AIR QUALITY ASSESSMENT IN CRAIOVA URBAN AREA*

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Received August 23, 2011

Abstract. The development of society and urban agglomerations that are major resource consumers and sizable waste and pollutant generators represents a current issue that requires an adequate management. The paper presents an air quality study that combines the monitoring results with the dispersion modeled ones considering an urban agglomeration located in South-West Romania. Different types of pollutant sources are included in the studied area, from large combustion plants to intense traffic. For the air quality analysis the contributions of all sources in the area have been considered. The results of the air pollutants dispersion mathematical modeling have been compared with the measured values and also there have been assessed the performances of the OML (Operationelle Meteorologiske Luftkvalitetsmodeller) model applied.

Key words: air quality, dispersion model, urban pollution.

1. INTRODUCTION

Air pollution in urban or highly industrialized areas represents an important issue due mainly to the negative effects on the human health and on the quality of the environmental components (air, water, soil, vegetation).

A general characteristic of the urban agglomerations is represented by the location nearby of some highly pollutant industries thus we can associate the “hot spot” concept in air quality terms with the most of the urban areas in the world.

This pattern is obviously present in Romanian large cities and urban agglomerations where the specific institutional, domestic and traffic activities and the ones related to the pollutant industry lead to systematic exceeding of the air quality limit values imposed by the national regulations.

* Paper presented at the Annual Scientific Session of Faculty of Physics, University of Bucharest, June 17, 2011, Bucharest-Magurele, Romania.
Considering these arguments, the air quality assessment in those “hot spots” must be recurrent in order to improve the air quality where the limits provided are exceeded or to maintain it where the values are under the limits and we must take the necessary measures in order to limit the effects on the human health. Studies of air quality in urban areas were made for different types of sources and areas in Romania [1, 2, 3, 4]. This kind of studies can be used to study indoor pollution [5].

This paper shows a case study on local air quality assessment (the Craiova urban agglomeration), one of Romania’s “hot spot” using both analysis of the air quality national monitoring network measured data and pollutant air dispersion mathematical modeling.

The first part of the paper will describe the monitoring network and the pollutant concentrations values recorded in the network stations. Also, there will be presented the air pollutants emissions inventory associated with the studied area, there will be applied the OML dispersion model in order to show the pollutants concentration spatial distribution and to identify the areas that present an exceeding of the limit values imposed by the legislation.

In the second part of the paper, the dispersion model performances will be assessed by comparison of the model’s results with the measured values obtained in the monitoring stations. The best correlation coefficients (over 0.3) have been obtained for the urban traffic monitoring stations that show the influence of the low height sources (traffic, residential heating).

As well, the atmospheric pollutants emissions inventories associated with the studied area will be presented. The dispersion model OML will be used for emphasizing spatial distribution of pollutants concentrations and for identification of areas where there is an exceeding of the legislation limits.

2. DATA AND METHODS USED

Air quality assessment in the Craiova urban agglomeration was made by the analysis of the concentration values measured at the air quality monitoring stations and those calculated by means of the mathematical modeling, for year 2006.

In order to assess the air quality by mathematical modeling in the Craiova urban agglomeration the OML model has been run using as input data the emissions inventory for all the identified sources types (point, surface, traffic) and meteorological data extracted from the TAPM prediction [6].

The analysis has been carried out for the pollutants NO₂, SO₂ and PM₁₀ monitored in the 5 automatic air quality monitoring stations.
2.1. ANALYSIS OF AIR QUALITY MONITORING DATA FOR THE URBAN AREA

The air quality monitoring network in the Craiova urban area contains 5 automatic stations:

*Calea Bucuresti station (CRA1)* – traffic station, the chosen location being the most clustered considering traffic;

*City Hall station (CRA2)* – urban background station, situated in an unexposed area directly to traffic and industry;

*Billa station (CRA3)* – mixed station – industrial and traffic - location being under the influence of the two power stations, the chemical plant and the high traffic area in the western part of the city;

*Isalnita station (CRA4)* – industrial station, situated in a suburban area under the influence of the chemical plant and the local power plant;

*Breasta station (CRA5)* – regional background station located far away of all the agglomeration major pollution sources.

The location of the air quality monitoring stations is showed in Fig. 1.

