A Russian Urban Air Quality Management System "Ecologist-City"

E. Genikhovich[1], A. Sosnin[2], K. Chestnov[2]

[1] *Voeikov Main Geophysical Observatory, 7 Karbyshev Street, 194021, St. Petersburg, Russia. ego@main.mgo.rssi.ru*

[2] *Integral LTD, P.O. Box 200, 193015, St. Petersburg, Russia. eco@integral.spb.su*

Abstract

A Russian urban air quality management system "Ecologist-City"® is installed and actively used in 35 major cities in Russia and other republics of the fUSSR including Moscow, St. Petersburg, Nizhnii Novgorod, Novosibirsk, Ekaterinburg, Samara, Perm and others. It can be employed for managing urban emission database (built as a combination of databases for individual enterprises including stationary point, line and area sources) and database for background concentrations, statistical processing of the data sets, estimating the traffic-related emissions ("Highway-City" module), calculating the upper-limit (98^{th} percentile) and mean annual concentration fields, mapping the results with a GIS system and evaluating the emission quotas for the main pollution sources. Dispersion algorithms are based on Russian national regulatory guidelines and, therefore, the results of calculations are legally authorized for implementation in the process of decision making in urban air quality management. This system can be run in both, diagnostic and prognostic, modes. The last one is used to evaluate the effectiveness of projected emission-control measures. Because of its modular structure, the system can be adjusted to specific requirements of the customers.

Introduction

Dispersion calculations are an important element of the system of air quality management existing in Russia. They are used as a basis for decision-making in such areas as setting the standards of emission for industrial sources, determining the levies imposed on emissions of harmful atmospheric pollutants, designing the emission-control measures, road networks and so on. Such an emphasis on dispersion calculations could be attributed to the fact that ambient air quality standards (AAQSs) are established in Russia for about two thousand of harmful pollutants and that systematic instrumental monitoring in all Russian cities together covers concentrations less than one hundred of those pollutants. It should be noted that AAQSs are used in Russia as the basis for emission control and that the standards ("permissible levels") of emission for industrial sources and enterprises are determined from dispersion calculations using the following condition: the sum of concentration from the sources (enterprise) considered and background concentration from other courses should not exceed corresponding AAQS (ecological air quality standards, if they are established, can be used in the same way). In modern Russia, a significant fraction of responsibility for the air quality management is shifted toward regional and municipal authorities. Accordingly, to run dispersion calculations on the scale of a city they need specialized tools usually called "urban air quality management systems" in this (UAQMS). One of the most widely used Russian UAQMS called "Ecologist-City" is described paper.

Structure and main functions of "Ecologist-City"

"Ecologist-City" is a program shell encompassing two main subsystems that, correspondingly, allow for creating and managing databases and carrying out dispersion calculations. The core of any UAQMS is a dispersion model which output should be compared with AAQSs. There are two sets of Russian national AAQSs corresponding to the short-term (20 to 30 min) and long-term (a season or a year) averaging times. That is why both, short- and long-term averaged, concentration fields should be calculated by UAQMS and compared with AAQSs. Analyzing the actual ratios between Russian short- and long-term AAQSs Berlyand (1982) concluded, however, that the first ones result in more stringent limitations on permissible levels of emissions from the point sources than the second ones. Russian short-term AAQSs should be compared with the fields of 98th percentiles of the probability distribution function of concentration (we will refer to those as "majorant" or "upper-limit" concentration fields).

Majorant concentration fields are calculated in "Ecologist-City" using the model algorithm presented in the national regulatory guideline called OND-86. It is non-Gaussian model, based on analytical approximations of numerical solutions of the advection-diffusion equation. This model was described by Berlyand (1982) and Genikhovich (1998). OND-86 allows for direct computation of the field of upper 98th percentiles without estimating the whole annual set of concentrations corresponding to different meteorological condition or their complete probability distribution function (PDF). It does not require any input of actual meteorological parameters; instead it makes use of a special climatological parameter, which characterizes the turbulent diffusion at "critical conditions" in the area of interests and has been evaluated in advance for different regions of Russia. In addition, it is necessary to know the value of the upper 95th percentile of PDF of the wind speeds in this area. Terrain features are accounted for in OND-86 using terrain amplification factors (TAFs) for all sources included in calculations (accordingly to OND-86 these TAFs can be determined using topographic maps of the domain of diffusion). A building-downwash and street-canyon sub-model makes the use of coordinates and heights of the buildings influencing the pollutant distribution; Genikhovich et al. (1987) described corresponding building-downwash algorithm, and its "Gaussian" version could be found in Genikhovich and Snyder (1994). Individual sources are characterized by their heights, emission and volume rates, overheating (temperature difference) relative to the ambient air, diameters for point sources or coordinates of the end points for line sources or, for example, a set of coordinates of apexes for area sources.

