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APPLICATION OF DISPERSION MODELS FOR DEVELOPMENT OF ATMOSPHERIC POLLUTION MANAGEMENT ZONES IN RIGA AGGLOMERATION

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Abstract: Almost in all European countries air quality models are used for regulatory purposes - issuing emission permits, cases studies for environmental impact assessment, analysis of future development and planning. Directive 2008/50/EC (into force from 11 June 2008) regulate that air quality status should be maintained where it is good and improved if necessary. Riga municipality has monitored air pollution in Riga and nearby areas for more than 10 years and results showed necessity to regulate pollution, particular nitrogen dioxide (NO_2), particulate matter (PM_{10}) and benzene because of too high concentration. Air dispersion model was applied to develop atmospheric pollution management zones for NO_2, PM_{10} and benzene. This was 4th time when NO_2 zoning is applied for Riga (previous in years 2004, 2007, 2010), but first time for PM_{10} and benzene. One of the actions showing roadmap for air quality improvement consist of revision of emission data and sources data base, and further modelling in order to identify hot spots for further actions.

Key words: *air quality management; urban air pollution control; modelling*

INTRODUCTION

Numerous investigations in Europe, USA and rest of the world shows diverse impact of air pollution in many fields causing climate change, impact on biodiversity, disrupting photosynthesis, reducing crop harvests, massive impact on human health causing various types of allergies, circulatory problems, respiratory diseases, disturbances of central nervous system, etc. (Afroz et al., 2003; Brunekreef and Holgate, 2002; Paoletti et al., 2010; Sunyer et al., 1993; Svartengren et al., 2000;) Poor air quality especially in urban areas mainly is determined by high pollution level with nitrogen oxides, particulates and benzene consequential of the human activities. To avoid worsening of situation, the European Commission establishes a legal instruments to improve the air quality. One of the management actions consist of air quality plans development for zones and agglomerations where air quality limit values are exceeded with a further strategical aim to find and implement control pollution actions. Effective air pollution management planning is essential in several meanings: (1) most appropriate instruments leading to air quality improvement; (2) any air quality improvement gives positive feedback in health, morbidity and mortality aspects. Actions what could be applied varies very much from strategical to site specific restrictions, but one of most popular instruments in order to identify high pollution zones and effective actions are modelling. In most European member states modelling as a tool is used for emissions and dispersion modelling for further decision making process. The main objective of this study is to identify high pollution zones in Riga agglomeration by using Gaussian dispersion model. Air pollution dispersion modelling has been performed by AERMOD for nitrogen dioxide, particulate matter (PM_{10}) and benzene dispersion.

METHODOLOGY

Study area

The Riga city (capital of Latvia) is located in Northeast Europe close to Baltic Sea Gulf. This is mostly economically developed center in Latvia. Riga is located in a temperate climate zone and weather conditions are determined by the Atlantic air masses, the Baltic Sea and the Riga Sea Gulf stretching deep into the country. The temperature during the year typically varies from -7°C to 24°C, occurrence of precipitation closely correlate to season – most likely precipitations is observed in January nor in May. The most common forms of precipitation are light rain, moderate snow, light snow, and thunderstorms. The relative humidity typically ranges from 45% (comfortable) to 97% (very humid), rarely dropping below 28% (dry). Typical wind speeds vary from 0 m/s to 6 m/s (calm to moderate breeze), rarely exceeding 9 m/s (fresh breeze). The wind is most often out of the south (24% of the time), south west (13% of the time), north (12% of the time), and south east (11% of the time).

Model configuration

In order to perform concentration calculations at receptors, database of sources (physical description) with emission spectral and volumetric data were prepared. Emissions of nitrogen dioxide varies from year to year, but overall there is rather week correlation between number of sources and emission amounts; situation PM_{10} case is slightly different – for the period until 2009 there are rather opposite fluctuations of number of sources and emissions what seems unbelievable, but actually could be explained by changes in national legislation. The issued air pollution permits were revised and emissions were recalculated according to European methodology, and since 2010 there is growing trend of PM_{10} emission sources and emission amounts as well. Situation with benzene (C_6H_6) is quite similar to PM_{10}, only source typology is different, while main sources of PM_{10} are coal processing and industrial heat processing (burning of heavy fuels, coal), benzene sources are mainly located in Riga Freeport territory and connected to oil products storage and processing. Variability of sources and annual emissions are shown in Figure 1.

Figure 1. Variability of number of stationary sources and annual emissions in Riga agglomeration, 2004-2014

All necessary ground level meteorological data (air temperature at 2 m height, wind speed and wind direction at 10 m height, global radiation at 2 m height) from Riga meteorological station (N 56.9506; E 24.1161) was obtained for meteorological inputs for AERMET data pre-processor what was used to calculate boundary layer parameters, such as the Monin-Obukhov length, convective velocity scale, temperature scale, mixing height, and surface heat flux.