![Fig. 1 – Air quality monitoring stations location in Craiova urban agglomeration.](image-url)
The air quality data for 2006 provided by the stations [7, 8] in Craiova have been assessed by comparison with the limits provided by the Ministry Order 592 from 2002 (LV: Limit Value provided by this order expressed in [µg/m³]). Table 1 presents summary results of measurements at monitoring stations.

### Table 1

Measured values in the monitoring network stations synthesis

<table>
<thead>
<tr>
<th>Station</th>
<th>Pollutant Type</th>
<th>Number of data</th>
<th>Annual Concentration [µg/m³]</th>
<th>Exceeding frequency/(number of exceeding) LV according to 592/2002 M.O.</th>
<th>Observations regarding averaging period considered for the exceeding calculations</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRA1</td>
<td>SO₂</td>
<td>6552</td>
<td>19</td>
<td>0.15%/(9)</td>
<td>1 h average</td>
</tr>
<tr>
<td></td>
<td>NO₂</td>
<td>7296</td>
<td>32</td>
<td>0%/0)</td>
<td>1 h average</td>
</tr>
<tr>
<td></td>
<td>PM₉₀</td>
<td>304</td>
<td>65</td>
<td>65%/198</td>
<td>24 h average</td>
</tr>
<tr>
<td>CRA2</td>
<td>SO₂</td>
<td>7423</td>
<td>22</td>
<td>0.13%/10</td>
<td>1 h average</td>
</tr>
<tr>
<td></td>
<td>NO₂</td>
<td>7690</td>
<td>27</td>
<td>0.01%/(1)</td>
<td>1 h average</td>
</tr>
<tr>
<td></td>
<td>PM₉₀</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CRA3</td>
<td>SO₂</td>
<td>8760</td>
<td>18</td>
<td>0.15%/10</td>
<td>1 h average</td>
</tr>
<tr>
<td></td>
<td>NO₂</td>
<td>8760</td>
<td>24</td>
<td>0%/0)</td>
<td>1 h average</td>
</tr>
<tr>
<td></td>
<td>PM₉₀</td>
<td>243</td>
<td>66</td>
<td>51%/124</td>
<td>24 h average</td>
</tr>
<tr>
<td>CRA4</td>
<td>SO₂</td>
<td>4930</td>
<td>25</td>
<td>0.36%/18</td>
<td>1 h average</td>
</tr>
<tr>
<td></td>
<td>NO₂</td>
<td>4180</td>
<td>19.71</td>
<td>0%/0)</td>
<td>1 h average</td>
</tr>
<tr>
<td></td>
<td>PM₉₀</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CRA5</td>
<td>SO₂</td>
<td>7272</td>
<td>18</td>
<td>0.03%/2)</td>
<td>1 h average</td>
</tr>
<tr>
<td></td>
<td>NO₂</td>
<td>7272</td>
<td>14</td>
<td>0%/0)</td>
<td>1 h average</td>
</tr>
<tr>
<td></td>
<td>PM₉₀</td>
<td>6528</td>
<td>48</td>
<td>36%/98</td>
<td>24 h average</td>
</tr>
</tbody>
</table>

**Sulphur dioxide concentrations.** For SO₂, an air pollutant whose major source is represented by the coal combustion emissions from the two thermal power stations located in the area, the 1h averages have reached and exceeded in some cases the limit value in all stations (as during December 8-9 period when there have been recorded values over 350 µg/m³ in all the agglomeration stations). There have not been recorded exceeding of the pollutant alert threshold (exceeding 500 µg/m³ three consecutive hours).

**Nitrogen dioxide concentrations.** As for NO₂, the highest average values are recorded by the traffic and urban background monitoring stations. The limit value has not been exceeded, the recorded 1h maximum values being around 150 µg/m³ in all the stations, except the one located at the City Hall (CRA2) where the limit value has been exceeded, the recorded maximum value being 213 µg/m³. Also, the limit value for the annual average has not been exceeded for all the monitoring stations.
Suspended particulate (PM$_{10}$). For the suspended particulate PM$_{10}$ that are continuously monitored in the traffic (CRA1, CRA3) and regional background (CRA5) stations, we can see exceeding of the annual average limit value in all the stations. The limit value for the 24 hours average has often been exceeded in the traffic (CRA1) and Billa (CRA3) monitoring stations. The major particulate emission sources in the Craiova urban agglomeration are represented by the combustion processes from the thermal power stations and the domestic heating, the power stations’ ash dumps, traffic and construction sites.

