Ultrafine particles at eight urban sites in Antwerp: instrument comparison and spatiotemporal variation in particle number concentration and size distribution

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Due to the short atmospheric lifetime of ultrafine particles (UFP) and their strong dependence on local sources, ambient particle number concentrations and size distributions may vary significantly on short spatial and temporal scales. Because UFP are a primary pollutant that is rapidly transformed by physicochemical processes (dispersion, coagulation, deposition, etc.) and emitted mainly by mobile sources, they show a very high spatial variation. The particle number concentration is known to be elevated near roads and to decrease with increasing distance to the road primarily as a result of dispersion. Therefore, UFP measurements at a single urban background air quality monitoring station may not be indicative of the actual exposure in the communities surrounding this station.

To address this problem and to more accurately estimate human exposure and subsequent health impacts of UFP, more intensive measurements on finer spatial scales are needed. Therefore, UFP measurements were carried out at eight urban background or hotspot sites in the city of Antwerp (Belgium).

UFP instrument comparison

As different types of UFP instruments were used, first a 3-week field comparison was carried out in January 2013. Four types of UFP instruments were involved: (i) a particle counter with water as condensation liquid (TSI-3783 or EPC, n = 5), (ii) a differential mobility analyzer with an electrometer and corona discharger to ionize the sampled aerosol (TSI-3031 or UFP monitor, n = 3), (iii) a scanning mobility particle size spectrometer (SMPS) with butanol condensation particle counter and a Kr-85 source (Grimm CPC-5420 with L-DMA, n = 3), and (iv) a second type of SMPS with a butanol particle counter and a Ni-83 source (TSI-3772 with L-DMA, n = 1).

All devices were set up in measuring stations or trailers at an urban background site next to a moderately busy road. The results indicate good comparability of the instruments per type of instrument. The particle number concentration measured by the five EPC instruments was strongly correlated (R^2 > 0.98). More particles were detected in the high inlet flow mode (3.0 L/min) than with a lower inlet flow (0.6 L/min). The number of instruments sampling from a single TSI sampling system influenced the results as well. Without inlet screen assembly the average number concentration by the EPC instruments differed less than 12% from each other.

For the three UFP monitors good correlation (R^2 > 0.91) was generally observed between the size-specific particle number concentrations, except for the highest size channel (>200 nm). For the lowest size channel (20-30 nm) the difference between the UFP monitors was up to 30%, but the total number concentration differed less than 10%. For the three Grimm SMPS devices there was a strong correlation (R^2 > 0.95) between the size-specific particle number concentrations and also the total number concentration (10-1094 nm) was very comparable, with a difference of on average less than 3%.

Spatiotemporal UFP variation

In February 2013, the UFP number concentrations and size distributions were simultaneously measured (i) at three sites with an increasing distance (10, 30 and 55 m) to a major traffic road and (ii) at four other urban sites in Antwerp. At each of these seven sites an EPC was set up together with a UFP monitor or an SMPS. To relate the UFP measurements to the local traffic conditions, traffic intensity was monitored at all sites. Diffusive samplers were used to monitor weekly NO_x concentrations. In the road gradient study also black carbon concentrations were measured.

The research questions of this 4-week study were (i) to determine the effects of a busy traffic road on particle number, size distribution, black carbon and NO_x concentrations into adjacent neighbourhoods, (ii) to determine the small-scale spatial variability of particle number concentration and size distribution within an urban area, (iii) to examine how this variation is affected by the site location (source vs. receptor), traffic intensity and meteorology, and (iv) to analyze particle number data with high time resolution in order to determine regional vs. local contributions to particle number levels.

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