Monitoring results

Air quality monitoring at national level were performed at background, industrial and traffic sites in Riga agglomeration. Measurements were done continuously bay differential optical absorption (DOAS) method for nitrogen dioxide and benzene, but PM_{10} concentrations were obtained gravimetrically on daily basis. Monitoring results show some indications: (1) at traffic monitoring sites substantial decreasing trend for PM10 and benzene were identified; (2) at industrial sites and background level substantial changes didn`t detected. Long-term results were shown in Figure 2.

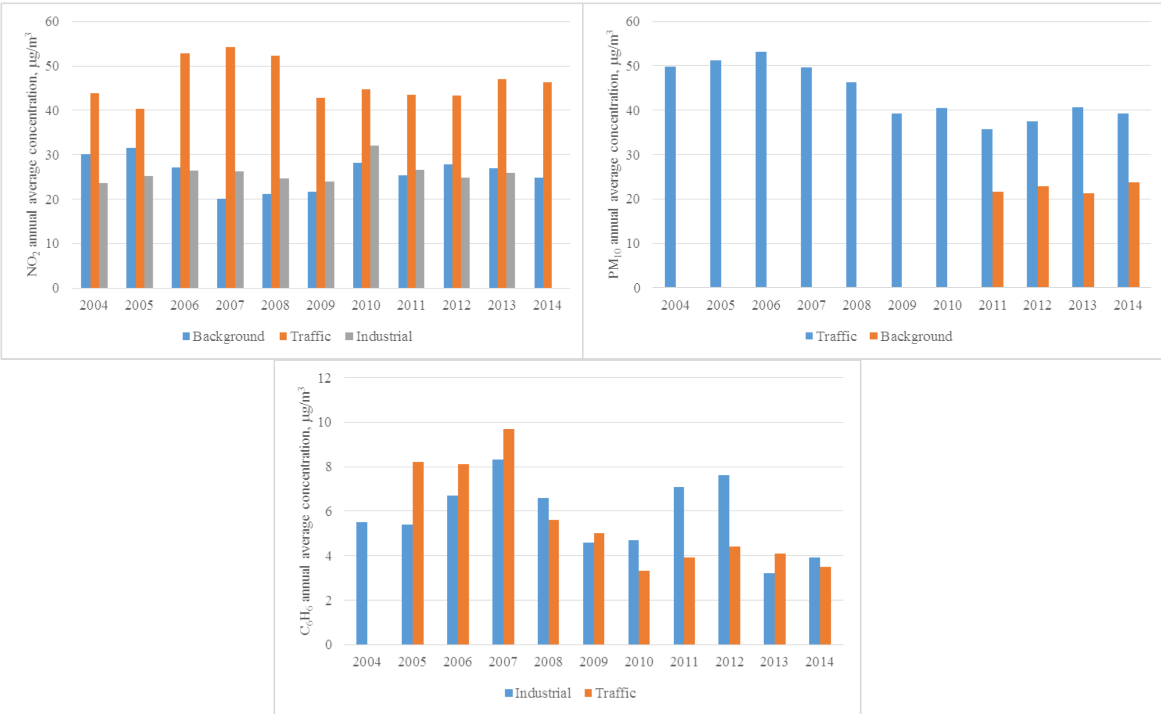

Figure 2. Long-term monitoring results in Riga agglomeration, 2004-2014

Correlation analysis of monitoring results shows very strong correlation ($r = 0{,}9$; $p<0{,}05$) between PM_{10} and benzene concentrations in city central part indicating massive impact of mobile sources.

MODELLING RESULTS

Simulation results for NO_2 didn`t show any substantial changes for 10 years period, higher pollution zones strongly correlate with traffic flow, indicating high pollution zones (above determined annual limit value 40 $\mu g/m^3$) in street canyons. In case of particulate matter PM_{10} dispersion high pollution zones are dissipated and associated with traffic jams, specific hot spots (coal storage and processing enterprises, welding operations, metal and steel works). Benzene spatial distribution were modelled for strictly defined pollution zones which are associated with limit values, lower and upper assessment levels. Maps of benzene pollution were elaborated for following pollution zones: I zone – benzene annual concentration exceeds limit value 5,0 $\mu g/m^3$; II zone – benzene annual concentration varies between 3,5 and 5,0 $\mu g/m^3$; III zone – benzene annual concentration varies between 2,0 and 3,5 $\mu g/m^3$; IV zone – benzene annual concentration is less than 2,0 $\mu g/m^3$. According to EK regulations and local legislation rules particular zones could be associated with further development plans, while in high pollution zone any additional pollution sources are prohibited, in less polluted zones (e.g. 2,0 - 3,5 $\mu g/m^3$) there is strong need for further monitoring in order to inform habitats and air quality managers about air pollution condition. According to modelling results, benzene pollution zones are very closely connected to city traffic, traffic jams and Riga Sea Port activities. Source-receptor modelling of benzene shows how important is source geometry and working regime; while in 2014 69 % of benzene emissions comes from industry including volatile organic compound sources only 29 % of benzene concentrations at receptor level gives this type of source. As most significant source in case of benzene pollution within all city is traffic. Map of benzene pollution zones were given in Figure 3.

