, CO, PM_{10} and $PM_{2.5}$), based on time-activity patterns of different population groups (e.g. children, elderly, office and home works, etc.) in a range microenvironments (e.g. bedroom, kitchen, lounge, office, classroom, shop, bar/restaurant, transport, outdoors, large buildings, etc.) across a city, as a function of urban background and roadside pollutant concentrations, under different traffic conditions (Bell et al., 2004). In this way, the potential health benefits of traffic measures, designed to reduce the concentrations at the roadside and urban background locations, can be estimated by linking the modelling of roadside pollutant concentrations with the probabilistic modelling of population exposures. In order to achieve this, it is necessary to assign a pollution profile to each road type across a network.

The modelling framework in RUPERT combines new and existing models relating traffic and air pollution data, with particular emphasis of the impact of congestion, and a probabilistic model of personal exposure. The relationships between predicted PEFDs across a city and outdoor concentrations will provide a basis from which to estimate the potential health benefits of measures to reduce concentrations at roadside and urban background locations. In this paper, we present a technique for classifying roads based on the traffic characteristics and fleet compositions. The pollutant concentrations data for 2001 from 10 roadside pollution monitoring units in Leicester were analysed to understand the spatial and temporal variability of the pollutant concentrations patterns. It was found that variability of pollutants during the day can be associated with specific road traffic types. These results are being used as an element in the PEFDs model to estimate the impact of urban traffic on exposure.

2. Methodology

2.1. Study site

There are several air quality monitoring schemes (or systems) running in parallel in Leicester (Latitude: 52.38N, Longitude: 01.08W, population: 280 thousand inhabitants). Firstly, the AURN site maintained and run by DEFRA (Department for Environment Food and Rural Affairs) measures levels of O_3, CO, SO_2, PM_{10} and NO_x. The Leicester AURN site is classified as an 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 and shopping areas. Leicester AURN site is located in a pedestrian piazza (i.e. an open space for pedestrians' use) between eight and eleven-storey council offices. It is situated approximately 30 m from a three lane one-way road, which is subject to congestion at peak times. Sampling heights are typically within 2–3 m. Secondly, Leicester City Council (LCC) monitors air quality at roadside mainly using 10 RPMs and seven air quality monitoring stations (i.e. not at roadside). At other specific locations, regular monitoring is carried out for short-term periods of typically one month using a mobile van. Additional data from two AURN urban sites in London (Marylebone Road and Bloomsbury) and two rural sites in Rochester and Harwell have been analysed for