FIELD MEASUREMENTS WITHIN A QUARTER OF A CITY INCLUDING A STREET CANYON TO PRODUCE A VALIDATION DATA SET

Klaus Schäfer, Stefan Emeis, Herbert Hoffmann, Carsten Jahn
IMK-IFU, Forschungszentrum Karlsruhe GmbH, Garmisch-Partenkirchen

Wolfgang J. Müller, Bernd Heits, Dirk Haase, Wolf-Dieter Drunkenmölle
Niedersächsisches Landesamt für Ökologie (NLÖ), Hannover

Wolfgang Bächlin, Ingenieurbüro Dr. Lohmeyer GmbH & Co KG, Karlsruhe

Bernd Leitl, Frauke Pascheke, Heinke Schlünzen, Michael Schatzmann
Meteorologisches Institut, Universität Hamburg (UHH), Hamburg

Concept of measurements
Quality assurance / quality control activities
Interpretation of measurement results

Harmonisation 09, 02 June 2004
For the execution of the European Air Quality Framework Directive 96/62/EC and its daughter directives, 12-monthly air pollution maps with a spatial resolution of 200 m² are required.

Tools for this task with the necessary quality are not available up to now and were developed on the basis of numerical models (meso-/micro-scale model system M-SYS) in frame of the project VALIUM (AFO 2000 program).

Validation of this model system is necessary.

Continuous measurements of air pollutants inside a street canyon and in the surrounding area of 1 km x 1 km (Göttinger Straße in Hannover) were performed in addition to the routine NLÖ monitoring from beginning 2001 until end of 2003.

Investigations were combined with wind tunnel experiments at UHH.
Concept of measurements

Both air pollutants and meteorological parameters were measured by in situ instruments at four sites inside the street canyon (HRVS, HRV1, 2, 3) and at three sites in the surroundings (HRSW, HRV4, HRV5).

Path-averaging optical measurement techniques (two, sometimes three DOAS systems) were used continuously on the ground and on the roof of a building at the street.

Acoustic remote sensing of wind and turbulence profiles and mixing layer heights was performed by a SODAR south-west of Göttinger Straße in about 500 m distance, completed by a ceilometer and a Wind-Temperature-Radar.

Three intensive operational phases in different seasons with tracer SF$_6$ experiments and investigation of vertical gradients (path-averaging FTIR measurements for CO, DOAS measurements for NO$_2$) were executed.
Forschungszentrum Karlsruhe
in der Helmholtz-Gemeinschaft

9th Harmonisation Conference
Garmisch-Partenkirchen

SF6 line source and sampling sites
Annual mean of **PM10 and NO\textsubscript{2}** (year 2002) at all stations and number of days which exceed the boundary value 50 µg/m\textsuperscript{3} for PM10 and number of hours which exceed the boundary value 200 µg/m\textsuperscript{3} for NO\textsubscript{2} corresponding EC Daughter Directive 1999/30/EG

<table>
<thead>
<tr>
<th>Station</th>
<th>PM10 Annual mean (µg/m\textsuperscript{3})</th>
<th>PM10 Number of days &gt;50 µg/m\textsuperscript{3}</th>
<th>NO\textsubscript{2} Annual mean (µg/m\textsuperscript{3})</th>
<th>NO\textsubscript{2} Number of hours &gt;200 µg/m\textsuperscript{3}</th>
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</thead>
<tbody>
<tr>
<td>HRSW</td>
<td>29</td>
<td>42</td>
<td>25</td>
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</tr>
<tr>
<td>HRV1</td>
<td>43</td>
<td>102</td>
<td>58</td>
<td>0</td>
</tr>
<tr>
<td>HRV2</td>
<td>41</td>
<td>104</td>
<td>61</td>
<td>4</td>
</tr>
<tr>
<td>HRV3</td>
<td>40</td>
<td>90</td>
<td>53</td>
<td>3</td>
</tr>
<tr>
<td>HRV4</td>
<td>28</td>
<td>34</td>
<td>27</td>
<td>0</td>
</tr>
</tbody>
</table>
Intensive operational phases

- **Tracer 07 August 2002, 09:00 – 16:00 CET**
  - northerly winds (street parallel) up to 3 m/s

- **23 October 2002, 13:00 – 17:00 CET,**
  - westerly winds around 6 m/s

- **24 October 2002, 09:00 – 17:00 CET,**
  - westerly winds around 7 m/s

- **25 October 2002, 13:00 – 17:00 CET,**
  - southerly winds (street parallel) around 6 m/s

- **26 October 2002, 11:00 – 17:00 CET,**
  - westerly winds around 10 m/s

- **11 April 2003, 09:00 – 17:00 CET,**
  - westerly winds around 3 m/s

- **23 April 2003, 09:00 – 17:00 CET,**
  - easterly winds around 3 m/s,
  - probe sampling without tracer release also canister sampling analyses for about 50 VOC 2 USA in 3 m altitude in the street canyon
Quality assurance / quality control activities

Long-term comparison of different measurement methods (ISO 13752 Air quality)

Comparisons of different measurement systems during 36 hours before / after IOPs

Measurement systems of NLÖ are references
Long-term meteorological investigations

- Doppler-SODAR measurements with vertical resolution down to 12.5 m
- Comparison between wind data from SODAR and from roof-top station shows influence of surrounding buildings upon roof-top measurements
- Due to stable layering larger differences at night exist
Long-term NO$_2$ study of the path-integrated DOAS and in situ measurements at different stations from February 2001 until May 2002:

- Means of all simultaneous half-hourly means of the stations HRVS, HRV1, HRV2, HRV3: range from 30 up to 70 µg/m$^3$
- Correlation of the DOAS measurement with single and averaged in situ measurement results including about 16,000 up to 18,000 values