Long-term averaged concentrations are calculated in "Ecologist-City" using the model MEAN introduced by Genikhovich *et al*. (2000). It is based on integration of an expression for the short-term concentrations over the phase space of governing meteorological parameters with the weight function determined as the probability density of joint occurrence of these parameters. The aforementioned expression is also based on an analytical approximation of numerical solution of the same advection-diffusion equation; thus, both, long- and short-term, models have a similar theoretical basis. They employ also a similar approach when accounting for complex terrain and building downwash.

These short- and long-term models, however, use different input information. To run MEAN, in particular, one should know probability densities (or, when using this model as a diagnostic one, frequency distributions) for the wind speed, wind direction and a parameter, which characterizes the thermal stratification of the atmosphere (see Genikhovich *et al*., 2000). Even input emission data are partially different: emission rates for OND-86 correspond to annual maximums, and those for MEAN correspond (in the simplest case) to annual mean values. Similarly, different values could be used, for example, for volume rates and overheating of flue gases.

The databases in "Ecologist-City" should provide input information required for dispersion calculations. This information can be either logged in manually or transported from the external electronic databases. It could be directly linked to dispersion models. The data could be also sorted out accordingly to different keys or used to generated simple statistical reports characterizing for example total emissions from different enterprises, industries and so on.

"Ecologist-City" includes also a module "Highway-City" to estimate traffic-related emissions and a program "Ecomap" which is used to depict city maps superimposed with computed concentration fields. The data exchange and flexible interaction with standard GISs are possible for the users too. In addition, the system can be used for backward dispersion calculations. In this regime, it determines for example the "permissible quotas" of air pollution for different enterprises.

Working with the system

"Ecologist-City" is user-friendly software, which enables users to solve numerous applied

