Study of changes in concentration of pollutants in the atmosphere of St. Petersburg under conditions of a critical ecological situation

V.S. Komarov,[1] Al-Nabelsi Talal,[2] V.I. Akselevich,[2] and S.N. Il'in[1]

[1] *Institute of Atmospheric Optics, Siberian Branch of the Russian Academy of Sciences, Tomsk*
[2] *Russian State Hydrometeorological University, St. Petersburg*

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Changes in the concentration of pollutants under conditions of a critical ecological situation are considered. The so-called phenomenon of "smoky haze," covering St. Petersburg on September 5 of 2002, is analyzed as an example.

Introduction

The intense development of industry, transportations, and power production industry in Russia has caused a continuous increase of pollution emissions into the atmosphere. Therefore, the environmental monitoring now includes regular observations of the air pollution, which are carried out at more than 700 stations throughout the territory of the Russian Federation. These stations make up the unified State Monitoring Network (SMN) for monitoring of atmospheric pollution. Pollutant concentrations are monitored using the unified standard measurement methods (standard MMs), whose rules and programs are regulated.[1] The use of unified measurement programs and methods for determination of concentrations provides for uniform measurements at all the SMN stations.[2]

In general, such a monitoring system already does not meet the current needs in the information about the state of the environment. Indeed, it can be used for routine work and compilation of the state database, from which it would be possible to reveal the state, causes, and tendencies in the variation of the environmental parameters. However, at the current SMN organization, the data on the pollutant concentrations have, in the best case, a 24-hour lag. Local authority can obtain the information *post factum*, that is, for the past days, but this is useless for real-time monitoring. At the same time, it is impossible to guarantee the environmental safety of the population without the real-time detection of episodes of high pollutant concentrations, as well as emergency emissions of pollutants into the atmosphere.

When such situations occur, for the corresponding authority to take the proper measures for liquidation of negative consequences, the air quality should be monitored in real time. This vitally important problem can be solved only by equipping SMN with automated gas analyzers (GAs), permanently monitoring the air quality in the routine mode. The implementation of GAs into the SMN is a very urgent problem, promising and practically necessary for Russia.

In the late 1980s, ANKOS automated stations were designed for monitoring of the atmospheric air.[3] These stations are intended for continuous monitoring of the time- and space-variable characteristics of atmospheric pollution and meteorological parameters of the air in big cities and industrial centers, as well as for the fast prediction of the pollution level. They were employed in several cities of the former USSR. However, the mass implementation of these stations into SMN was stopped in early 1990s because of the lack of funding.[4]

Finally, in the early 2000s in St. Petersburg, eight (eleven by January 1 of 2005, and 15 are planned by the end of 2005) automated stations were manufactured. These stations are joined into the unified automatic system, whose operation is controlled from the common information-analytical center. The main instrumentation of these stations is represented by gas analyzers certified as measurement facilities. They are produced in the Russian Federation by the OPTEK Instrument-Making Plant. This automatic system for monitoring of the air pollution has yielded reliable many-year information about the air pollution in St. Petersburg, as well as its tendencies and causes. An important circumstance is also that the continuous observations of the concentrations of harmful pollutants with the interval of 20 min favors the detailed investigation of the processes of appearance and development of heavy (and, especially, critical) ecological situations, which occur sometimes in the city.

This paper considers the results of investigation into the variation of the pollutant concentrations under conditions of the critical ecological situation, which occurred in St. Petersburg in September 1–10 of 2002 under the effect of heavy smokes caused by mass peat fires. This phenomenon was not predicted properly, and the mass media informed the population about it *post factum*. Neither the beginning nor the duration

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or the end of this phenomenon was predicted. Correspondingly, the Ministry of Emergency Situations of the RF did not respond appropriately to this situation.

