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Determination of fleet hourly emission and on-road vehicle emission factor using integrated monitoring and modeling approach

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ABSTRACT

Roadside air quality and vehicle emission are important and challenging issues in urban air quality management which need to be adequately characterized. This study involves designing a monitoring program that produces suitable data to determine the on-road hourly fleet emission and emission factors of individual vehicles in a street canyon. Simultaneous hourly monitoring of roadside gaseous pollutants (both windward and leeward sides), traffic volume and speed, and wind in a busy street of Bangkok was conducted in the rainy season when traffic emission was predominant in the city. Higher pollutant concentrations often occurred at midday (11:00 to 14:00h) when higher traffic density (3700–3800vehicles h^{-1}, weekdays) was observed. The levels of toluene and xylenes found in this study are higher than the roadside levels reported in other Asian cities. Hourly maximum concentrations reached 258ppb for toluene, 51ppb for *m*,*p*-xylenes, 15ppb for *o*-xylene, 526ppb for NO_x, and 10.5ppm for CO. Hourly monitoring data during the periods when the street canyon effects were pronounced were selected for determination of the fleet hourly emission and vehicle emission factors by back calculation using a street canyon model (Operational Street Pollution Model). The average fleet hourly emission at daytime of NO_x (6.2kg km^{-1} h^{-1}), CO (54kg km^{-1} h^{-1}), toluene (2.1kg km^{-1} h^{-1}), *m*,*p*-xylenes (0.73kg km^{-1} h^{-1}) and *o*-xylene (0.27kg km^{-1} h^{-1}) did not vary much. However, the emission rates were substantially reduced at nighttime following the traffic pattern. The obtained pollutant emission factors varied within each group of vehicles with the average values agreed reasonably with the chassis dynamometer results for NO_x but somewhat higher for CO and TX. The model estimated results are, however, considered to better represent the real driving conditions in the street at the average vehicle travel speed of around 20km h^{-1}. A statistical sampling design is proposed to generate necessary data for the traffic emission inventory in a city.

1. Introduction

Traffic emission is known as the major source of air pollution in urban areas, which contribute substantially to ambient levels of particulate matter (PM) and a range of gaseous pollutants such as volatile organic compounds (VOC), NO_x, CO and SO_x (Gwilliam et al., 2004; Colvile et al., 2001; Kawashima et al., 2006). The situation is worse in many Asian developing countries where a rapid growth in vehicle fleets is observed which often results in high traffic density and congested street conditions. In Bangkok, the capital city of Thailand, the new vehicles registered in the city in 2006 was increased by 39% as compared to that in 2002 (DLT, 2006). Traffic is estimated to contribute up to 80% of NO_x, 75% of CO, 54% of particulate matter, and most of the non-methane hydrocarbons (NMHC) in Bangkok (BMA and UNEP, 2001).

The roadside air quality in developing countries, however, is not adequately characterized, especially for those toxic VOC that are reported to be emitted at high rates from vehicles

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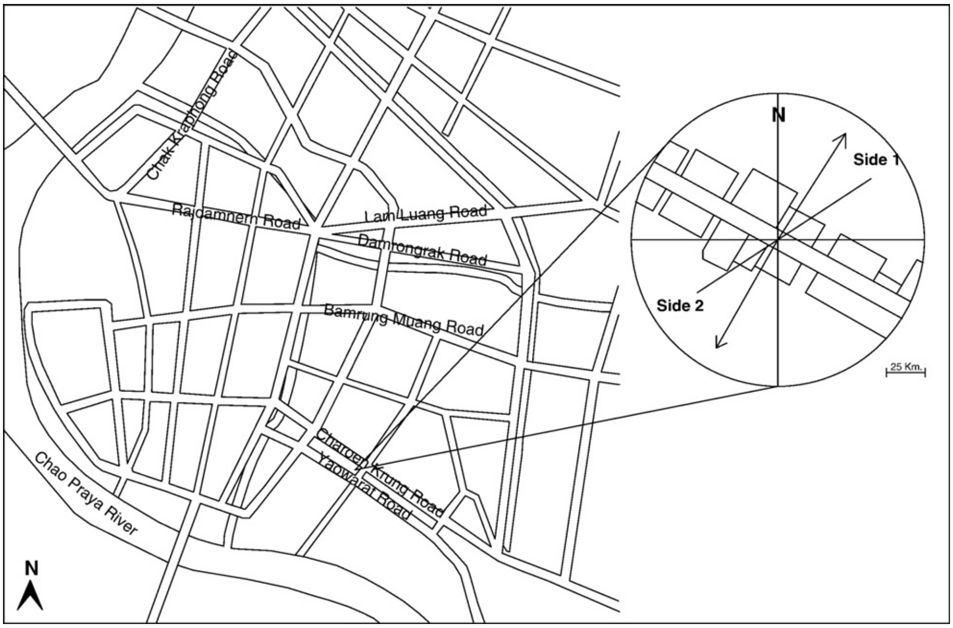