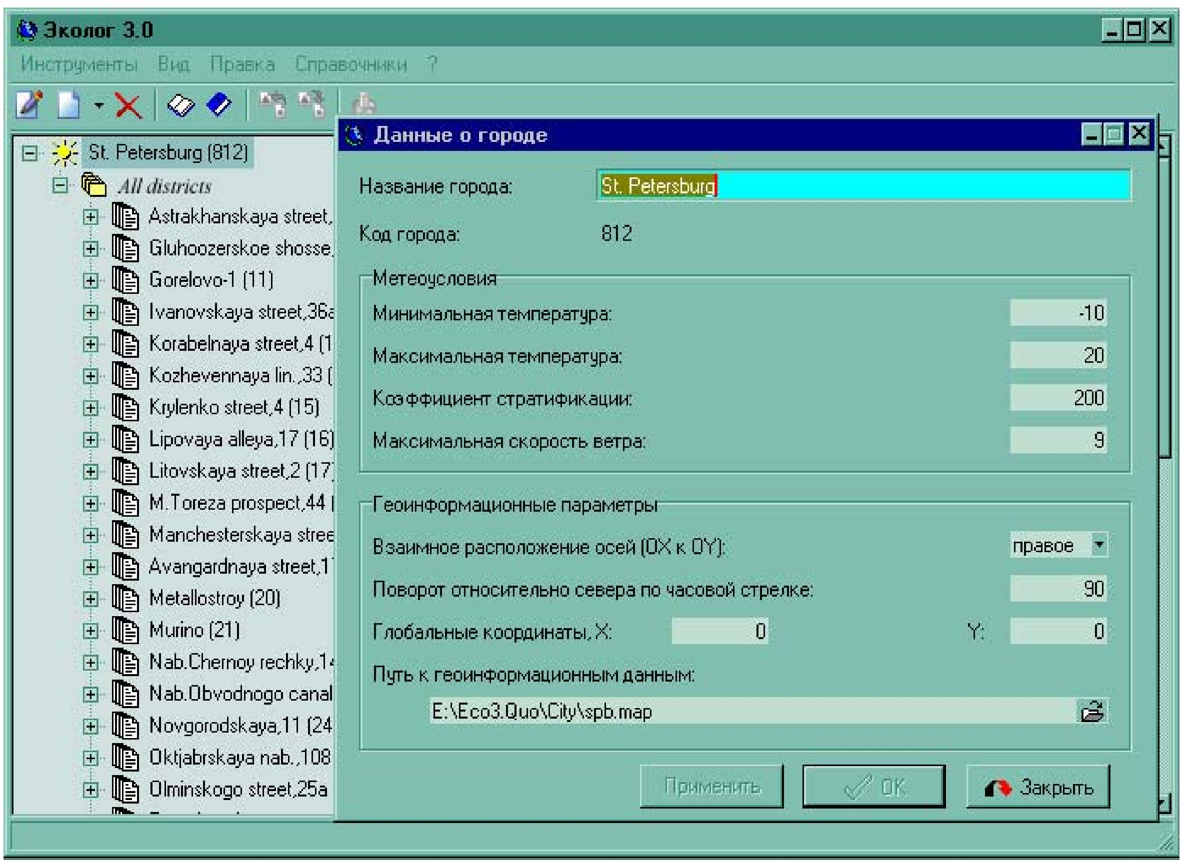

Figure 1. Main menu with a first-level submenu (city characterization).

problems. It works in the Windows environment and at the moment speaks mainly Russian. Even now, however, a certain part of on-screen messages could be represented in English. It can be seen in Fig. 1, which depicts the main menu and the first-level submenu for putting in general characteristics of the city under consideration. A fully English version of the system will appear in the nearest future. The main menu and first- and second-level submenus are shown in Fig. 2. These submenus are used in creating the database for enterprises and sources, correspondingly.