For the analysis of the pollutant concentrations (C, mg/m^3) under conditions of the critical (nonstandard) ecological situation observed in September 1–10 of 2002, the following data were used:

– observations of the carbon monoxide (CO), nitrogen monoxide (NO), nitrogen dioxide (NO_2), and dust concentrations at three automated air pollution monitoring stations: No. 6 (Gavanskaya St.), No. 7 (Tavricheskii Ave.), and No. 8 (Komarova St.), with the interval of 20 min;

– results of manual three-term (7, 13, and 19 LT) observations of the carbon monoxide, nitrogen monoxide, nitrogen dioxide, ammonia (NH_3), phenol (C_6H_5OH), formaldehyde (HCHO), and dust concentrations at five environmental monitoring stations situated in different districts of St. Petersburg: No. 1 – Petrogradskii District (78, Professor Popov St.); Nos. 4 and 5 – Kalininskii District (88, Grazhdanskii Ave. and 47, Polyustrovskii Ave.); No. 7 – Vasileostrovskii District (2a, 23th line V.O) and No. 8 – Moskovskii District (15, Novoizmailovskii Ave.). Ammonia was measured only at three stations, nitrogen monoxide was observed at two stations; formaldehyde – at one station, and phenol – at two stations, but only twice a day;

– official data of the Committee of Nature Management, Environmental Protection, and Provision of Ecological Safety at the Administration of St. Petersburg.

In addition, to reveal the causes of the appearance and development of the critical ecological situation in St. Petersburg, the following data were used:

– observations at four ground-based meteorological stations: St. Petersburg, Pushkin, Lisii Nos, and Kronshtadt with the interval of 3 hours;

– results of temperature and wind sounding at the station Voeikovo, carried out twice a day (00 and 12 GMT).

The analysis of the initial meteorological data shows that during the weather observations with the interval of 3 h the following weather phenomena were observed for the studied period according to the information of the St. Petersburg, transmitted into the Weather System: haze – 10 times, mist – 12 times, smoke – 4 times, shower – 2 times (in particular, between observations). In addition, from the data of 2-time radiosonde observations it was found that in the morning hours (five of which were characterized by low visibility) the surface inversion was observed nine times. In the period under study, the stable stratification was observed only five times, while the unstable one was observed 15 times.

An important feature of the considered period was also different character of observations at different stations. Some stations situated within the city (Pushkin, Lisii Nos, Kronshtadt) observed fog, but fog was not observed in St. Petersburg at these same periods, though it was observed as weather between the observation terms at the relatively low humidity.

Let us consider now the peculiarities in variations of the concentrations of some pollutants (in particular, carbon monoxide, nitrogen monoxide, nitrogen dioxide, and dust) in the period of the critical ecological situation observed in St. Petersburg in September 1–10 of 2002. For this purpose, look at Fig. 1, which presents the temporal variations of the concentrations of these pollutants.

As follows from Fig. 1*a*, in the considered period, the diurnal mean concentration of carbon monoxide (denoted as "mean") exceeded the maximum permissible concentration (MPC dm) in 46% of cases. The highest diurnal mean value was observed on September 5 of 2002 and amounted to 12.2 mg/m^3. The maximum ("Max") concentration of carbon monoxide exceeded the one-time maximum permissible concentration (MPC ot) in 76% of cases. The maximum values peaked on September 6 (23.37 mg/m^3) and September 9 of 2002 (17.4 mg/m^3).

