International Congress on Environmental Modelling and Software

2nd International Congress on Environmental Modelling and Software - Osnabrück, Germany - June 2004

Jul 1st, 12:00 AM

Air Quality Modelling in Latvia

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Abstract: As a potential member country to the European Union (EU), Latvia has harmonized the national environmental legislation with the EU air quality (AQ) legislation. The AQ management system in the country is being developed in accordance with the requirements laid down in the appropriate EU directives thus introducing advanced management tools based on the AQ modelling. According to the Latvian legislation, the simple empirical model, "Ecolog" (Russia), should not be used for air quality modelling. The new tool for pollution dispersion assessment and management, EnviMan, OPSIS AB Company, Sweden was obtained by the Latvian Hydrometeorological Agency in 1998. Initially it was used only for processing and storage of data collected from automated AQ monitoring stations. First modelling exercises began in 2000-2001 when a map of Riga was digitized and related to the GIS databases with regard to emission sources; input meteorological data were prepared as well. At the moment, the digital maps have been prepared, and source emission databases are being revised for another 9 industrially developed Latvian towns.

Keywords: Air pollution; Modelling; Traffic emissions; Latvia

1. INTRODUCTION

In the year 2000, 45% of the world's population lived in urban areas, with a much higher fraction (75%) in the more developed countries (Population Reference Bureau, 2001a). By 2007, it is projected that half of Earth's population will be city dwellers if trends continue, and most of this additional urbanization will take place in developing countries (Population Reference Bureau, 2001a). Given the large and increasing fraction of the population exposed to the atmospheric environments of cities, the growing interest about an air pollution level is understandable.

The central purpose of dispersion modeling is to describe the relationship between pollutant emission, transmission and ambient air concentrations of one or several pollutants as a function of space and time in a mathematically exact way. This is done with the calculation depending on emission volume, individual meteorological conditions and, if necessary, a number of parameters which take into account transformation and deposition processes in the atmosphere. Air pollution modeling is used to establish criteria for planning the location of industrial plants and complexes requiring official approval, for determining minimum stack heights, for developing and assessing air quality control strategies (to investigate the effects of emission restrictions on air quality) and thus for maintaining or restoring air quality (Baumbach, 1996).

Over the last decades, a number of air pollution models have been developed at the National Environmental Research Institute (NERI), Department of Atmospheric Environment, ATMI, Denmark and U.S. Environmental Protection Agency. The aim of this study is the practical use of two models – Operational Street Pollution Model (OSPM) and AERMOD (U.S.).

2. NUMERICAL MODELING

2.1. The operational street pollution model (OSPM)

The Danish OSPM model is a parameterized semi-empirical model making use of a priori assumptions about the flow and dispersion conditions in a street canyon. In the model, concentrations of exhaust gases are calculated using a combination of a plume model for the direct contribution and a box model for the recirculating part of the pollutants in the street. Parameterization of flow and dispersion conditions in street canyons was deduced from extensive analysis of experimental data and model tests. Results from these tests have been used to improve the model performance, with regard to different street configurations and a variety of meteorological conditions. The model calculates air concentrations of NO, NO_2, NO_x, O_3, CO and benzene in the street canyon at both sides of the street (Berkowicz, 1999; Brandt, 2000).

An importance feature of OSPM is modeling of the turbulence in the street. The turbulence in the street is assumed to be composed of two parts: a part dependent on wind speed (ambient turbulence) and a part due to traffic induced turbulence. The last dominates when the wind speed is low.

2.2. Air pollution data from traffic

Comparisons of measured and modeled hourly concentrations of NO_x in Riga (Valdemara street) are shown in Figure 1 for the measuring period in 2003 (7110 hours). Valdemara street is a typical street canyon with about 18 500 vehicles/day. The street is 15 m wide and is flanked on both sides with about 22 m high buildings. Direction of the street is 223 degrees. The pollution monitoring station is situated on the West side of the street where the building facades are closed. Hourly emissions of NO_x are estimated using the traffic counting data and average emission factors estimated according to computer program COPERT (Ntziachristos and Samaras, 2000; Vardoulakis, 2002). An average diurnal traffic profile was constructed from the counting data.