2.2. MODELS USED FOR THE AIR QUALITY ASSESSMENT

2.2.1. The OML model

OML (“Operationelle Meteorologiske Luftkvalitetsmodeller” meaning Operational Meteorological Air Quality Models) is a Gaussian model designed in the ’80 by the Environmental Research National Institute of Denmark for the air assessment in different areas. The model became operational in the ’90 and it is used on a large scale in scientific world dealing with the air pollution research. The model can be used both for urban and rural areas, on a 20 km radius.

The model has been designed and revised in 2005–2006 [9] to work for most of the possible meteorological conditions, to avoid dispersion phenomenon model discontinuities, become applicable for operational purposes. The OML model is described in detail by Berkowicz [10] and Olesen [11] and tested on several experimental data sets [12, 13].

Compared with other Gaussian models, OML introduces new dispersion parameters appraisal methods as continuous functions that depend on physical parameters of the boundary layer, new pollutant plume rise calculus methods, boundary layer penetration modeling, new horizontal dispersion calculus methods for very small wind speeds or for systematical wind direction changes, new building effect simulation methods. The new OML version includes a simple NO$_x$-NO$_2$-O$_3$ photochemical chart.

In order to run the model, meteorological and emission data were needed. The meteorological data from the air quality monitoring stations could not be used by the processor of the meteorological model because they do not provide enough parameters and, on the other hand, the data hourly coverage is less than half of the values needed. Besides, in the designated area vertical profile radiosampling does not exist.

Consequently, in order to generate the needed data, the surface and profile data extraction for 2006, was done by running the TAPM model in “downscaling” mode. TAPM is a dynamic meteorological mesoscale model developed by CSIRO (Australia).
2.2.2. The TAPM model

The meteorological component of TAPM [14] is a prediction model, incompressible, non-hydrostatic, with primitive equation solved in terrain-following coordinate system.

The model solves the momentum equations for horizontal wind components, the incompressible continuity equation for the vertical velocity and scalar equations for potential virtual temperature, specific humidity of water vapours, cloud water and rain water.

The solution for the wind field, potential virtual temperature and specific humidity is sequential assimilated through their synoptic values provided in the model database.

Detailed description of the TAPM model and its performance is provided by Hurley elsewhere [15, 16, 17, 18].

The meteorological data used by TAPM as input data are provided by a synoptic scale analysis model (LAPS – Limited Area Prediction System) and consists in six hours interspaced modeled data on a geographical network – longitude/latitude with a 0,75 degree resolution (app. 75 km) that covers the North Hemisphere.

Terrain data is provided by US Geological Survey, Earth Resources Observation Systems (EROS) Data Centre Distributed Active Archive Centre (EDC DAAC) with a latitude resolution of 30 seconds (about 1 km).

US Geological Survey also provides terrain use data with the same resolution.

2.3. METEOROLOGICAL DATA USED IN AIR POLLUTANT DISPERSION MODELING

The necessary data for running the meteorological processor [19] have been extracted from the resulting files of the TAPM run in the central point of OML calculation grid. For this, an external application has been developed that interfaces TAPM with the OML’s meteorological processor.

Wind data extracted from the TAPM meteorological module for 2006 confirm the wind frequency distribution by directions (wind rose) being similar with the ones generated from measurement data in the precedent years.

Fig. 2 – 2006 wind rose generated using TAPM extracted data.
2.4. EMISSION DATA USED IN AIR POLLUTANT DISPERSION MODELING

Emission data comes from the emission inventory done by the Craiova Environment Protection Agency for the air quality assessment in the agglomeration. This inventory is a disaggregated one that is every identified pollution source is described by its emission and physical parameters. There have been considered point, surface and linear sources.

The emission inventory for 2006 on different types of sources and activities is shown in Table 2.

