

Car Fleet Emissions of Particles and other Pollutants Estimated from Urban Air Quality Measurements

A contribution to subproject SATURN

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Summary

Determination of emission factors of particles, i.e. PM_{10} , $PM_{2.5}$ as well as smaller (ultrafine) particles, and other pollutants from the actual car fleet for different types of vehicles is essential for reliable air quality and human exposure model calculations of the particles from the traffic.

Measurements of fine and ultrafine particles were carried out since 1999, at street and roof level in central Copenhagen, and in shorter campaigns at street level in the city Odense. Measurements were carried out by Differential Mobility Analyser (DMA) with a high time resolution corresponding to the variation in traffic and meteorology. The particles were separated in 29 size fractions from 0.01 micron to 0.7 micron. Significant correlation at street level was observed between the CO , NO_x , and ultrafine particles, indicating that the traffic is the major source of ultrafine particles in the air. Time series of the size distributions have been analysed using factor analysis for identification of the important sources and a constrained linear receptor model for source apportionment and for determination of single source size distributions of ultrafine particles from diesel and petrol fuelled vehicles.

A significant reduction of the number of nano-particles were observed and related to the reduction of sulphur in diesel fuel. Measurements of PM_{10} were carried at street level and the data were also applied for source apportionment. Dynamometer measurements of ultrafine particles were performed at selected diesel and petrol vehicles for comparison with the field measurements.

Measurement campaigns were performed in an apartment facing a street. The campaigns included the above parameters in order to determine the penetration and deposition of particles in the apartment. Preliminary results are presented.

Elemental and organic carbon (EC/OC) measurements with high time resolution (1-hour) in PM_{10} were carried out at a very busy street and related to other traffic pollutants. The correlations between EC and CO and also OC and NO_x/CO were relatively low. A clear correlation between EC and NO_x was observed, indicating a significant contribution to EC from diesel traffic.

Monitoring of other pollutants (e.g. benzene and toluene) from traffic was continued and the trend of the emission from traffic was determined.

Aim of the research

The main goal is to provide tools for determination of traffic generated air pollution. The study is based on the activities in Copenhagen and other Danish cities. They are experimental studies of air pollution from traffic in local (street) and urban scale. The data are used for development and validation of local and urban scale air quality models. The studies have been extended also to include meas-

urement and modelling of indoor/outdoor relationships of traffic pollutants in apartments along busy streets.

Activities during the year

Measurements of ultrafine particles by a Differential Mobility Analyser (DMA) at the street station Jagtvej in Copenhagen, the urban background station at H.C. Ørsted Institute and the street station Albanigade in Odense were continued. The measurements of ultrafine particles were analysed and applied for determination of the emission and number size distribution from the actual car fleet, separately for diesel and petrol vehicles. The measurements were supplemented with 24 hours and 1-hour measurements of PM₁₀ at street level.

The on-road measurements of emissions from traffic were compared with dynamometer measurements on selected types of vehicles.

Two measurement campaigns were performed in an apartment at Jagtvej in Copenhagen. The campaigns included the above parameters in order to determine the penetration and deposition of particles in the apartment (to be published, Wåhlin et al. 2002).

Preliminary measurements with 1-hour time resolution of organic and elemental carbon (OC/EC) were performed during a campaign in a street in central Copenhagen (le Bihan et al. 2001).

The measurements of benzene, toluene and xylenes were continued. The experimental data has been analysed and applied for determination of emissions for CO, NO_x and benzene of the car fleet in Copenhagen (Palmgren et al. 2001a).

The monitoring of NO_x/NO, CO, TSP, O₃ etc. under the Danish Air Quality Monitoring Programme was continued and used as a support for the data analysis.

Principal results

The present study include measurement of the ultrafine particles from traffic under normal driving conditions and in ambient air, in order to be able to establish the relationship between the sources and the exposure of the population. Measurements of ultrafine particles were carried out by a DMA with a high time resolution corresponding to the variation in traffic and meteorology. The particles were separated in 29 size fractions from 0.01 µm to 0.7 µm.

Receptor analysis of the measured data was performed, using factor analysis (or principal component analysis) for the identification of the important sources. The factor analysis of the weekly average cycle (Wåhlin et al., 2001a) showed that petrol traffic and diesel traffic can be identified as two factors, which are responsible for almost all the variation (95 %) of the concentrations of CO, NO_x, and particles in the size range < 300 nm. A third non-traffic factor (insignificant covariance with CO and NO_x), is responsible for some of the variation of the particle concentrations in the size range > 300 nm. This size range indicates that the non-traffic factor is associated with long-range transport of secondary aerosol particles. A constrained linear receptor model has been used for source apportionment and for determination of single source size distributions of ultrafine particles from diesel and petrol fuelled vehicles.