<table>
<thead>
<tr>
<th>Station</th>
<th>Correlated Station</th>
<th>Correlation</th>
<th>Standard Deviation $S_r$, [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Gradient</td>
<td>$R^2$</td>
</tr>
<tr>
<td>HRT1</td>
<td>HRVS</td>
<td>1.04</td>
<td>0.58</td>
</tr>
<tr>
<td>HRT1</td>
<td>HRV1</td>
<td>1.01</td>
<td>0.44</td>
</tr>
<tr>
<td>HRT1</td>
<td>HRV2</td>
<td>0.97</td>
<td>0.32</td>
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<tr>
<td>HRT1</td>
<td>HRV1/V2</td>
<td>1.00</td>
<td>0.46</td>
</tr>
<tr>
<td>HRT1</td>
<td>HRVS/V1/V2/V3</td>
<td>0.98</td>
<td>0.55</td>
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<tr>
<td>HRVS</td>
<td>HRV1</td>
<td>0.94</td>
<td>0.67</td>
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</tbody>
</table>
CORRELATION HRT1 (DOAS) - HRVS

y = 1.04x

R² = 0.58
Ozone comparison

- HRV4 and HRV5 with $R^2$ equal to 0.96, HRV4 and HRSW 0.95
- HRT1 and HRSW with $R^2$ equal to 0.63, long-term mean 44 µg/m³ at HRSW and 34 µg/m³ at HRT1
Comparison of different measurement systems

- CO and CH\textsubscript{4} by both FTIR spectrometers with HRV5 (in situ device TE48) at that site (homogeneous mixing)
- Weather stations HRV5 and HRV8 with HRSW

Differences in the order of measurement accuracy

Comparison of tracer SF\textsubscript{6} measurements

- SF\textsubscript{6} by FTIR spectrometry with probe sampling / laboratory analysis in the UHH wind tunnel (15 January 2002)
- Path-averaging of sample analyses results and FTIR

No systematic differences between path-averaging and probe sampling measurement techniques
30 July 2002, about 10:00 until 31 July 2002, about 23:00
26 October 2002, about 19:00 until 27 October 2002, about 24:00
Mixing layer height (MLH) from SODAR data

Minimum of two criteria: height of sharp decrease of echo intensity and height of elevated echo maximum

Frequency of occurrence (in % per 25 m height interval) in October 2001:
Comparison of SODAR measurements with data from a Wind-Temperature-RADAR (WTR) of IMK-ASF and a ceilometer of Vaisala (backscatter at 0.9 µm) for 09 May 2002.
Interpretation of measurement results

SODAR measurement results of urban boundary layer

• Missing daily course of wind speed 40 m above roof level like over rough forests
• Daytime increase of variance of vertical wind speed with height up to 200 to 350 m agl, in summer and autumn even at night
• Daytime increase in turbulence intensity in summer stronger than over level terrain

Vertical profiles and the diurnal course of the variance are coined by the thermal properties of the urban surface and cannot be found over other rough surfaces
Daily variation of wind speed and turbulence parameter $\sigma_w$ in different altitudes from SODAR measurements in February 2003 and August 2003
Results for representativity of measurement sites and methods

• Investigation of in situ and path-averaged measurements of SF$_6$

• In situ measurements are characterised by higher temporal variations - in correspondence with the high spatial variation of the in situ measurements along the measurement paths

• The highest differences between the results of both measurement techniques were found during street-parallel wind directions

• Spatial and temporal SF$_6$ distribution at ground level during a cross-wind episodes shows a rotor-like circulation pattern
Circulation patterns inside the street canyon – the rotor

• Air pollutant concentrations (CO, NO$_2$) measured in situ and path-averaged by FTIR and DOAS

• at both sides near the ground of the Göttinger Straße

• at roof-top level and near the ground at the western side of Göttinger Straße

• cross-wind air flow conditions
CO measurements (path-integrated and in situ)
weather data from HRSW
11 April 2003

- CO HRT10 (FTIR) [mg/m³]
- CO HRT11 (FTIR) [mg/m³]
- CO HRV1 [mg/m³]
- CO HRV3 [mg/m³]
- CO HRVS [mg/m³]
- Wind speed [m/s]
- Wind direction [Grad gN]
- Global radiation [W/m²]
CO measurements (path-integrated and in situ)
weather data from HRSW
11 April 2003
Correlation between MLH and air pollutants in the street canyon and at roof-top level

• About 36% of NO\textsubscript{x} concentration variations at roof-top level are caused by the MLH
• At ground-level stations no such correlation is found
• The correlation for PM10 and PM2.5 with MLH is not significant at both levels
• PM10 and PM2.5 concentrations at ground level inside the street canyon are higher than at roof-top level by a factor of 1.5 and 1.25 respectively whereas the factor is 6 for NO\textsubscript{x}
• Roof-top and background monitoring stations are representative for the urban boundary layer
ValiData - Database and pre-analysis tool

**Air monitoring data:** Gaseous components, particle matter PM10, PM2.5

**Meteorological data:** Temperature, pressure, humidity, solar radiation, wind and turbulence fields, mixing layer height

**Intensive operating phases data:** SF$_6$ tracer experiments, open-path measurement systems (DOAS, FTIR)

**Location of measurement sites:** Inside street canyon, above roof sites, background sites

**Description:** Measurement sites, measurement equipment, quality data

**Time:** Duration of continuous measurements: 2001 – 2003, minimum temporal resolution: 30 minutes, Central European Time
2.4 Measurement device information

Components of station HRSW

25 components at each >30 continuous and temporary sites

Description following EU Guidelines for Air Quality

Quality Assurance parameters for each component
4. Filterfunctions

- value limits
- day range
- time resolution

7.1 Analysis scatterplot

7.2 Analysis polardiagram