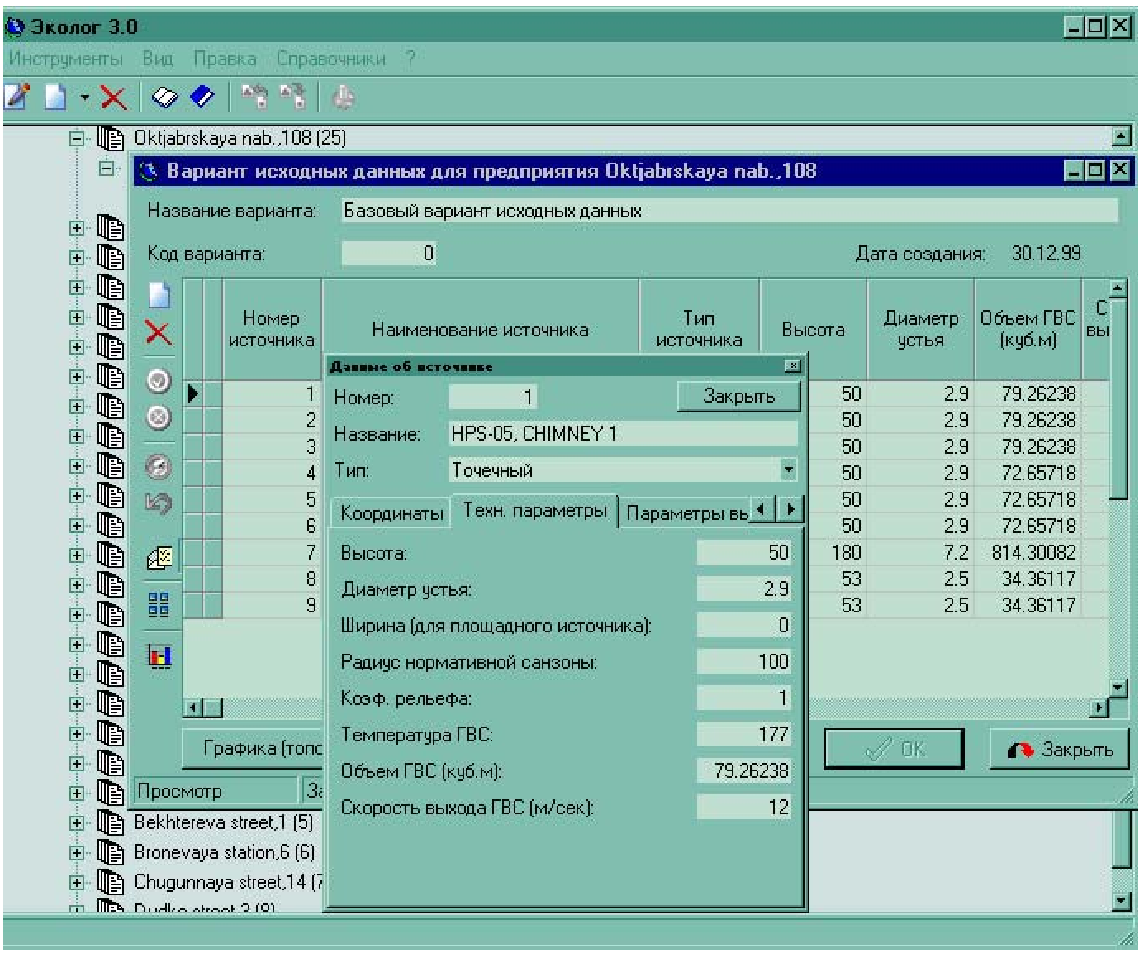

Figure 2. Main menu with first- and second level menus (enterprise– and source characterization).

Examples of application of the system given in this section to illustrate the resources of the system correspond to real computations of the NO_2 concentration fields for the city of St. Petersburg, Russia. The only sources of this pollutant accounted for here were those of municipal and industrial thermal power stations and residential boilers. Computations were carried out to estimate a specific input of these sources into the air pollution in the St. Petersburg area. On the whole, 80 point sources were included in calculations. Because the main part of pollution was emitted trough tall stacks, building-downwash effects were not taken into account. The source data were structured into separate "enterprises", and it was possible for each receptor point to sort either enterprises or individual sources depending on their input to the level of concentration at this receptor point.

Isolines of the calculated ground-level majorant concentration field are shown in the Fig. 3 with an electronic map of the city in the background. The map of the whole computational domain is represented in the side panel. The same field is shown also on the Fig.4 superimposed with a distribution ("cross section") of concentration along the solid straight line shown in black on this figure. A blown-up part of this field is shown also on Fig. 5. The flags there correspond to receptor points (1), (2) and (3) selected manually by the user; the code number (0301) there indicates the pollutant considered (NO_2 in our case), and corresponding concentrations at the receptor points normalized with AAQS are shown below this code. The results of computations indicate also that, for example, the "total" normalized concentration at the point (1) from all sources considered is 1.39; the highest (22.7%) and the second largest (21.3%) inputs in this concentration can be attributed to the "sources No 4 and No 2 of enterprise No 24". The total input of this enterprise in the level of pollution at the receptor point (1) amounts for 87.3%, and the enterprise No 35 is responsible for the second largest (8.0%) input at this receptor point for all enterprises considered. Similar information can be presented for all receptor points, sources and enterprises included in computations.

