New Method Of Determination Of Emission Factors For Different Types Of Vehicles On A Busy Road

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Abstract

In this paper, two new methods are developed for the determination of the average emission factors of fine and ultra-fine particles for different groups of vehicles on a busy road. For the first time, the average emission factors are calculated for the two groups of vehicles – heavy-duty trucks and light-duty cars. The approximate model presented herein allows simple and reliable predictions of fine particle concentrations near a busy road, and a simple method for the determination of the average emission factor for different types of vehicles on the road.

Introduction

During the last decade, aerosols of fine and ultra-fine particles, emitted from combustion sources, have been of increased concern in relation to human health in urban areas. Therefore, busy roads, being the main source of fine particles in the urban environment, are of a particular interest in aerosol science. As a result, accurate determination of average emission factors for vehicles on a road is of major importance for the evaluation of the impact of road pollution on human health and the environment.

Recently, the CALINE4 model, designed for calculation of concentrations of carbon monoxide near a busy road (Benson, 1992), has been adapted for the analysis of aerosols of fine and ultra-fine particles (Gramotnev *et al*, 2003). A scaling procedure for this model has been developed and justified.

At the same time, use of CALINE4 or any other model for predicting concentrations of fine particles near a busy road requires knowledge of the average emission factors for different types of vehicles. However, the values of the emission factors obtained under laboratory conditions differ by up to ~3 orders of magnitude, depending on make and age of the vehicles, dilution conditions, etc. (Graskow et al, 1998, Watson et al, 1998, Ristovski et al, 1998, Cadle et al, 2001), and lie within the intervals of $\sim 10^{12}$ to $\sim 10^{14}$ particles/vehicle/kilometre for gasoline (light-duty) vehicles, and $\sim 10^{14}$ to $\sim 10^{15}$ particles/vehicle/kilometre for diesel trucks. Gross et al. (2000) also estimated during on-road measurements that the ratio of the average emission factors for trucks and cars is ~48. However, the actual values for the emission factors have not been determined.

Thus there is a strong need to develop reliable methods in the determination of average emission factors for different types of vehicles on a busy road. As mentioned above, these emission factors could then be used in CALINE4 or other models for predicting aerosol pollution from existing and proposed roads.

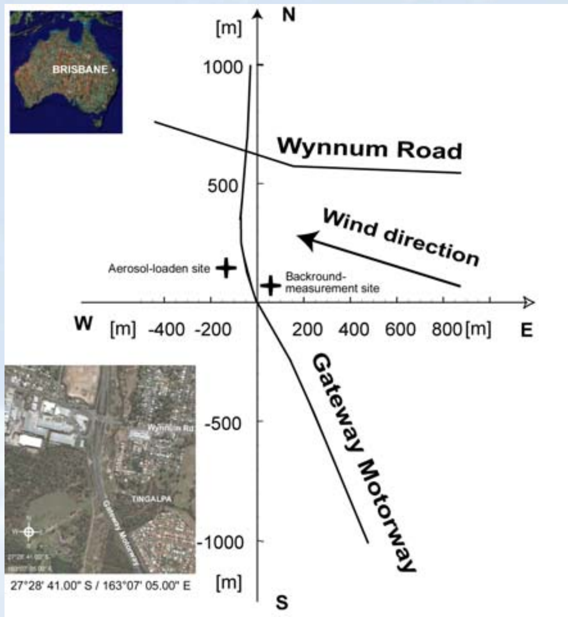

Fig. 1: The area of measurements near Gateway Motorway, Brisbane, Australia. The indicated receptor point is at the distance ~ 60 m from the curb of the road. The scale of the map and the direction to the North are as indicated (the distances on the axes are given in meters). The cross indicates the receptor point. The insert presents a section of the map with the area of measurements.

Methods

The measurements were taken near the Gateway Motorway (Brisbane, Australia – see Fig.1) at different traffic conditions. In order to monitor traffic affluence video-recording units were employed to discriminate between heavy vehicles and passenger cars. The total number concentration of fine and ultra-fine particles was expected to be below the micrometer- range and was measured at the distance of 15 m from the kerb at 2 m height above the ground using a scanning mobility particle sizer (TIS-SMPS-3071) and a condensation particle counter (TSI-CPC-3010), both powered by an external AC-generator. The concentrations were measured in 110 equal intervals (channels) of Δlog(Dp), where Dp is the particle diameter in nanometers. Five and ten scans were taken on the weekday (at the rate $\tau_1 \approx 2.73$ s per channel) and on the weekend ($\tau_2 \approx 1.36$ s per channel), respectively, and the average total number concentration was determined. The meteorological parameters (wind speed, wind direction, temperature and humidity) were measured every 20 seconds by a mobile weather station. Standard deviations of the wind speed and direction, their one hour averages, and other meteorological parameters are presented in Table 1. The values of the emission factors E_f for the average fleet on the road were calculated by means of the CALINE4 model (Gramotnev et al, 2003) – see last row of Table 1.

This novel approach is based on measurements of particle concentration only at one point near the road (Gramotnev *et al*, 2003). The examples of the calculated and experimental dependencies of concentration among fine particles on distance from the road clearly demonstrate the applicability of the method (see figure 2).

