Experimental Studies of Ultrafine Particles in Streets and the Relationship to Traffic

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Objectives

The adverse health effects of air pollution from traffic are well known, especially the health effects of particles. In the new EU directives on ambient air quality the limit values of particles have been strengthened significantly. The limit values have been set for $PM_{10}/PM_{2.5}$, but all new investigations have indicated close relationship to the smallest particles. The aim of the present study is to quantify the emissions of ultrafine particles from diesel and petrol vehicles and include the results in models of exposure estimates. Preliminary results are shown below.

Instrumentation and measurements

A 28 cm Hauke-type Differential Mobility Analyser (Winklmayr et al., 1991) - built at JRC - in connection with a TSI Model 3010 Condensation Particle Counter was used to measure particle numbers in 29 electrical mobility channels in the size range 6-700 nm. The scanning was approx. 3 minutes. Corrections for 50% average channel efficiency, and for zero and multiple electron charging, were made (Wiedensohler, 1988).

The measurements were performed in a street canyon close to central Copenhagen (Jagtvej) in the period 19 January - 8 march 1999. Half-hour average spectra and particle concentrations were calculated, synchronised with half-hour routine measurements of NO_x and CO.

Results

The average weekly cycles of particles and CO concentrations are shown in Figure 1. Although the correlations between particles, NO_x (not shown) and CO are generally good, some deviations were observed. The differences can be related to differences in the traffic patterns of petrol and diesel vehicles (diesel taxies dominates at night, petrol cars during rush-hours).

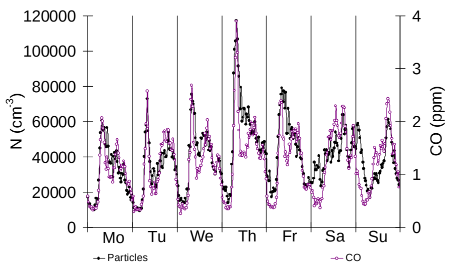

Figure 1. The average weekly cycle of particle number and CO concentrations at Jagtvej, Copenhagen, 19.01.99-08.03.99.

Half-hour average particle spectra representing daytime at workdays are shown in Figure 2. The shapes seem very similar with a peak of the size distribution at approx. 20 nm. Detailed receptor analysis reveals that small differences exist with shifts to a coarser average size in the spectra collected during rush hours (8:30-9:00 and 16:30-17:00).

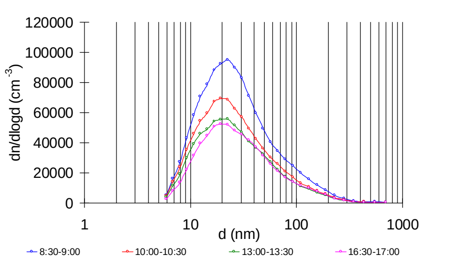

Figure 2. Average particle size distributions during specific workday half-hours.

Receptor analysis

A receptor analysis on the half-hour average concentrations of CO, NO_x and particles, including the average particle size spectra (spectrum derivatives dN/dlogd), has been performed. The correlation matrix of the 32 variables was diagonalised, and 95.6% of the total variance was accumulated in a 3-dimensional subspace. A dimension higher than 3 does not improve the description. Rotated loadings of CO, NO_x and N (particles number) are shown in Table 1. The squared rotated loadings of dN/dlogd, see figure 3.

The 'Non-traffic' source (small CO and NO_x loadings) gives only a minor contribution to the total particle number, and is concentrated in the coarse fraction. The second source describes the general contribution from traffic ('Petrol+ diesel'), because the loadings of CO and NO_x are high. All petrol traffic is apportioned to the traffic source. The major part of the particles is apportioned to the traffic source.

Table 1. Averages, standard deviations, 3-dimentional loadings and communalities (sum of the squared loadings) of CO, NO_x and particles number concentrations at Jagtvej.