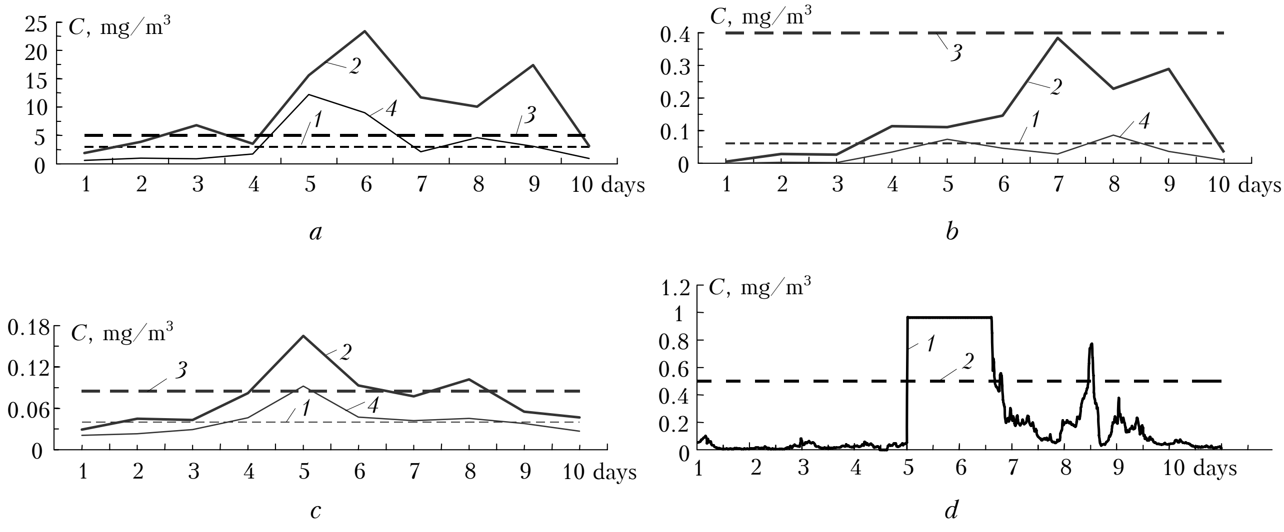

Fig. 1. Temporal variations of the concentration of carbon monoxide (*a*), nitrogen monoxide (*b*), nitrogen dioxide (*c*), and dust (*d*): (*a*, *b*, *c*) MPC dm (*1*), Max (*2*), MPC ot (*3*); mean (*4*); (*d*) dust (*1*), MPC ot (*2*).

From Fig. 1*b* it can be seen that for the same period the diurnal mean concentration of nitrogen monoxide exceeded the maximum permissible concentration in 17% of cases. The highest diurnal mean value was observed on September 8 of 2002 and amounted to 0.086 mg/m^3. The maximum concentration of nitrogen monoxide did not exceed the maximum permissible one. The one-time maximum value was observed on September 7 of 2002 and amounted to 0.384 mg/m^3.

From Fig. 1*c* it can be seen that diurnal mean concentration of nitrogen dioxide exceeded the maximum permissible concentration in 53% of cases. The highest diurnal mean value took place on September 5 of 2002 and amounted to 0.092 mg/m^3. The minimum value of the mean concentration for this period occurred on September 1 of 2002 and amounted to 0.021 mg/m^3. The maximum concentration of nitrogen dioxide exceeded the maximum permissible value in 38% of cases. The highest concentration was observed on September 5 of 2002 (0.165 mg/m^3).

The situation with dust, whose concentration was estimated at station No. 8, turned out most complicated. Actually, if the diurnal mean concentration of dust exceeded the maximum permissible value in 20% of cases and had one peak (0.965 mg/m^3) observed on September 5 and 6, then the one-time concentration had two peaks exceeding MPC ot (Fig. 1*d*), first of which (0.965 mg/m^3) occurred on September 5–6, while the second one (0.54–0.77 mg/m^3) on 11–13 LT of September 8 of 2002.

From the observed concentrations of CO, NO, NO_2, dust, and ozone (O_3), we can see that the one-time maximum concentration for CO, NO_2, and dust were exceeded in the considered period. And the time of this excess was not the same, as is clearly seen from Table 1, which summarizes the data obtained at station No. 7 "auto" (such stations are situated near motor ways or in regions with intense traffic) and station No. 8 "urban background," situated in a residential area of the city.

The analysis of Table 1 shows that the longest periods of the excess of the pollutant concentrations over the one-time maximum concentrations were observed for 39 hours on September 4–6 for CO, for 5 hours on September 5 for NO_2, and for 29 hours on September 5–6 for dust.

If we consider the synoptic situation, then it turns out that a slow-moving and rather intense anticyclone, determining the corresponding weather, was observed in the region of St. Petersburg on September 4–6 (Table 2).

