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Estimation of road transport related air pollution in Saint Petersburg using European and Russian calculation models

Olga V. Lozhkina *, Vladimir N. Lozhkin

Saint-Petersburg University of State Fire Service of EMERCOM of Russia, 196105, Moskovsky pr., 149, St. Petersburg, Russia

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A B S T R A C T

The paper analyzes Russian and European emission and dispersion models aimed at the estimation of road transport related air pollution on street and regional scale as exemplified with St. Petersburg, Russia. It demonstrates the results of model calculations of peak concentrations of main harmful substances (NO_X, CO and PM_{10}) along the St. Petersburg Ring Road at high traffic volume and adverse meteorological conditions (calm, temperature inversion) executed by means of a Russian street pollution model, and it evaluates the computed results against the measurements from monitoring stations. The paper also examines the ways of adaptation of the COPERT IV model – a software tool for calculation of air pollutant and greenhouse gas emissions from road transport on regional or country scale – to the inventory conditions of the Russian Federation, compares the COPERT IV numerical estimates with the national inventory data. It also reveals the obstacles and possibilities in the harmonization of the Russian and European approaches.

Introduction

Commonality of problems of the Russian Federation and the European Union in relation to the requirements of the Convention on Long-range Trans-boundary Air Pollution (CLRTAP), as well as the necessity to improve the efficiency of air quality management on local and regional levels, requires reliable monitoring and forecast of road transport related emissions with their space–time specification.

The assessment of air pollution caused by vehicle emissions and forecasting of air quality in short- and/or long-term perspectives can be carried out using different methodological approaches and software (Bandeira et al., 2011; Borrego et al., 2000; Coelho et al., 2014; De Blasiis et al., 2013; EMEP/EEA Guidebook, 2013; Lozhkin and Lozhkina, 2011; Wang et al., 2009). There are two principal types of computational models:

(1) "Bottom-up": Such models provide data on emission of pollutants from motor vehicles on street scale. The calculation is performed according to the full-scale survey of the structure of traffic flows, followed by the assessment of dispersion of hazardous substances in the vicinity of roads. This approach is realized, for example, in CAR-FMI (Härkönen et al., 1996; Härkönen, 2002; Kukkonen et al., 2001), CALINE 4 (Benson, 1984, 1992), OSPM (Berkowicz, 1998, 2000; Ketzel et al., 2012) models and in some National models (Kotikov and Lukinsky, 2013; Lozhkin et al., 2013), one of them is detailed below.

* Corresponding author. Tel.: +7 9217592971; fax: +7 8126049889.
E-mail address: olojkina@yandex.ru (O.V. Lozhkina).

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(2) "Top-down": Such models are aimed at the determination of emissions of major pollutants on the region or country scale and are based on the statistical information about the vehicle fleet structure. The EU embodiment of such a model is the software and methodology COPERT IV (Gkatzoflias et al., 2012).

The combination of bottom-up and top-down approaches for the emission inventory in the city has been investigated by Bandeira et al. (2011), Borrego et al. (2000), Coelho et al. (2014), Smith et al. (2008), Vogel et al. (2000) and Wang et al. (2009).

Wang et al. (2009) showed that the bottom-up vehicular emissions of HC, CO and NO_X derived for the Beijing urban area were, respectively, 15%, 13% and 5% higher than those obtained by the top-down model. Borrego et al. (2000) and Smith et al. (2008) also verified in their studies in Lisbon (Portugal) and in Amsterdam (Netherlands) that the top-down approach underestimated the emissions.

Different validation methods are required to improve the quality of urban traffic emissions inventories, including the measurements of ambient concentrations, remote sensing, mass-balance. Mensink (2000) validated urban emission inventories in Antwerp thorough the comparison of the COPERT II emission factors with on-board-measurements and modelled traffic flow with the observed one. He indicated that traffic emission factors showed large uncertainties not only because of the lack of measurements precision, but also because of factors like driving behavior and vehicle maintenance. Later Mensink and Cosemans (2008) found that the modelled concentrations of NO_2 and PM_{10} derived with PARAMICS traffic model, OSPM street model and the Gaussian IFDM model, showed a good performance, within 15% accuracy, with their measured values in a street canyon in Antwerp.

The system of air quality control in big cities based on calculating approaches should provide information about city background level as well as about short-term peak concentrations of pollutants. Peak levels in the vicinity of roads are directly connected with pollution originated from traffic. Knowledge of the peak values and their dispersion is important as they most frequently overcome the threshold values (Ziv et al., 2002; Jicha et al., 2000).

While implementing evaluation studies on the calculation of road transport emissions, it has become obvious that high environmental impact provides harmonization of National Legislation with EU Directives (Concordance table, 2012), adaptation of the advanced European methodologies for the inventory of road transport related air pollutants, like COPERT IV, to Russian conditions together with own national environment protection experience (Lozhkin et al., 2011; Lozhkina et al., 2014; Lozhkin and Lozhkina, 2011, 2014).

Thus, the objectives of the present study were:

1. Illustrate the possibilities and conceptual framework of a Russian street pollution model developed in St. Petersburg with the participation of the authors by generating of peak hourly traffic emissions and pollutants concentrations on the St. Petersburg Ring Road.
2. Investigate the ways of the adaptation and application of the European COPERT IV model to the Russian inventory conditions by the estimation of annual road transport related air pollution in St. Petersburg in 2010–2012.
3. Compare the hourly emission estimates computed by means of a National bottom-up model and the top-down COPERT IV model for the busiest section of the St. Petersburg Ring Road.

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Methodology and data

Description of the Russian street pollution model

Traffic emissions were calculated by means of the software program Maghistral (Integral Co Ltd., St. Petersburg, Russia) developed on the base of the National Methodology of calculating the contribution of vehicle emissions to the urban air pollution (Methodology, 2010) elaborated with our participation at the JSC "Scientific and Research Institute for Atmospheric Air Protection".

The concentrations of traffic-emitted pollutants were estimated by means of the Ecolog-3 software (Integral Co Ltd., St. Petersburg, Russia) based on the Russian normative document for the calculation of the dispersion of hazardous substances in the atmospheric air – OND-86. OND-86 methodology was elaborated by the Main Geophysical Observatory (Genikhovich and Sciermeier, 1995; Genikhovich et al., 2002).

The Maghistral software is compatible with the Ecolog 3 software, and street emission data can be automatically transferred to the dispersion model.

The Methodology (2010) is aimed at the assessment of main transport related pollutants: CO – carbon oxide, CH – hydrocarbons in terms of $CH_{1.85}$, NO_2 – nitrogen dioxide, PM – particle matter, SO_2 – sulfur dioxide, CO_2 – carbon dioxide; formaldehyde; benzpyrene.

It considers 5 main categories of vehicles: (1) Passenger cars; (2) Light Duty Vans (LDV) <3500 kg; (3) Heavy Duty Vans (HDV) 3500–12,000 kg; (4) Heavy Duty Vans (HDV) >12,000 kg; (5) Buses >3500 kg.