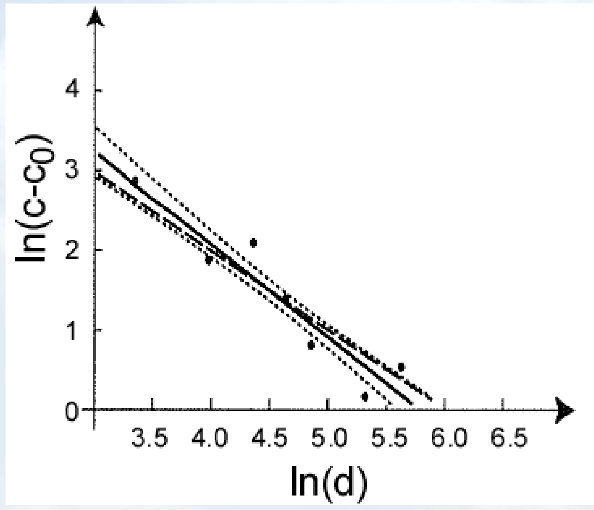

Fig. 2: The experimental (solid line) and theoretical (dashed line) dependencies of the average total number concentration (in cm^{-3}) with deducted background ($c - c_0$) at a distance from the middle of the road (in meters). The dotted curves give the standard errors for the experimental (solid) line of the measurements taken on 30 July 2002 - see also Table 1.

Results

Using the method developed in (Gramotnev *et al*, 2003), the emission factor was determined for the average fleet on the Gateway Motorway (Brisbane, Australia) at different traffic conditions: 18.1% of heavy trucks on the weekday, 30 July 2002, and 2.7% on the weekend, 24 November 2002. The total number concentration of fine and ultra fine particles was found in the range from 14 nm to 710 nm. One hour average of wind speed and direction that are input values for the CALINE4 model are presented in table 1 together with their standard deviations.

In the case of the line source approximation, the calculated emission factor for the average fleet can be calculated as follows:

$$E_f = n_t \cdot e_t + (1-n_t) \cdot e_c \qquad (1)$$

where e_c and e_t, are the emission factors for cars and heavy duty trucks, respectively, and n_t is the fraction of heavy-duty trucks in the traffic flow. Therefore, using the emission factors calculated for the average vehicle on the road (see last row in the table) and the fractions of heavy-duty vehicles n_t =0.181 and 0.027 for the experiments on 30 July and 24 November, respectively, we can write a set of two approximate linear equations similar to equation (1).

Application of the methods of linear modeling (Kreyszig, 1999) to this set gives the value of the emission factor for heavy-duty trucks: $17.2 < e_t < 29.6$ (x 10^{14} particle/vehicle/mile), and the value of the emission factor for cars $0.26 < e_c < 0.45$ (x 10^{14} particle/vehicle/mile).

Table 1: **Parameters**	**30 July 2002**	**24 Nov. 2002**
concentration at 15 m, [particle/cm^3]	$20.3 \cdot 10^3$ (±16%)	$2.2 \cdot 10^3$ (±13%)
background concentration, [particle/cm^3]	$2.3 \cdot 10^3$ (±4%)	$0.74 \cdot 10^3$ (+9%)
traffic flow, [vehicle/hour]	4295 (±2%)	3694 (±2.2%)
heavy duty diesels, [vehicle/hr]	776 (±2.3%)	100 (±15%)
cars and light trucks, [vehicle/hr]	3694 (±2.3%)	3594 (±2.3%)
wind direction, [°] degrees to the North	142° (SD = 48.0°)	28.54° (SD = 39.43°)
wind speed, [m/s]	2.3 m/s (SD = 0.8)	2.2 m/s (SD = 0.7)
humidity, [%]	33	35
emission factor, [particle/vehicle/mile]	$4.5 \cdot 10^{14}$ (±23%)	$0.37 \cdot 10^{14}$ (±24%)
emission factor, [particle/vehicle/km]	$2.8 \cdot 10^{14}$ (±23%)	$0.23 \cdot 10^{14}$ (±24%)

Conclusion

In this paper, a new method has been developed for the determination of the average emission factors of fine and ultra-fine particles for two groups of vehicles (heavy-duty trucks and cars) on a busy road. The investigation requires experimental measurements of particle concentrations at different traffic conditions (e.g., on a weekday and on a weekend). This method is also applicable when the traffic conditions are not changing.

At the investigated site with an expected traffic flow and expected fractions of cars and heavy-duty vehicles, then the determined values of the average emission factors e_c and e_t, together with the use of the CALINE4 model allows the prediction of the fine particle pollution in the vicinity of that road. Similar calculations can also be carried out for any existing road without measuring particle concentrations, but rather counting the traffic flow on the road. The latter is already frequently done to monitor traffic densities and traffic safety. Hence application of this model would be easily applicable.

For the first time, the emission factors have been determined during the on-road measurements. The method clearly demonstrates the advantage compared to the laboratory approaches giving strongly different results. The correction factors compensating for the discreteness of the traffic flow (i.e., for the breach of the line source approximation) have also been introduced.

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