Study of Air Pollution in St. Petersburg Area

A contribution to subproject SATURN

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Summary

We started this project in 1997 and it was partially carried out in the framework of cooperation between Russian and Danish scientists. The first year of the project was spent in preparations, which included selecting and adjusting the office space, purchasing, shipping and installing instruments, training specialists and so on. The active phase of the project actually started in 1998. Main results obtained correspond to the following main directions of works:

Field campaigns. Since the end of 1998, two DOAS gas analyzers are being used to monitor continuously six pollutants, SO_2, NO, NO_2, O_3, benzene and toluene. Simultaneously, meteorological measurements are carried out on the meteorological mast installed on the roof of the building, which hosts the instruments. The monitoring site is located in the street canyon with the traffic intensity up to 2000 vehicles per hour. The data collected during two years of observations with the use of DOAS instruments were processed to analyze air pollution levels in one of the streets (Pestelya Street) in the downtown of St. Petersburg.

Emission inventory. During the period of observations traffic counts were manually taken several times during different seasons of year.

Modeling and model evaluation exercises. Measured concentrations and traffic counts were used together with results of backward dispersion calculations carried out with the OSPM street-canyon model (Denmark) and OND-86 (Russian national regulatory model) to estimate emission factors for NO_x and benzene for the actual structure of the car fleet in St. Petersburg.

Data analysis. The collected data set was analyzed using different statistical and modeling techniques.

New development. New scientific results were obtained including the following ones:
a) New approaches to adaptive dispersion modeling as a tool for the integrated assessment and hybrid monitoring of air pollution in cities were suggested.
b) A new technology of dispersion calculations in the urban scale based on filtering of the computed fields of concentration was developed.
c) A new PDF approach of processing the data of tracer experiments for validation of dispersion models was developed and tested.
d) A new approach to description of the urban air pollution and, more generally, urban meteorology using equations of hydro- and thermodynamics of porous media was introduced.

Policy issues. The data collected in the framework of the project were directly logged into the municipal automatic system of air pollution monitoring and management to be used by the city authorities in decision-making on environmental issues. They were also used to analyze

air pollution levels in the downtown of St. Petersburg. These measurements show that concentrations of most of the species (except NO_2) are rather moderate and well inside Russian ambient air quality standards. The results of monitoring and modeling have also been used in preparation of the new version of the national guideline on dispersion modeling, which will go into effect in 2002.

Aim of the research

This project was initiated in 1997 and partially carried out in the framework of cooperation between Russian and Danish scientists. The first year of the project was spent in preparations, which included selecting and adjusting the office space, purchasing, shipping and installing instruments, training specialists and so on. An active phase of the project actually started in 1998 and is still in progress. Unfortunately, since May 2001 the traffic pattern on the street, where the instruments are located, has drastically changed due to reconstruction of the nearby bridge. The data collected during this period will be analysed separately.

The goals of the project were as follows:

- To organize field campaigns (which should provide necessary information for evaluation of the dispersion models),
- To collect emission data about sources of air pollution in St. Petersburg,
- To organize model evaluation exercises, and
- To develop new dispersion models and technologies of their application in developing the environmental policy.

It turned out, however, that there were no reliable emission data for the industrial sources in St. Petersburg. That is why we limited ourselves only with emission data relevant to the field campaigns in the street canyon.

Activities during the year

In 2001 the measurement campaign in St. Petersburg was continued (see Genikhovich et. al., 2000). In addition to all routine procedures connected with maintaining of DOAS instruments, they were calibrated in June using test gases. This calibration was made for NO, NO_2, SO_2 and ozone. Besides, in December 2000 – February 2001 parallel measurements of NO, NO_2 and ozone at the same spot in Pestelya Street were also carried out using standard monitors together with DOAS instruments.

Collected monitoring data were analysed using different statistical techniques. OSPM (Denmark) and OND-86 (Russia) dispersion models were used together with these data to estimate the emission factors for the actual structure of the car fleet in St. Petersburg from backward dispersion calculations.

Principal results

Overall statistical characteristics of the hourly averaged concentrations measured at the street and roof levels are presented in Table 1. Both mean values and 98 percentiles, correspondingly, are well inside Russian national ambient air quality standards called "maximum permissible concentrations" (MPCs) except NO and ozone (averages for both, street and roof, levels) and NO_2 (both 98 percentiles and means). But even in these cases the exceedance of standards is not higher than 55%. In comparison with EU standards, however, concentrations of benzene are very high. The ratio of NO_2 and NO_x average values, which can be considered as measure of transformation NO and NO_2, is different at the street (≈0.5) and roof (≈0.65) levels. The ratios of mean concentrations at two levels for benzene, toluene and NO_x are equal to 2.9, 2.6 and 1.7, correspondingly. One can notice that this ratio for NO_x is significantly lower than for hydrocarbons. This fact could be attributed to the influence of all sources of NO_x located outside Pestelya St. Coefficients of variance in Table 1 are higher for hydrocarbons and SO_2 than for other pollutants; for each of these species, however, except ozone and NO they do not depend significantly on the measurement level.