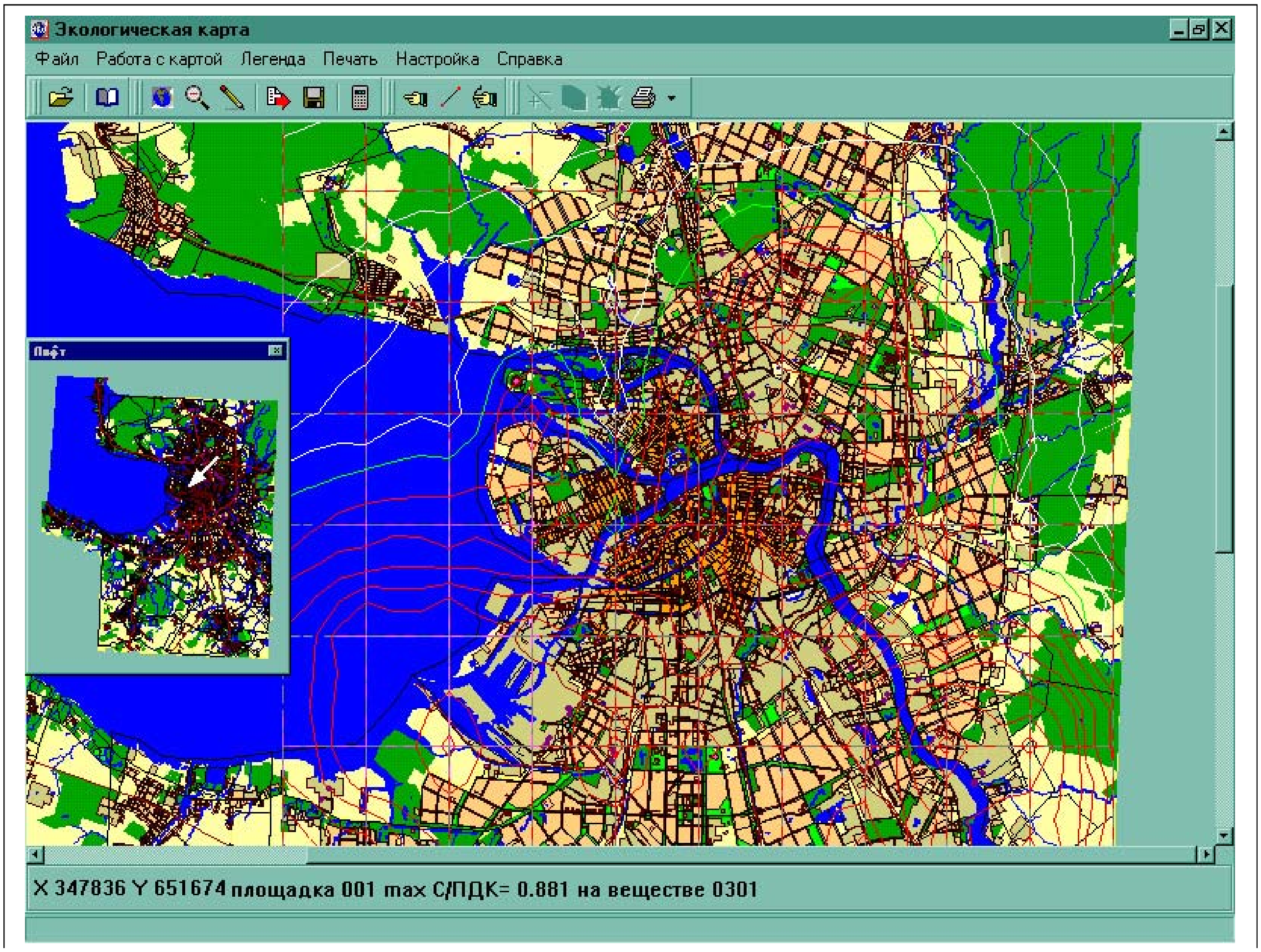

Figure 3. Map of St. Petersburg superimposed with isolines of normalized concentration of NO_2; the whole computational domain is shown in the side panel.

Concluding remarks

Urban air quality management systems are convenient and efficient tools widely used in Russia in practical applications. At the moment, in particular, "Ecologist-City" is installed in 35 major cities in Russia and other republics of the fUSSR including Moscow, St. Petersburg, Nizhnii Novgorod, Novosibirsk, Ekaterinburg, Samara, Perm and others. Municipal administrations and/or other authorities responsible for the environmental and health protection actively use it. Decisions, made on the basis of calculations of short-term concentration fields carried out with this UAQMS, are accepted in Russia as a legal reason for establishing the levels of permissible emissions and emission control. In the nearest future computations with the long-term dispersion model will have a status similar to those with the short-term one.