Fig. 1. Sampling sites and the street configuration showing Side 1 and Side 2 (building heights are presented using horizontal open-up consistently to OSPM).

(Schauer et al., 1999 and 2002). High pollution concentrations are often observed at roadsides (Truc and Kim Oanh, 2007; Monod et al., 2001), which contribute substantially to urban air pollution burden and could impose serious health effects. In many center parts of Asian urban areas the streets are normally narrow and flanked by tall buildings forming street canyons with special vortex circulating the traffic emission within the street (Berkowicz, 1997 and Berkowicz et al., 1997). This would result in a high pollution built up result in a high exposure for people running business along the street or in shop houses (Kim Oanh and Prapat, 2003).

Information on the status of roadside air quality and the traffic emission is required for better urban air quality management. This in turn requires a reliable vehicle emission inventory which relies on accurate emission factors (EF). Unfortunately, EF database for the actual vehicle fleets is almost non-existent in most of developing countries. The long vehicle life, low maintenance, low fuel quality, highly congested road conditions and lack of control devices would result in much higher vehicle EF in developing countries than those reported for developed countries. A cost-effective method for estimation of vehicle EF is necessary which would help to develop actual EF databases representing local conditions.

There are a number of methods currently employed to determine the emissions from motor vehicles. Each method would introduce certain uncertainty in EF and some methods may not be always affordable due to the high monitoring cost involved. It is also necessary to cross-check EF using more than one method to gain more confidence in the results. The traditional and most commonly used method is the chassis dynamometer testing which requires a well-equipped laboratory and is based on simulated driving cycles. This method is essentially used to establish uniform emission standards for regulatory purposes and for testing of new technologies, it does not necessarily reflect the real on-road driving conditions and the level of maintenance of the actual fleet (Palmgren et al., 1999). It is also expensive and time consuming with low vehicle through output. The on-road remote sensing method for monitoring of vehicle exhaust would be able to produce the real-world vehicle emission. The method is costly and faces a number of operational difficulties including the signal/noise, weather, and a range of interferences (Bishop and Stedman, 1996). Tunnel simulation method could also provide the real-world emission factors of vehicles (Sjodin et al., 1998; Stemmler et al., 2005) but, first at all, a well-defined tunnel is required, which may not always be easy to find in many cities. Recently, a few attempts on back calculation of traffic emission using the open flow line source models have been reported which show promising results (Kawashima et al., 2006; Gramotnev et al., 2003).

This study has been designed to back calculate the air pollution emission factors of the actual fleet in a busy street canyon of Bangkok using a street canyon model. The roadside levels of selected gaseous pollutants (CO, NO_x, VOC), hourly vehicle density in the street and meteorology were monitored and the data are used as the input for the calculation.

2. Methodology

The monitoring site was located in one of the busy roads in a commercial area of Bangkok, the Yaowarat road in the Chinatown, which is expected to be strongly affected by traffic emission. Especially, the measurements were done during the wet season (continuously for 18days in September 2003) when contribution from other sources like open biomass burning would be low. This would result in a more pronounced relative contribution of traffic emission (Kim Oanh et al., 2006). The selected road (Fig. 1) is a street canyon with both sides bordered by buildings. The street orientation is NW–SE (120° from the North), i.e. almost perpendicular to the prevailing NE–SW monsoon, in particular the SW wind in Bangkok during the wet season (Zhang and Kim Oanh, 2002),