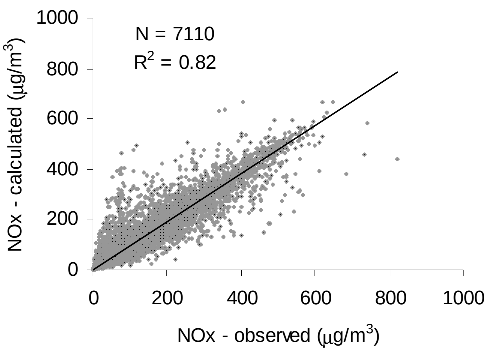

Figure 1. Comparison between measured and modeled concentrations of NO_x in Riga (Valdemara street).

Good correlation between the modeled and measured concentrations is evident from the results presented in Figure 1. Precise diurnal and yearly traffic data and successful using of COPERT obtain so good correlation.

2.3. AERMOD

To calculate the dispersion of non-sedimenting substances from point sources which are not subject to physical and chemical transformations during transport, a calculation model based on Gaussian diffusion is used for approval procedures.

The AERMOD modeling system consists of two pre-processors and the dispersion model. The meteorological preprocessor (AERMET) provides AERMOD with the meteorological information it needs to characterize the Atmospheric Boundary Layer (ABL) (Irwin, et al., 1988). The terrain pre-processor (AERMAP) both characterizes the terrain and generates receptor grids and elevations for the dispersion model. AERMET uses meteorological data and surface characteristics to calculate boundary layer parameters (mixing height, friction velocity) needed by AERMOD. AERMOD contains improved algorithms for: 1) dispersion in both the convective and stable boundary layers; 2) plume rise and buoyancy; 3) plume penetration into elevated inversions; 4) computation of vertical profiles of wind, turbulence, and temperature; 5) the urban boundary layer; 6) the treatment of receptors on all types of terrain from the surface up to and above the plume height (Hayes, 1986).

AERMOD is a steady-state plume model. In the stable boundary layer (SBL), the concentration distribution is assumed to be Gaussian in both vertical and horizontal. In the convective boundary layer (CBL), the horizontal distribution is assumed to be Gaussian, but the vertical distribution is described with a bi-Gaussian probability density function. This behavior of the concentration distribution in the CBL was demonstrated by (Willis, and Deardorff, 1981) and (Briggs, 1993).

2.4. Air pollution data from point sources

Riga is a city with 1 million inhabitants. Figure 2 shows the location of the industrial sources of SO_2.

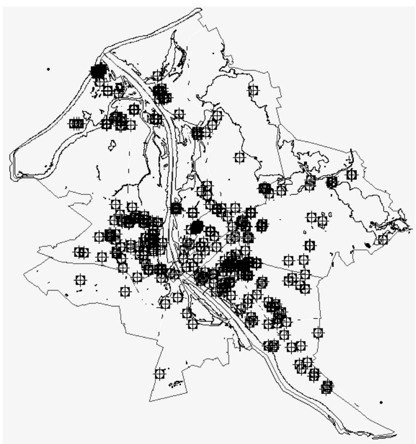

Figure 2. Location of SO_2 sources in Riga city (scale 1:40 000) .

The Latvian Environmental Agency Emissions Inventory was used as a basis for SO_2 emission data. The inventory includes the emissions from stationary sources (power plants, other point sources and residential heating). Sources are considered as point sources. Computations included approximately 200-point sources.

The meteorological data site (56º58' N and 24º02' E) used was from Spilve airport located at central part of Riga. A period of 3 years from 2001 to 2003 was studied. Peaks in measured sulfur dioxide concentrations are caused in large part by the major combustion sources, Figure 3.

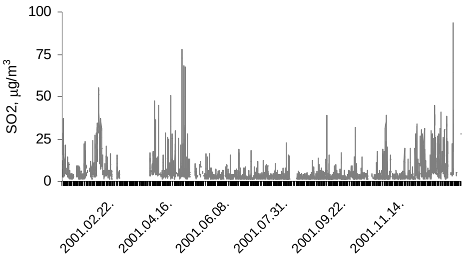

Figure 3a. Time series of SO_2 hourly concentrations in Riga: January-December 2001.

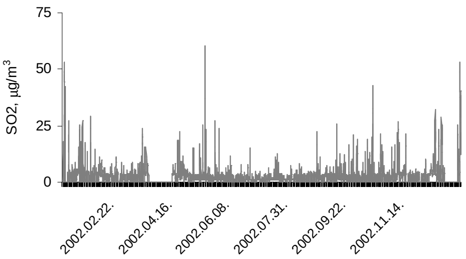

Figure 3b. Time series of SO_2 hourly concentrations in Riga: January-December 2002.