<table>
<thead>
<tr>
<th>Source type</th>
<th>SO$_2$ [t/yr]</th>
<th>NO$_x$ [t/yr]</th>
<th>PM$_{10}$ [t/yr]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrocentrale I Isalnita power plant</td>
<td>24465.50</td>
<td>9198.67</td>
<td>2418.25</td>
</tr>
<tr>
<td>Electrocentrale Craiova II power plant</td>
<td>18427.79</td>
<td>6645.12</td>
<td>2046.33</td>
</tr>
<tr>
<td>PETROM Craiova DOLICHIM fertilizer plant</td>
<td>5.93</td>
<td>2277.60</td>
<td>4241.09</td>
</tr>
<tr>
<td>Other industrial sources</td>
<td>8.24</td>
<td>89.33</td>
<td>12</td>
</tr>
<tr>
<td>Industrial dump</td>
<td>0.00</td>
<td>0.00</td>
<td>201.95</td>
</tr>
<tr>
<td>Area sources – residential heating</td>
<td>95.30</td>
<td>105.63</td>
<td>628.63</td>
</tr>
<tr>
<td>Traffic</td>
<td>35.73</td>
<td>1072.02</td>
<td>57.19</td>
</tr>
</tbody>
</table>

There have been identified 99 point pollution sources from different industrial and commercial activities in the agglomeration.

![Fig. 3 – Spatial distribution of emission point sources (stacks) identified in Craiova agglomeration.](image)
Air quality assessment in Craiova urban area

Surface and traffic emission sources have been distributed in the calculation grid cells using geoprocessing routines on the developed database in GIS advanced analysis.

In the modeling process a calculation grid of $18 \times 20$ km on a 500 m step has been used.

3. RESULTS AND DISCUSSIONS

3.1. AIR POLLUTANT DISPERSION MATHEMATICAL MODELING RESULTS

The modeling results are graphically displayed as dispersion maps (spatial distributions of the concentration fields) that show isoconcentrations curves for the four pollutants considered and for all the average periods (1h, 24h, year) that are associated with limit values, overlapped on the geographical map of the area.
It must be stated that, because the air quality regulations allow a number of exceeded values for some pollutants, it is justified the analysis of both maximum absolute values and of the values obtained by eliminating a number of maximum values (as the 19th maximum value for the NO$_2$ represents the maximum value obtained after the elimination of the first 18 maximum values allowed) [7, 8].

Figures 5–13 show the considered pollutants dispersion maps for different average periods (1h, 24h, year).

We might conclude that the NO$_2$ modeled values exceed the limit value on short term (1 h), the spatial distribution showing the maximum values around the intense traffic roads and in the central part of Craiova. High values have been recorded also in the air quality monitoring stations: the traffic station (CRA1 Calea București) and the station in the central area (CRA2 City Hall).

![Fig. 5 – Modeled NO$_2$ maximum hourly concentrations [µg/m$^3$].](image-url)
Fig. 6 – The 19th maximum hourly value for the modeled NO$_2$ concentrations [µg/m$^3$].

Fig. 7 – Modeled NO$_2$ annual average concentration [µg/m$^3$].
Fig. 8 – The 36th maximum daily value for the modeled PM$_{10}$ concentrations [µg/m$^3$].

Fig. 9 – Modeled PM$_{10}$ annual average concentration [µg/m$^3$].
Air quality assessment in Craiova urban area

Fig. 10 – Modeled SO₂ maximum hourly concentration [µg/m³]. The white circles show the position of the main two SO₂ emission sources: the CET II thermal power stations and Isalnita.

Fig. 11 – The 25th maximum hourly value for the modeled SO₂ concentrations [µg/m³].
Fig. 12 – The 4th maximum daily value for the modeled SO2 concentrations [µg/m³].

Fig. 13 – Modeled SO2 annual average concentration [µg/m³].
For SO₂ annual average concentration provided by the model we can see that the limit value for the ecosystems protection (20 µg/m³) has not been exceeded in any of the modeling grid’s points, the values being rather small compared to the limit value. This fact is not confirmed by the monitoring data that show high values for the annual average that exceed the limit value for the City Hall (CRA2) and Isalnita (CRA4) stations.

This disagreement can be explained by the fact that the model did not include the background SO₂ concentration. Due to its geographical position, Craiova is affected by the regional pollutant transport, especially SO₂ from the big thermal power plants situated in Valea Jiului (Rovinari, Turceni) and in Mehedinti County (Halanca). This fact has been proven in national air quality assessment studies using modeling.

Figure 14 shows SO₂ concentration spatial distribution, pointing at the transport process on the East-West directions of the SO₂ masses emitted by the big thermal power plants that use coal as fuel. We can even quantify an induced value of the background concentration in Craiova area of 12–15 µg/m³ (position marked with square).