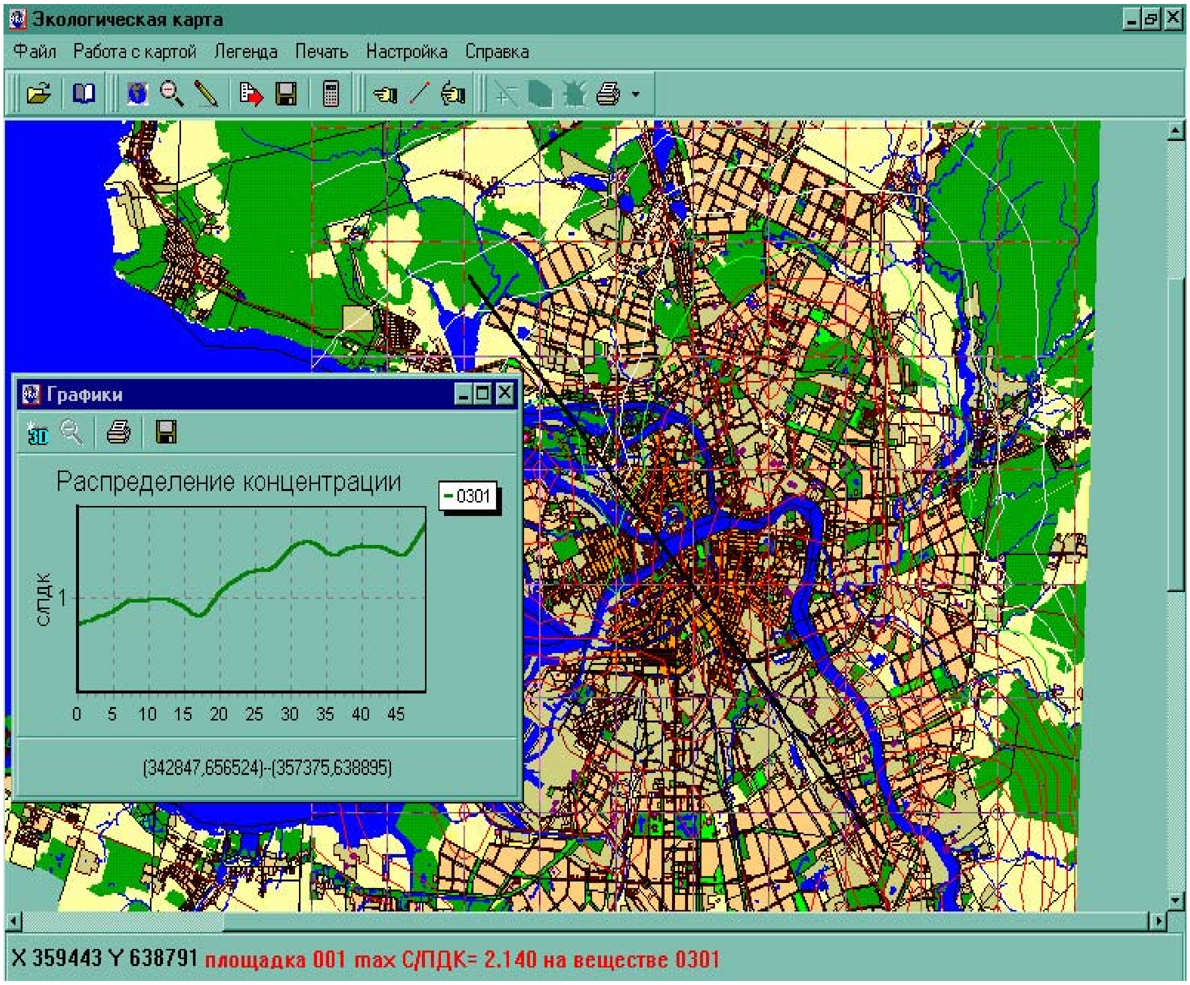

Figure 4. Map of St. Petersburg superimposed with isolines of normalized concentration of NO_2; a "cross-section" of the concentration distribution along the solid black line is shown in the side panel.

There are certain features of Russian UAQMSs that could be of some interest even for foreign users. First of all, the short-term dispersion model built in into these UAQMSs can be used in any, not necessarily Russian, city as a "screening tool" for estimating the "majorant" fields of upper 98^{th} percentiles of PDF of concentrations. The errors of these estimates are inside 25% (see for example Berlyand, 1982; Genikhovich, 1998). Higher percentiles, required for example by EU directives, can be easily estimated with this model using well-known correction factors. It should be noted that these estimates actually do not require any meteorological input. It greatly simplifies the task of collecting the input data and make possible fast computations of multiple scenarios of emission reduction, for example, and comparison of their efficiencies. The system can be used also for backward dispersion calculations; in this mode it can determine permissible levels of emissions.