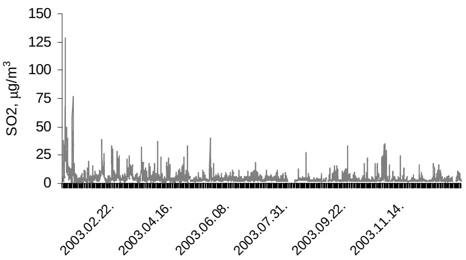

Figure 3c. Time series of SO_2 hourly concentrations in Riga: January-December 2003.

Comparisons of measured and modeled hourly concentrations of SO_2 in Riga (Maskavas street) are shown in Figure 4 for the measuring period of 3 years. Information about terrain (as surface roughness) is included. We put in the representative value for the local roughness around the monitoring site.

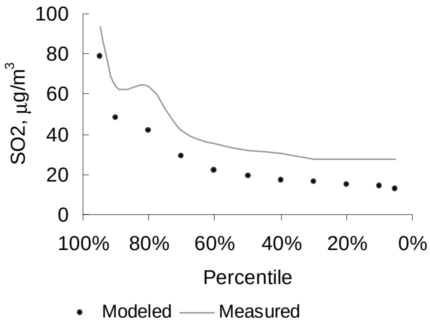

Figure 4a. Percentiles of SO2 concentration in Riga: January-December 2001.

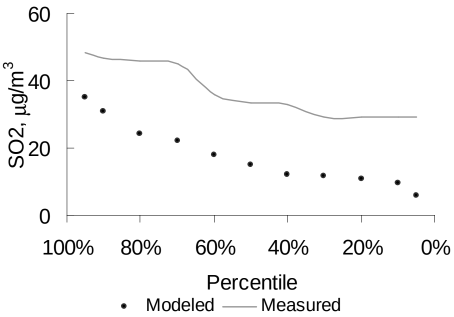

Figure 4b. Percentiles of SO2 concentration in Riga: January-December 2002.

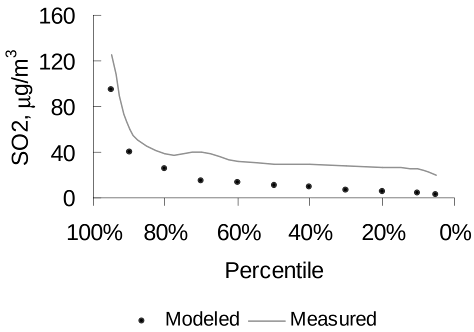

Figure 4c. Percentiles of SO2 concentration in Riga: January-December 2003.

Differences between measured and monitored data are caused by incomplete emission inventory data; especially we have not any SO_2 data from mobile emission sources (locomotives, etc.). Variations of SO_2 concentrations could be explained by economical activity, exactly by industrial activity. The quality of the emissions inventory was a critical factor in all three cases. In particular the following aspects were important: 1) information on the operating times of the largest industrial sources, including periods of shutdown; 2) emission data for small industrial sources e.g. stack height, diameter, release velocity and temperature, especially if the source significantly influences a monitoring site; 3) it was important to use local meteorological data, especially wind direction and wind speed.

2.5. GAS MEASUREMENTS

UV DOAS (Ultraviolet Differential Optical Absorption Spectroscopy) technique was used to determine the concentration of NO_x and SO_2. Challenging the UV DOAS system with a known concentration of span gas assesses accuracy and precision for specific gases measurement. Performance of QC measures will be in accordance with OPSIS *Analyzer Software User`s Guide.* The measurement uncertainty is 2 $\mu g/m^3$, sensitivity – 1 ppb. SO_2 monitor was located at central part of Riga city.

3. CONCLUSIONS

OSPM model is the most commonly used tool in regulatory street canyon applications. It is specially designed to produce time series of pollutant concentrations within near-regular canyons, and it requires a relatively small amount of input information and computational resources. From other point of view, OSPM model is based on a number of empirical assumptions that might not be applicable to all urban environments.

Gaussian plume models are popular because of their relative simplicity and the possibility of easily including special features. AERMOD is mainly designed to simulate point, area and/or grid sources in open terrain.

The tool for pollution dispersion assessment and management, EnviMan combines both of mentioned models.

In each study (OSPM, AERMOD) the quality and detail of information available from the emissions inventory was a large factor and specific, achievable improvements could be identified in each case. Nonetheless, from the emissions data available there was a good agreement between modeled and measured values of the main pollutants, SO_2 and NO_x.

4. ACKNOWLEDGEMENTS

The authors would like to thank Janis Kleperis (from Riga City Council, Environmental Department) for the help with traffic data.

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