As for suspended particulate PM₁₀, the model shows limit value exceeding and allowed number of exceeding breach (the 36th value exceeds the limit value). This exceeding takes place on large areas covering the whole Craiova urban area and the Isalnita industrial platform.
These high values of the particulate concentration are due mainly to the residential heating activities (wood burning in stoves), to the traffic and the industrial ash dumps in the Isalnita industrial platform.

Particulate concentration high values that often exceed the limit value for the daily average are confirmed by the recorded values in the Calea București (CRA1), Billa (CRA3) and Breasta (CRA5) monitoring stations.

Similar pollutant concentration distribution profiles with limit value exceeding in the above mentioned areas have been obtained from the modeling process for the annual average.

3.2. MODELED AND MEASURED DATA COMPARISON

In order to assess the OML performances for the air quality diagnosis, BOOT statistical analysis was used on the hourly data temporal series extracted from the corresponding points of the automatic monitoring stations location. Based on this analysis there are a series of drawn conclusions.

The analysis has been made for every pollutant using monitoring data from all the stations, the missing values from the series being eliminated.

The results of the BOOT model [21] are presented in Tables 3, 4 and 5.

**Table 3**

<table>
<thead>
<tr>
<th>Station</th>
<th>Measured/ modeled</th>
<th>avg [µg/m³]</th>
<th>sigma [µg/m³]</th>
<th>bias [µg/m³]</th>
<th>mse</th>
<th>cor</th>
<th>fa2</th>
<th>fb</th>
<th>fs</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRA1</td>
<td>Measured</td>
<td>30.1</td>
<td>19.9</td>
<td>0.00</td>
<td>0.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Modeled</td>
<td>29.7</td>
<td>33.8</td>
<td>0.38</td>
<td>1.41</td>
<td>0.205</td>
<td>0.525</td>
<td>0.013</td>
<td>-0.516</td>
<td></td>
</tr>
<tr>
<td>CRA2</td>
<td>Measured</td>
<td>28.8</td>
<td>20.3</td>
<td>0.00</td>
<td>0.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Modeled</td>
<td>35.0</td>
<td>40.5</td>
<td>-6.17</td>
<td>1.81</td>
<td>0.161</td>
<td>0.521</td>
<td>-0.193</td>
<td>-0.666</td>
<td></td>
</tr>
<tr>
<td>CRA3</td>
<td>Measured</td>
<td>25.3</td>
<td>17.9</td>
<td>0.00</td>
<td>0.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Modeled</td>
<td>18.7</td>
<td>20.6</td>
<td>6.60</td>
<td>1.42</td>
<td>0.152</td>
<td>0.419</td>
<td>0.299</td>
<td>-0.137</td>
<td></td>
</tr>
<tr>
<td>CRA4</td>
<td>Measured</td>
<td>19.7</td>
<td>16.1</td>
<td>0.00</td>
<td>0.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Modeled</td>
<td>7.3</td>
<td>11.6</td>
<td>12.46</td>
<td>3.24</td>
<td>0.227</td>
<td>0.203</td>
<td>0.923</td>
<td>0.326</td>
<td></td>
</tr>
<tr>
<td>CRA5</td>
<td>Measured</td>
<td>14.0</td>
<td>12.3</td>
<td>0.00</td>
<td>0.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Modeled</td>
<td>6.7</td>
<td>11.7</td>
<td>7.31</td>
<td>3.21</td>
<td>0.141</td>
<td>0.219</td>
<td>0.705</td>
<td>0.050</td>
<td></td>
</tr>
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</table>
Table 4
BOOT statistical results on the OML dispersion model – SO2