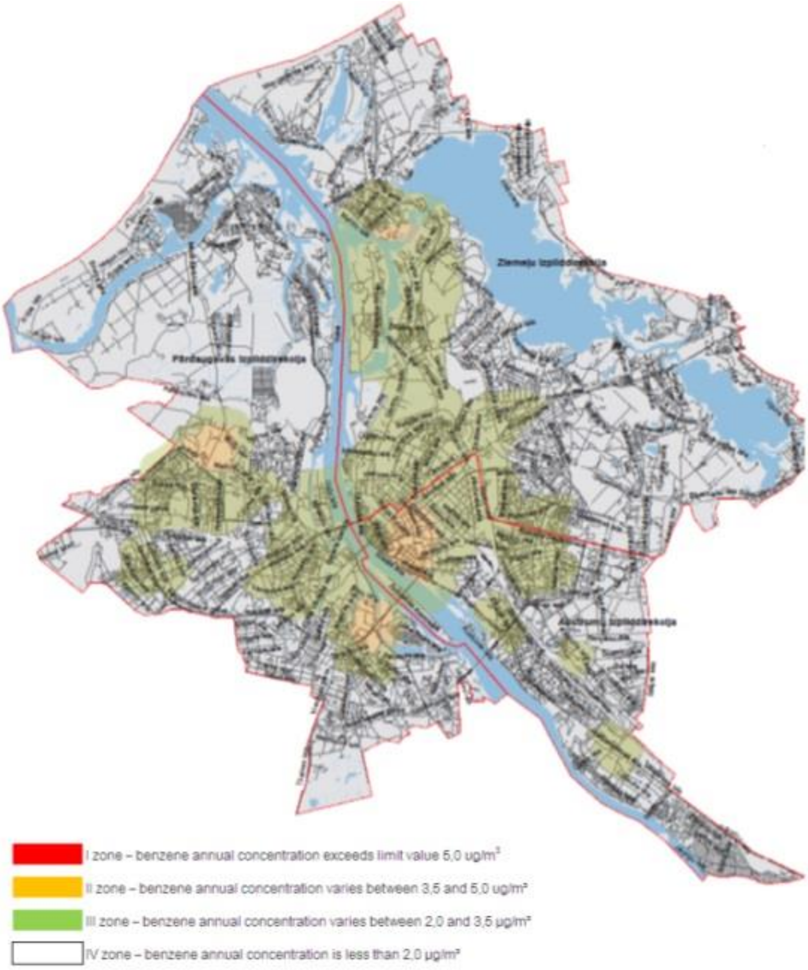

Figure 3. Benzene modelling results, annual average concentrations (μg/m^3)

Additionally, in order to evaluate modelling results, these results were checked according to data quality objective criteria what is set to 50%. This quality procedure were successfully performed for three monitoring points, results are given in Table 1.

Table 1. Evaluation of benzene modelling results

Monitoring point type	Monitoring results, μg/m^3	Lower assessment level, μg/m^3	Upper assessment level, μg/m^3	Modelling results, μg/m^3
Industrial	3.90	1.95	5.85	2.35
Traffic	3.48	1.74	5.22	3.79
Background	3.31	1.66	4.97	1.96

CONCLUSIONS

(1) Dispersion model is very usable tool for modelling of zonation of atmospheric pollutants and zoning for NO_2, PM_{10} and benzene has been accomplished;

(2) NO_2 pollution in city centre closely correlate with traffic flow and future actions for improvement are necessary;

(3) Modelling results showed highest concentrations of PM_{10} in relation to traffic impact and in Riga Sea Port territory where activities are conducted to coal handling and processing;

(4) Main benzene pollution sources in Riga are traffic and volatile organic compound sources located in Riga Freeport territory;

(5) Growing tendency of volatile organic sources could rise benzene pollution level in Riga central and North part, but connection between number of sources, emissions and ground level concentrations is quite complex. While in 2014 69 % of benzene emissions comes from industry including volatile organic compound sources only 29 % of benzene concentrations at receptor level gives this type of source;

(6) Modelling results of benzene shows evidences of further monitoring necessity in city center and other territories where benzene pollution levels varies between 3,5 $\mu g/m^3$ – 5 $\mu g/m^3$.

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