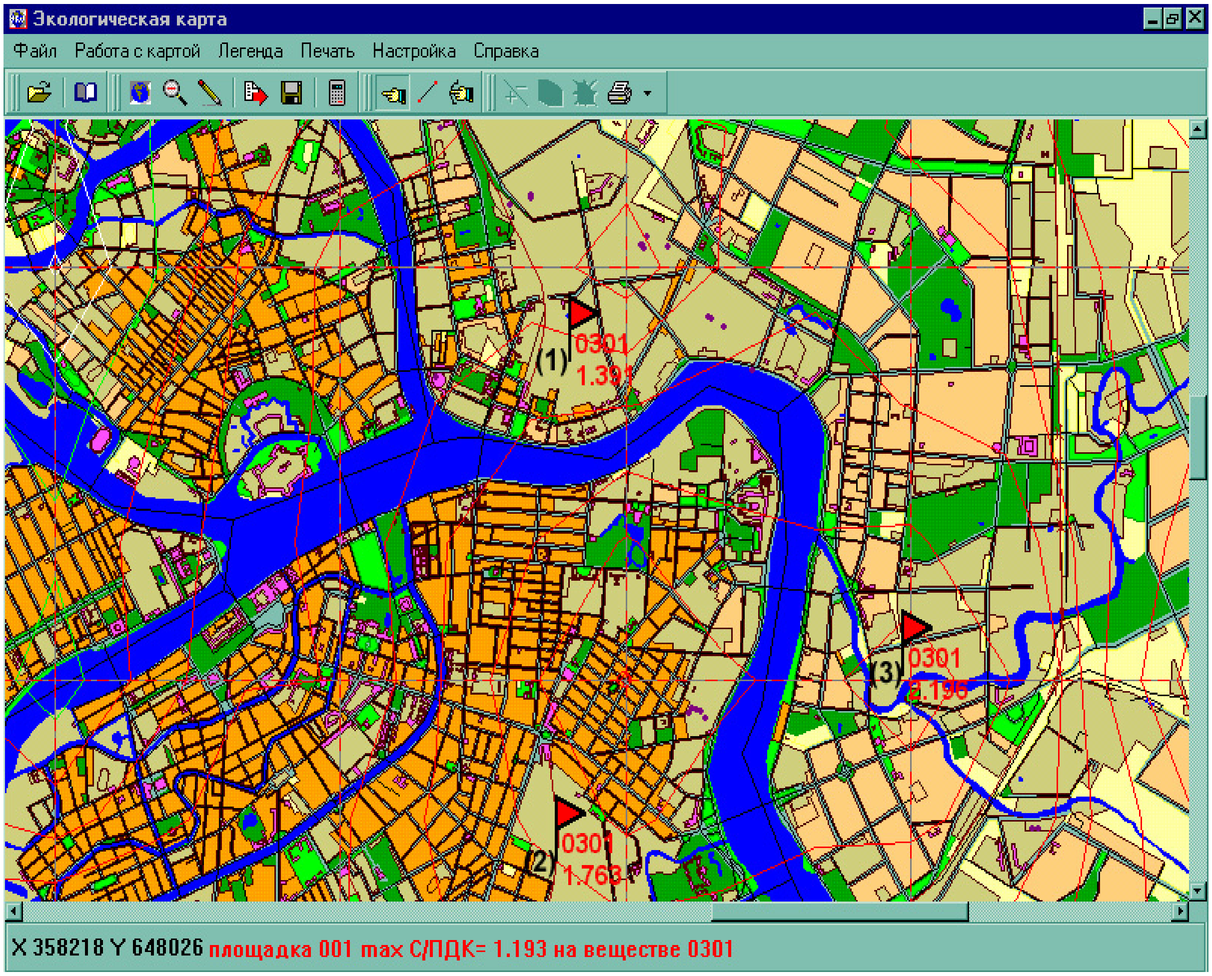

Figure 5. A fragment of the map of St. Petersburg with selected receptor points marked with flags. Figures under markers indicate the code of pollutant and its dimensionless concentrations.

It seems to be possible also to use Russian UAQMSs in order to achieve better understanding of similarities and differences between requirements to the atmospheric environment imposed by Russian and, for example, western regulatory guidelines. It is especially important for European countries because, at least as a goal, we all should try to achieve a certain level of harmonization in those requirements in Europe. These UAQMSs cold be also of certain interest for the users involved in technical cooperation with Russian partners, design and construction of enterprises located in Russia and other activities related to the problems of environmental protection in Russia.

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