<table>
<thead>
<tr>
<th>Station</th>
<th>Measured/modeled</th>
<th>avg [µg/m³]</th>
<th>sigma [µg/m³]</th>
<th>bias [µg/m³]</th>
<th>nmse</th>
<th>cor</th>
<th>fa2</th>
<th>fb</th>
<th>fs</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRA1</td>
<td>Measured</td>
<td>18.8</td>
<td>31.3</td>
<td>0.00</td>
<td>0.00</td>
<td>1.000</td>
<td>1.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Model</td>
<td>8.3</td>
<td>12.3</td>
<td>10.45</td>
<td>7.67</td>
<td>0.054</td>
<td>0.313</td>
<td>0.771</td>
<td>0.874</td>
</tr>
<tr>
<td>CRA2</td>
<td>Measured</td>
<td>22.3</td>
<td>31.3</td>
<td>0.00</td>
<td>0.00</td>
<td>1.000</td>
<td>1.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Model</td>
<td>9.0</td>
<td>14.8</td>
<td>13.34</td>
<td>6.51</td>
<td>0.069</td>
<td>0.304</td>
<td>0.851</td>
<td>0.716</td>
</tr>
<tr>
<td>CRA3</td>
<td>Measured</td>
<td>18.8</td>
<td>28.4</td>
<td>0.00</td>
<td>0.00</td>
<td>1.000</td>
<td>1.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Model</td>
<td>8.5</td>
<td>17.9</td>
<td>10.33</td>
<td>7.54</td>
<td>0.033</td>
<td>0.321</td>
<td>0.756</td>
<td>0.452</td>
</tr>
<tr>
<td>CRA4</td>
<td>Measured</td>
<td>25.2</td>
<td>44.1</td>
<td>0.00</td>
<td>0.00</td>
<td>1.000</td>
<td>1.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Model</td>
<td>3.3</td>
<td>14.7</td>
<td>21.89</td>
<td>30.58</td>
<td>0.054</td>
<td>0.047</td>
<td>1.533</td>
<td>0.999</td>
</tr>
<tr>
<td>CRA5</td>
<td>Measured</td>
<td>19.8</td>
<td>29.9</td>
<td>16.36</td>
<td>19.93</td>
<td>0.038</td>
<td>0.048</td>
<td>1.414</td>
<td>0.700</td>
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<tr>
<td></td>
<td>Model</td>
<td>3.4</td>
<td>14.4</td>
<td>21.71</td>
<td>19.71</td>
<td>0.038</td>
<td>0.048</td>
<td>1.414</td>
<td>0.700</td>
</tr>
</tbody>
</table>

The heather abbreviation mean:
- avg = mean of measured/modeled data [µg/m³]
- sigma = standard deviation [µg/m³]
- bias = simulated concentrations mean error [µg/m³]
- nmse = normalized mean square error
- cor = correlation coefficient
- fa2 = fraction of predictions within a factor of two of observations
- fb = fractional bias
- fs = normalized standard deviation.

Table 5
BOOT statistical results on the OML dispersion model – PM10

<table>
<thead>
<tr>
<th>Station</th>
<th>Measured/modeled</th>
<th>avg [µg/m³]</th>
<th>sigma [µg/m³]</th>
<th>bias [µg/m³]</th>
<th>nmse</th>
<th>cor</th>
<th>fa2</th>
<th>fb</th>
<th>fs</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRA1</td>
<td>Measured</td>
<td>66.6</td>
<td>46.1</td>
<td>0.00</td>
<td>0.00</td>
<td>1.000</td>
<td>1.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Model</td>
<td>56.5</td>
<td>35.9</td>
<td>10.07</td>
<td>0.65</td>
<td>0.325</td>
<td>0.660</td>
<td>0.164</td>
<td>0.251</td>
</tr>
<tr>
<td>CRA3</td>
<td>Measured</td>
<td>68.8</td>
<td>51.4</td>
<td>0.00</td>
<td>0.00</td>
<td>1.000</td>
<td>1.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Model</td>
<td>49.1</td>
<td>30.4</td>
<td>19.71</td>
<td>0.83</td>
<td>0.370</td>
<td>0.651</td>
<td>0.334</td>
<td>0.512</td>
</tr>
<tr>
<td>CRA5</td>
<td>Measured</td>
<td>50.4</td>
<td>40.7</td>
<td>0.00</td>
<td>0.00</td>
<td>1.000</td>
<td>1.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Model</td>
<td>28.7</td>
<td>14.8</td>
<td>21.71</td>
<td>1.48</td>
<td>0.175</td>
<td>0.636</td>
<td>0.550</td>
<td>0.930</td>
</tr>
</tbody>
</table>
The model’s performance can be assessed by examining the different statistical parameters. Although those are not comparable with the standard values that qualify as very good or good performance model, we can still analyze the values for different parameters and determine the best results of the model:

- fractional bias – fb (wanted <0.2)
- normalized mean square error – nmse (wanted <1)
- fraction of predictions within a factor of two of observations – fa2 (wanted >0.5)
- correlation coefficient – cor (wanted >0.2).

### 3.3. ANALYSIS OF MODEL PERFORMANCE FOR NO₂

The performance criteria stated above are:

- fb (<0.2) – CRA1
- nmse (<1) – this value was not obtained
- fa2 (>0.5) – CRA1, CRA2
- cor (>0.2) – CRA1, CRA4.

