Air quality assessment in Bologna by an urban dispersion model

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NO² and PM₁₀ are critical pollutants in the urban area of Bologna

Bologna (380,000 inhabitants) is located in the Po Valley

- Porticoes: about 37 km
- Street Canyon: the ratio between the height of the buildings and the width of the streets is often 1.5-2
Domain of the simulation with ADMS - Urban

- Traffic flows on 213 road links: Bologna Council - ATC
- Splitting of vehicles into categories: ACI-PSC
- Emission factors: Corinair 2000 and TNO

Meteorological datasets: CALMET / LAMA

Urban Model: ADMS-Urban

Background concentrations: CHIMERE

Output: NO₂ and PM₁₀
- values required by EU directives
- outdoor concentrations used to calculate population exposure
RUN

- **1 year period**: April 2003 ÷ March 2004

- **Summer pollution episode**: 10 – 16 June 2003 with max observed value $[O_3] = 250 \, \mu g/m^3$, 11/06/03

- **Winter pollution episode**: 12 – 19 February 2004 with max observed value $[PM_{10}] = 164 \, \mu g/m^3$, 26/02/04

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**Emissions for road sources** (213 road links)

- Cars and duty vehicles (source Bologna Council)
- Buses were considered for each road link (source ATC)
- Mopeds and Motorbikes percentages inside ZTL 73% (source PSC BO), outside ZTL 17%

**Vehicle categories**
from ACI Bologna (source Copert 2002)

**Emissions Factors**
Corinair 2000 for CO, NOx, NMVOC
+ EF exhaust and non exhaust for $PM_{10}$, TNO (95)
Emissions from road sources in S. Felice domain

<table>
<thead>
<tr>
<th></th>
<th>CO t/y</th>
<th>NOx t/y</th>
<th>VOC t/y</th>
<th>Benzene 3% VOC t/y</th>
<th>PM$_{10}$ t/y</th>
<th>NH$_3$ t/y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road sources</td>
<td>2352</td>
<td>166</td>
<td>370</td>
<td>11</td>
<td>16</td>
<td>4</td>
</tr>
</tbody>
</table>

Road sources daily pattern
(source PSC-BO)

Two different meteorological datasets

- CALMET: mass consistent meteorological pre-processor which uses the meteorological data taken from surface and upper air stations (northern Italy)

- LAMA: non-hydrostatic meteorological model Lokal Modell with a continuous assimilation of surface and upper air stations (Italian peninsula, the Alps and part of the Mediterranean Sea)
Background hourly concentrations: CHIMERE

Eulerian photochemical–transport model with the aerosol module (from Prev’air – INERIS www.prevair.org)

Continental CHIMERE: 50 km horizontal resolution

ADMS-Urban: 50 m horizontal resolution

Urban model results for 1 year period
(April 2003 - March 2004)

<table>
<thead>
<tr>
<th>S. Felice receptor point</th>
<th>NO$_2$ annual mean µg/m$^3$</th>
<th>NO$_2$ 18$^{th}$ highest hourly value µg/m$^3$</th>
<th>PM$_{10}$ annual mean µg/m$^3$</th>
<th>PM$_{10}$ 35$^{th}$ highest daily value µg/m$^3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>simulated</td>
<td>68</td>
<td>195</td>
<td>46</td>
<td>68</td>
</tr>
<tr>
<td>observed</td>
<td>52</td>
<td>123</td>
<td>42</td>
<td>73</td>
</tr>
</tbody>
</table>
## Urban model results for the pollution episodes (in square brackets results obtained with LAMA meteorological input)

<table>
<thead>
<tr>
<th>Averaging period</th>
<th>$\text{NO}_2$ simulated period mean µg/m³</th>
<th>$\text{NO}_2$ observed period mean µg/m³</th>
<th>$\text{PM}_{10}$ simulated period mean µg/m³</th>
<th>$\text{PM}_{10}$ observed period mean µg/m³</th>
</tr>
</thead>
</table>

### NO$_2$ : 1 hour average

**winter episode (12 -19 February 2004)**

**summer episode (10 -16 June 2003)**
PM$_{10}$ daily average for the period (April 2003–March 2004)

Spatial variation map of simulated annual average for PM$_{10}$ (April 2003–March 2004)
Spatial variation map of simulated 35th highest daily value for PM$_{10}$ (April03-March04)

75 µg/m$^3$ observed

Spatial variation map of simulated annual average for NO$_2$ (April03-March04)

50 µg/m$^3$ observed
Spatial variation map of simulated 18th highest hourly value for NO₂ (April03-March04)

Traffic flows

Monitoring Station

123 µg/m³ observed

NO₂ outdoor concentration levels in 3,333 children houses + 2 schools

- Monitoring station
- Annual average NO₂ ug/m³
- School outdoor annual average NO₂ ug/m³
- Residential outdoor annual average NO₂ ug/m³

Traffic flows

Domain

0 1 2 Kilometers

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We will identify mean population (children) fractional time spent in the different micro-environment. We will use only three micro-environments:

- **Residential indoor**
- **School indoor**
- **Traffic**

**Residential Indoor** = Derived from the residential outdoor concentrations applying the EXPOLIS infiltration factors

**School Indoor** = Derived from the school outdoor concentrations applying the EXPOLIS infiltration factors

**Traffic** = Derived from Italian and European studies as function of the mean concentration in the streets of the interested area
Population exposure (2)

Annual Mean Children Exposure

= Residential Indoor \times F_{RI} + School Indoor \times F_{SI} + Traffic \times F_T

(a weighted mean)

F_{RI} = Fractional time spent in Residential Indoor
F_{SI} = Fractional time spent in School Indoor
F_T = Fractional time spent in Traffic

Conclusions

- Urban model, combined with the regional chemical transport model, performs quite well to assess long term averages of PM_{10} and NO_2
- Peak pollutions are poorly reproduced
- Modelling integrated system in the analysis of present and future scenarios can be a valuable support for the local administrations in applying EU directives on air quality
- Methodology for population exposure estimates, based on infiltration factors, is now in progress.
Buses were considered for each road link (source ATC)
**CALMET**

- Wind speed (m/s)
- Wind direction (°)
- Reciprocal of the Monin-Obukhov length (m⁻¹)
- Mixing height (m)
- Near surface temperature (°C)
- Surface albedo
  
  +

- Incoming solar radiation incidente (W/m²)
  (local station Sasso Marconi)

**LAMA**

- Wind speed (m/s)
- Wind direction (°)
- Near surface temperature (°C)

  +

- Incoming solar radiation incidente (W/m²)
  (local station Sasso Marconi)

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**Focus on Children – Why?**

1) Children have increasing importance in public health evaluations.

2) Children’s mobility is usually short-radius. Bologna high-resolution outdoor AQ simulations are referred to a small area of the city and so short-radius mobility could be a great advantage. Furthermore, we can estimate a simplified but realistic time-activity table without surveys.

3) Mobility surveys on children could be more easily done in the schools of the area. In the future, monitoring data could also be collected inside and outside next to the school.
Time series of CALMET mixing height and NO$_2$ concentration in the summer episode

![Graph showing the time series of CALMET mixing height and NO$_2$ concentration in the summer episode. The graph includes data points for each day from 10/06/2003 to 16/06/2003 at 8:00 p.m.](image-url)