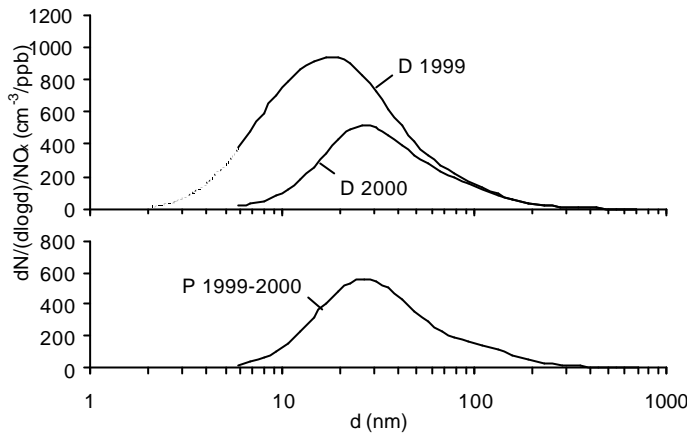


Figure 1. The diesel ('D 1999', 'D 2000') and petrol ('P 1999-2000') emission profiles for Jan-Mar 1999 and Jan-Mar 2000.

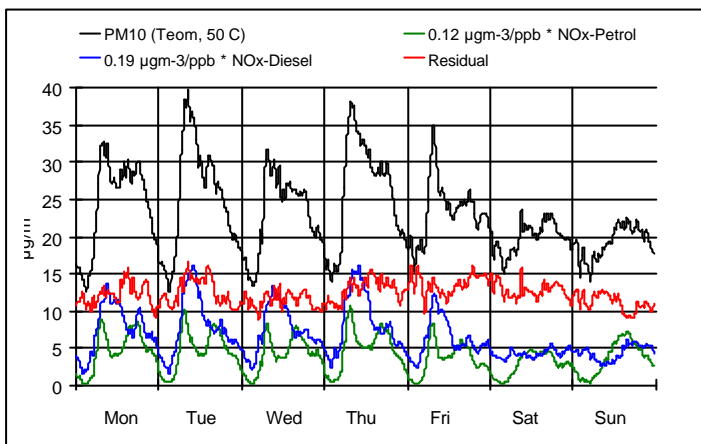


Figure 2. Average weekly PM_{10} and contributions from petrol and diesel vehicles and non-traffic.

Measurements of particle number concentration and size distributions in a Copenhagen street canyon in January-March 1999, and one year later in 2000, have revealed that the number of particles in the ultrafine size range below 100 nanometers decreased significantly in the period between the two campaigns. The decrease was especially large in the size range below 30 nanometers, Figure 1 (Wählén et al. 2001b, and presented at "The Third International Conference on Urban Air Quality" Loutraki 19-23. March 2001)

PM_{10} measurements by TEOM were analysed, and the contributions from diesel and petrol vehicles and non-traffic sources were determined. The non-traffic PM_{10} was approx. 50%, figure 2.

Elemental and organic carbon (EC/OC) measurements with high time resolution (1-hour) in PM_{10} were carried out at a very busy

street and related to other traffic pollutants. The correlations between EC and CO and also OC and NO_x/CO were relatively low. A clear correlation between EC and NO_x was observed, indicating a significant contribution to EC from diesel traffic.

Particle number concentrations and size distributions in the range 6-700 nm were measured in an apartment facing a street, at the street station, and at an urban background station. Constant concentration tracer gas (SF_6) technique was used for the measurement of the air exchange rate. The penetration efficiency and the deposition rate can be estimated by fitting the concentration rate balance where indoor sources are ignored. The analysis indicates that the deposition rate of particles in the apartment is negligible in the particle size range 100 - 500 nm. In the size range below 100 nm the deposition rate increases with decreasing particle diameter to a value of approximately 1 h⁻¹ at 10 nm. The penetration efficiency shows a maximum of 60% at 100 nm. A more complete data sets will be analysed and published (Wählén et al. 2002).

The studies of benzene emissions from traffic have been finalised (Palmgren et al. 2001a)

Main conclusions

Traffic is the dominating source of ultrafine particles in busy streets, but also the contribution to PM_{10} is significant. The application of averaged PM data, collected continuously, in combination with routine monitoring data and manually counted traffic rates, is a powerful tool to determine contribution and emission factors of particles from diesel and petrol vehicles from the actual car fleet under normal driving conditions in cities. The method is useful for demonstration of the effect of measures taken to reduce the air pollution. Similar analyses have been carried out for EC/OC and benzene.

The data are available for determination of emissions, development of particle modules to the air quality in street urban air quality models and their validations. This type of models is necessary for estimation of the human exposure of air pollutants in urban areas.

Aims for the coming year

A four year Danish programme on urban particle pollution was initiated during 2001, and a significant part of this programme comprises characterisation of particles, including size distributions and chemical and physical properties. The experimental studies of emission from traffic will be expanded, mainly in Copenhagen. Measurement campaigns of ultrafine, fine and coarse particles will be continued in Copenhagen by DMA and $PM_{2.5}/PM_{10}$ in order to include particles in the street pollution and urban background model. The measurements in streets will be supplemented by measurements on vehicles at dynamometers, and indoor/outdoor PM pollution. Studies of the transformation of particles in urban air and contribution from non-tailpipe emissions will be initiated.

Acknowledgements

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