Table 1: Statistical characteristics of the observed concentrations (in $\mu g/m^3$)

	Reliable data (%)	Mean value	Median	Coefficient of variance	Min	Max	98^{th} percentile	99.9^{th} percentile
Street level								
Benzene	74.38	18.84	14.08	0.82	-1.28	121.79	62.35	73.51
Toluene	79.73	65.96	45.37	0.97	-4.78	489.00	245.38	285.61
NO	36.95	93.46	68.78	0.85	-3.19	391.18	282.91	301.36
NO_2	85.21	59.22	56.58	0.45	5.93	257.11	121.64	132.30
Ozone	80.45	33.57	32.55	0.49	2.51	109.87	71.11	75.47
NO_x	36.78	198.12	163.72	0.69	3.53	700.28	511.88	550.28
SO_2	73.34	14.25	9.02	1.19	0.98	320.05	59.96	78.85
Roof level								
Benzene	66.21	6.32	5.03	0.84	-1.51	76.77	21.01	26.57
Toluene	65.71	25.52	19.37	0.95	-5.80	348.66	92.67	115.17
NO	84.34	37.13	22.97	1.10	-1.43	370.15	164.24	198.81
NO_2	92.45	43.57	40.77	0.45	3.87	223.79	92.49	102.27
Ozone	92.60	44.96	42.67	0.45	4.09	193.16	90.37	94.84
NO_x	83.74	99.54	77.86	0.75	7.24	639.50	316.55	375.93
SO_2	73.95	13.21	7.47	1.27	-0.23	266.44	61.31	80.57

More detailed results of statistical analysis are presented by Genikhovich et al. (2002). As an example, a "concentration rose" is shown on Fig. 1 (leeward concentrations correspond here to SSE winds). This picture illustrates a high level of inhomogeneity and anisotropy of urban concentration fields.

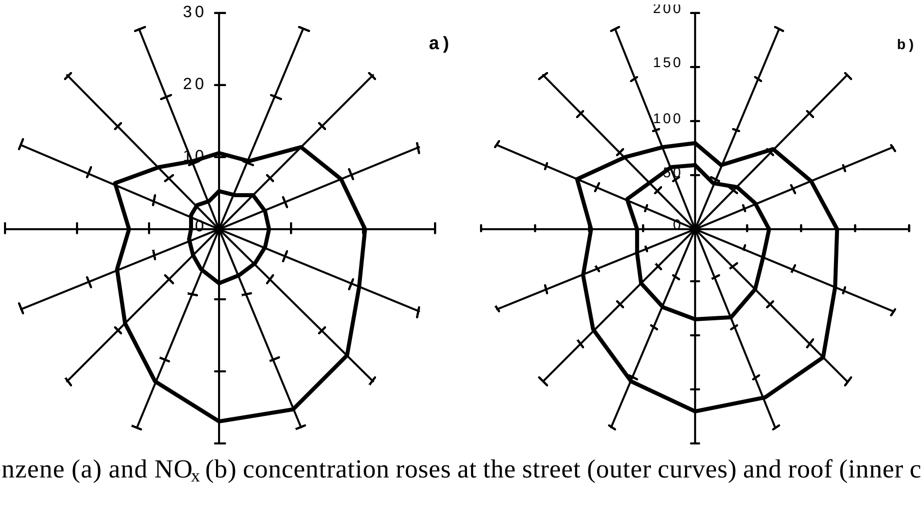

Figure 1. Benzene (a) and NO_x (b) concentration roses at the street (outer curves) and roof (inner curves) levels.

The Danish OSPM model (Berkowicz et al., 1997) was used to estimate total traffic emissions and emission factors. In addition, similar estimates were obtained using the Russian regulatory dispersion model OND-86. A corresponding methodology is described in a separate contribution (Ziv et al., 2002). Traffic emission factors retrieved with the use of OSPM as well as corresponding reference values introduced in the national guideline are presented also in Table 2. These results can be considered as indication that emission estimates based on this guideline could be too conservative. Additional tests should be completed to prove this conclusion.

Table 2: Emission factors (g/km) for NO_x and benzene.

Pollutant	Value	Cars	Vans	Trucks	Buses
NO_x	Reference	1.8	2.9	6.45	6.65
	Present study	0.84	0.84	3.28	3.28
Benzene	Reference	0.63	0.45	0.91	0.98
	Present study	0.16	0.16	0.44	0.44

Main conclusions

The results obtained were presented at many international conferences including 24th and 25th NATO/CCMS conferences (held in the USA and Belgium), 3rd International Conference on Urban Air Quality in Loutraki, Greece, 7th International Conference on Harmonization within Atmospheric Dispersion Modelling for Regulatory Purposes in Belgirate, Italy, and 3rd International Symposium on Environmental Hydraulics in Tempe, AZ, USA.

Presented results can be considered as a proof that open-path optical gas analysers are efficient tools for monitoring urban air pollution. They turned to be more robust and simple in maintaining than other instruments we were working with. The St. Petersburg city administration, based on comparatively analysis of performance of different instruments, is now considering an opportunity to purchase several similar instruments to be used in the municipal automatic system of air pollution monitoring and management.

Aims for the coming year

- Continuous monitoring of the urban air pollution with the use of open-path gas analyzers and transfer the monitoring data into the municipal automatic air quality monitoring system.
- Statistical data analysis.
- Backward dispersion calculations and evaluation of emission factors for the actual car fleet in St. Petersburg.

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