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Short communication

Variation of particle concentrations and environmental noise on the urban neighbourhood scale

Stephan Weber*, Tom Litschke[1,2]

Department of Applied Climatology and Landscape Ecology, Institute of Geography, University of Duisburg-Essen, Campus Essen, D-45141 Essen, Germany

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ABSTRACT

Particulate air pollution and environmental noise received increased attention within the environmental health community during recent years due to their potential impacts on human health. In this study the spatio-temporal variation of noise and particles was estimated by a short set of mobile measurements within an urban neighbourhood in Essen, Germany. Particle concentrations (PM_1 and $PM_{coarse} = PM_{10} - PM_1$) were measured by an optical particle counter continuously along the measurement route while environmental noise was measured at fixed points on the same route. Additionally, wind and turbulence parameters were gathered above rooftop height and within an urban street canyon.

The spatial distribution of noise was very homogeneous while the distribution of particle concentrations turned out to be rather inhomogeneous. The spatial correlation between noise and particles was found to be poor for PM_{coarse} during all measurements. However, for PM_1 and noise a moderate positive correlation ($r \sim 0.5$) emerged under conditions of weak turbulent atmospheric mixing. The spatio-temporal covariation between particles and noise is believed to be more evident for ultrafine (<100 nm) particles.

1. Introduction

People living in urban areas are exposed to a complex mixture of environmental pollutants. Due to the heterogeneous spatial distribution of emission sources, different source types, complex urban geometry and differences in meteorology the people's exposure towards pollutants is characterised by a significant spatio-temporal variability.

In order to study the variation of urban pollutants with a high spatio-temporal resolution mobile measurements were conducted across different spatial scales recently. These mobile investigations have focussed on gaseous and particulate pollutants (e.g. Bukowiecki et al., 2002; Pirjola et al., 2004; Weijers et al., 2004; Kolb et al., 2004; Tang and Wang, 2006) or environmental noise (Tang and Wang, 2007). These measurements were performed on the urban scale, the neighbourhood scale and within street canyons. The results demonstrated the mobile measurement technique to be a powerful method to map urban pollutant concentrations and to assess main factors influencing variation of pollutants on the different spatial scales.

Particulate air pollutants and environmental noise received increased attention during recent years due to their relevance to human health (Klaeboe et al., 2000; Tobias et al., 2001; Lusk et al., 2004; Babisch et al., 2005; Pope and Dockery, 2006; Muzet, 2007). Based on single spot measurements in two Italian cities a close relation between carbon monoxide concentrations and traffic noise was stated experimentally (Tirabassi et al., 1998; Tirabassi, 1999). This is related due to the emission of both stressors from the same source, motorised traffic in urban areas. However, the variation of both quantities within both cities was not taken into account.

* Corresponding author. Tel.: +49 201 183 3387; fax: +49 201 183 3239.
E-mail addresses: stephan.weber@uni-due.de (S. Weber), tom.litschke@uni-due.de, tlitschke@tuev-nord.de (T. Litschke).
[1] Tel.: +49 201 183 2452; fax: +49 201 183 3239.
[2] Present address: TÜV Nord Umweltschutz GmbH & Co KG, Große Bahnstraße 31, 22525 Hamburg. Tel.: +49 40 8557 2662; fax: +49 40 8557 1901 9048.

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Here we try to investigate the spatial variability of both noise and particle concentrations by a short set of mobile measurements on the urban neighbourhood scale. The data was also analysed for influence of meteorological conditions on the distribution of noise and particles.

2. Study area

Measurements were performed within a busy urban street canyon (average daily traffic (ADT) = 49,000 vehicles 24 h^{-1}) and its surrounding neighbourhood in Essen, Germany. The study area covers about 20 ha. The street canyon 'Gladbecker Straße' (federal highway B224) is a hot-spot of particulate air pollution in Essen with yearly average concentrations of about 36 $\mu g\, m^{-3}$ PM_{10} in 2005 and 2006. Mean building height of the symmetric canyon $H = 17$ m and mean width $W = 21.6$ m result in an H/W ratio of 0.8. Further details on the street canyon and its geometry can be found in Weber et al. (2006).

The surrounding neighbourhood is characterised by residential houses generally comprised of 4–5 floors. ADT data is estimated by the city authorities to be less than 1000 vehicles 24 h^{-1}. Manual short-term traffic counts during the field campaign yielded traffic amounts of around 1% the vehicle number at B224.