	Ave-rage	St. dev.	Loadings 'Non-traffic'	'Petrol+ diesel'	'Diesel'	Commu-nality
CO	1.20 ppm	0.61 ppm	0.01	0.92	0.03	0.86
NO_x	51 ppb	27 ppb	-0.01	0.94	0.23	0.95
N	39462 cm^{-3}	18045 cm^{-3}	0.03	0.90	0.44	0.99

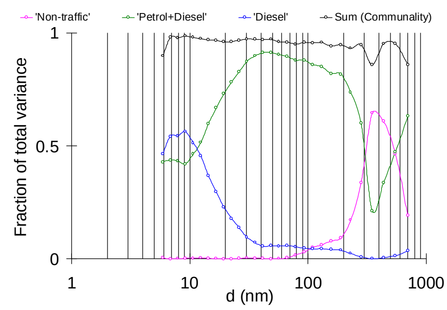

Figure 3. Squared eigenvector loadings (explained fraction of variance) of the particle size spectrum variables (dN/dlogd).

The third source ('Diesel') is a traffic source as well (significant loading of NO_x), and not correlated with the general diurnal pattern of traffic. The source is attributed to diesel traffic alone (low loading of CO). A considerable part of the finest part of the particle spectrum is apportioned to the 'Diesel'-source.

A more detailed receptor analysis using a constrained physical receptor model (Wåhlin, 1993) has shown that a range of possible solutions exists with NO_x/CO emission ratios from petrol cars in the range 0.027-0.042 mol/mol.

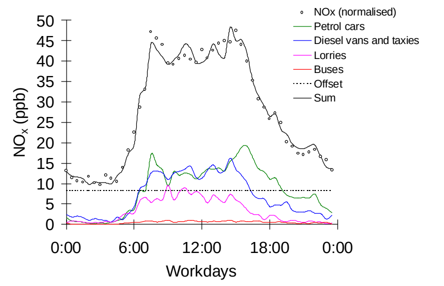

Figure 4. The average workday concentration cycle of NO_x, adjusted for meteorological influence, and normalised to the average wind vector at the site, 4 ms^{-1} from 240°. The fitted contributions from the different categories were determined by regression analysis using counted traffic rates.

The actual petrol NO_x/CO emission ratio is determined by detailed traffic counts data (discriminating diesel and petrol vehicles), and measurement data of NO_x and CO. Detailed actual traffic data do not exist for Jagtvej. However, an analysis was performed on traffic data from May 1999 and NO_x and CO data in the period January-March 1999 from a street station in Odense (figure 4 for NO_x.). NO_x and the CO contributions from petrol cars were calculated, and NO_x/CO = 0.036 mol/mol for petrol emissions was found.

The petrol cars in Copenhagen and Odense are assumed to be alike, and the driving pattern (cold starts, speed and accelerations) are almost the same at the two sites. Using this ratio, a specific solution can be found for the particle concentrations (figure 5).

The particle size spectra from different sources as shown in Figure 6. The size of the particles emitted by the diesel vehicles was considerably smaller than the size of particles emitted by the petrol vehicles.

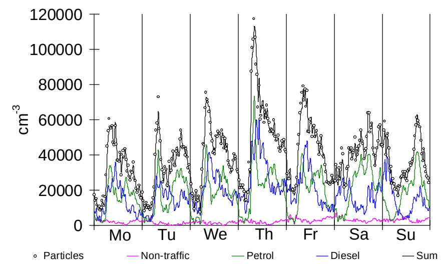

Figure 5. The average weekly cycle of particle concentrations measured at Jagtvej, 19.01.99-08.03.99, and the fitted contributions from the different sources.

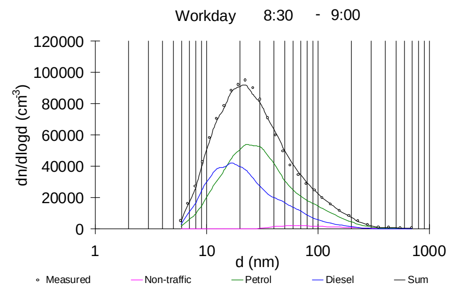

Figure 6. The average particle size spectrum during a morning rush-half-hour (workdays 8:30-9:00) resolved as the sum of spectra from different sources.

Conclusions

The study has shown that

- traffic is the dominating source (by number) of particles in the street,
- particles emitted from diesel vehicles are smaller than particles from petrol cars, and
- particles and particle size distributions from different vehicles can be estimated using a differential mobility analyser in combination with receptor modelling and traffic counting.

References

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