For NO₂ we can conclude that the model reflects well the reality for the urban stations (the traffic and urban background stations) where the modeled annual average values are very close to the measured ones and a very high percentage (over 50%) of the modeled 1h average values are in a ratio factor between 0.5 and 2 with the measured ones.

Thus, the model provides good results for the dispersion of the pollutants from surface sources – traffic and residential activities (the ones mainly responsible for the urban pollution with NO₂).

### 3.4. ANALYSIS OF MODEL PERFORMANCE FOR SO₂

For the SO₂ the statistical analysis shows weak performances of the model for most of the parameters. As shown before, due to a background pollution generated by sources located far away from the studied area and ones that were not included in the model run on an urban scale, it is hard to distinguish in a given moment of time the background input from the one of the sources in the considered area.

If we consider a consistent background input of 12–15 µg/m³ we can see a nearness of the modeled annual averages with the measured ones. This simple contributions addition does not solve the problem of the others statistical parameters like the correlations on an hourly basis. Besides that, the major SO₂ sources are point ones and the correlations on an hourly basis between the model and measured values are generally extremely hard to accomplish. All three ingredients that the model includes (transport through wind speed and direction, parameterized turbulence and source emission) require a perfect match to reality.
3.5. ANALYSIS OF MODEL PERFORMANCE FOR PM$_{10}$

The performance criteria stated above are:

- $fb (<0.2) – CRA1$
- $nmse (<1) –$ this value was not obtained
- $fa2 (>0.5) – CRA1, CRA3$
- $cor (>0.2) – CRA1, CRA3$.

For PM$_{10}$ we can see the same good behavior of the model for the urban stations (the traffic and the Billa industrial station) where the modeled annual averages are very close to the measured value and a very high percentage of the modeled 1h averages are in a ratio factor between 0.5 and 2 with the measured ones (over 65% and 83%). The correlation coefficients have values of 0.325 and 0.370.

Thus, we can state that the model provides also for PM$_{10}$ good results for the dispersion due to surface-traffic and residential activities sources.

4. CONCLUSIONS

By using the BOOT method along its quality parameters it has shown that the TAPM model provided relevant modeled meteorological data as input for the dispersion model in the area where the pollution monitoring stations are located. As for the OML model, it has rightly estimated the values of the pollutant concentration in the urban area.

The analysis of the dispersion model performances has been carried out using the BOOT statistical model on the data series. The statistical model showed a good behavior for the pollutants NO$_2$ and PM$_{10}$ and an unsatisfactory behavior for the SO$_2$. Thus, we can conclude that the model has a better behavior for the surface and traffic sources (with emission close to the ground) and a less satisfactory behavior for the point sources with high emission heights. That fact leads to the conclusion that for the dispersion modeling of the pollutants coming from sources like that, the input data (meteorological and emission) quality on an hourly level must be very accurate. Moreover, in the studied area has been identified a significant background pollution that has been systematically detected in the monitoring stations without the possibility of use for the model. This phenomenon has been rigorously explained by the authors.

As a general conclusion, we can say that in order to perform an air quality assessment as accurate as it may be for a designated area there must be used efficiently and combined the two investigation methods: on one hand, the monitoring with its benefits and drawbacks (high maintenance costs, limited spatial representativity, intricate quality assurance procedures) and on the other hand, pollutant dispersion modeling with its benefits and limitations (assuring a continuous pollution representation, lower costs, input of high quality data).
Acknowledgements. One author, G.GRIGORAS, was supported by the strategic grant POSDRU/88/1.5/S/56668 – priority axis no. 1, cofinanced by the European Social Found within the Sectorial Operational Program for Human Resources Development 2007–2013.

REFERENCES

2. C.G. Popescu, Relation between vehicle traffic and heavy metals content from the particulate matters, Romanian Reports In Physics, 63, 471–482 (2011).
4. C. Balaceanu, S. Stefan, The assessement of the TSP particulate matter in the urban ambient air, Romanian Reports in Physics, 56, 757-768 (2004).
5. Gilda Rusu-Zagar, Luminita Filip, Sabina Stefan, Raluca Stepa, Model For Control Of Indoor Air Quality In An Industrial Environment, Romanian Reports in Physics, 63, 196–207 (2011).