The 3.5 km mobile measurement route was subdivided into 45 similar subsections (SU) along which spatial averages of particle concentrations and fixed-point measurements of noise and meteorology were gathered in the centre of each section (see Section 3.2 for details). Besides the western area of the route (urban park) the measurements were conducted within street canyons to the NE of B224.

3. Material and methods

3.1. Instrumentation

Particle concentrations were measured by optical particle counters (OPC_{Can}, Grimm Aerosol, Model 1.107, Germany) which offer a sufficient temporal resolution for mobile applications (measurements every 6 s). At B224 the OPC was installed within a container at a height of 3.4 m above ground level (agl). OPC measures particle size distributions in the range $0.3 < D_p < 32\,\mu m$ by a light scattering technique (see Weber and Weber, 2008; Weber et al., 2006 for details of the OPC). Size distributions are converted into particle mass by the instruments software assuming constant densities for different size ranges. A comparison with on-site TEOM readings performed by the North-Rhine Westphalia State Environment Agency (LANUV NRW, comparison period 24 March–14 June 2007) showed an underestimation of average 24 h TEOM PM_{10} concentrations by 20% on average ($r^2 = 0.85$).

At the container a sonic anemometer (Metek USA-1, Germany) was installed at a height of 3.75 m agl to measure horizontal wind speed u_{Can} and turbulence parameters.

The same OPC model was installed at a height of 1.1 m agl on a trolley for mobile measurements (OPC_{Mob}). Particle concentrations were measured continuously while walking along the measurement route with a speed of about 1 $m\,s^{-1}$. During two consecutive days (13 and 14 June 2007; labelled day 1 and 2 hereafter) nine repeated mobile measurements of approximately 75 min duration were conducted in the time period from 11.00 to 16.30 CET on day 1 and 06.00 to 13.30 CET on day 2 covering a data-set of $n = 405$ measurement points in total.

Additional wind data above the urban canopy layer (UCL) was measured at a rooftop at 35 m agl by a sonic anemometer (Metek USA-1, Germany). This measurement gives a good estimation of the undisturbed wind above roof level (Weber et al., 2006).

Environmental noise was measured by a handheld noise level meter (Mod. Norsonic 118, Norsonic, Norway). At every SU we measured a time-averaged sound power level over a period of 15 s. The averaged equivalent sound power level (L_{eq}) was A-weighted by the instrument software and stored for post-processing. The noise meter was calibrated prior to each measurement.

3.2. Data handling

During post-processing OPC_{Mob} data was quality checked and averaged into 45 SU. Spatial averages of particle data were calculated for a coarse ($PM_{coarse} = PM_{10} - PM_1$) and a fine size fraction (PM_1). The mobile data was corrected for any 'time-trend' in urban background particulate matter during the measurements. Hence, OPC_{Can} data was first smoothed by a locally weighted least square regression approach (Cleveland, 1981). Afterwards the 'time-trend' during beginning and end of the mobile measurement was subtracted from OPC_{Mob}. Generally, this procedure had larger impact on the coarse fraction which exhibits a higher degree of time variation in comparison to PM_1. Corrected values deviated from raw data by on average 15% for PM_1 and 26% for PM_{coarse}.

4. Results and discussion

4.1. Meteorological conditions during the measurement period

Both measurement days were characterised by distinct differences in meteorological conditions (Table 1, Fig. 1).

Table 1
Daily averages of different meteorological quantities during day 1 and 2 (daily sum for precipitation, standard deviation in brackets)

Quantity	Day 1	Day 2
$u_{rooftop}$ [$m\,s^{-1}$]	3.11 (±0.84) *3.32 (±0.54)*	1.81 (±0.95) *1.96 (±0.66)*
$\phi_{rooftop}$ [°]	234 (±21) *225 (±45)*	123 (±51) *141 (±52)*
P [mm]	0 0	9.4 0
PM_{10} [$\mu g\,m^{-3}$]	50.6 (±23.3) *30.26 (±9.7)*	35.9 (±19.6) *36.59 (±22.3)*
PM_1 [$\mu g\,m^{-3}$]	33.7 (±19.0) *16.97 (±7.8)*	22.4 (±16.4) *21.08 (±17.7)*

Data for u, ϕ 35 m agl is from the rooftop sonic while the other data were measured at the container installed at B224. The values in italics indicate the averages during the measurement periods from 11 to 16.30 CET on day 1 and from 06.00 to 13.30 CET on day 2.