Table 1. Periods, during which the one-time maximum permissible concentration was exceeded for some pollutants in St. Petersburg on September 1–10 of 2002

Pollutants	CO	NO_2	Dust
MPC ot, mg/m^3	5.0	0.085	0.5
Station No. 7	23^{40} 4 IX – 14^{40} 6 IX 23^{40} 7 IX – 04^{40} 8 IX 09^{00} 8 IX – 12^{20} 8 IX 23^{00} 8 IX 09^{00} 9 IX – 09^{40} 9 IX	06^{00} – 10^{00} 5 IX 11^{00} 6 IX 11^{40} 6 IX – 12^{00} 6 IX 13^{40} 6 IX – 14^{40} 6 IX 11^{20} 8 IX – 13^{40} 8 IX 11^{00} 9 IX – 11^{20} 9 IX	20^{20} 4 IX – 14^{00} 5 IX 08^{40} 8 IX – 13^{20} 8 IX 08^{00} 9 IX – 09^{20} 9 IX
Station No. 8	05^{40} 3 IX 00^{00} 5 IX – 14^{40} 6 IX 09^{00} 7 IX 22^{00} 7 IX – 01^{40} 8 IX 03^{00} 8 IX 04^{20} 8 IX – 06^{00} 8 IX 07^{00} 8 IX – 12^{20} 8 IX 22^{20} 8 IX – 23^{00} 8 IX 00^{40} 9 IX 07^{20} 9 IX – 10^{00} 9 IX	10^{20} 5 IX – 15^{20} 5 IX 16^{20} 5 IX – 17^{00} 5 IX 17^{40} 5 IX – 18^{00} 5 IX 11^{00} 6 IX – 12^{20} 6 IX 14^{00} 6 IX – 14^{20} 6 IX 11^{00} 8 IX – 12^{20} 8 IX	10^{20} 5 IX – 15^{40} 6 IX 18^{20} 6 IX – 19^{00} 6 IX 11^{00} 8 IX – 13^{00} 8 IX

Table 2. Some data on meteorological conditions in St. Petersburg on September 4–6 of 2002

Date	Time, h	Wind		Surface inversion		Weather phenomena		Stratification
		direction	speed, m/s	thickness, m	intensity, °C	Phenomenon at the term /between terms	Visibility, km	
Sep 04 of 2002	00	calm		405	0.5	–	10	stable
	12	SW	2	–	–	–	10	unstable
Sep 05 of 2002	00	SE	1	242	3.0	smoke	2	stable
	12	SE	1	–	–	haze	0.2	stable
Sep 06 of 2002	00	calm		250	2.2	haze	0.2	unstable
	12	SW	2	–	–	haze	1	unstable

So, the smoky haze appeared at a slight southeastern wind and stable stratification. The development of unstable stratification and convective flows and then, first, the intensification of the southwestern wind and its further turn to the west and north-west favored the dispersal of the smoke haze. But even the form of stratification and the wind are difficult to forecast at the low wind velocity, when we deal with a smoky haze.

For the analysis of variations of atmospheric pollution, whose results were mentioned above, the one-time concentrations were compared with the one-time maximum permissible concentration (MPC ot), while the mean values were compared with the diurnal mean MPC (MPC dm).

It is accepted in practice[5] that the cases when the content of one or several substances exceeds the one-time maximum permissible concentration:

– 20–29 times with this level keeping for more than 2 days;

– 30–49 times with this level keeping for 8 h and longer;

– 50 and more times are classified as extremely high pollution (EHP) of the atmospheric air, and the cases of tenfold and higher excess are considered as high pollution (HP).

In September 2002 the level of air pollution in the city as a whole was "high." The major contributors to the pollution of the atmospheric air were nitrogen dioxide and suspended matter. The standard index (SI), being the highest pollutant concentration measured for a short period (20 min) normalized to the MPC of this pollutant,[1,6] amounted to 9.8 for nitrogen dioxide and 7.8 for suspended matter. The frequency of excess over MPC ot by the nitrogen dioxide and suspended matter concentrations was 28.3 and 22.9%, respectively. The mean level of air pollution was 2.8 MPC dm for suspended matter and 1.8 MPC dm for nitrogen dioxide. The level of air pollution by pollutants such as phenol, hydrogen chloride, and ammonia was "increased." The standard index for them amounted to 3.2, 1.6, and 3.9, respectively.

The air pollution in all areas of the city, where the concentrations of sulfur dioxide, nitrogen monoxide, and hydrogen sulfide were monitored, was low: the monthly mean and one-time concentrations did not exceed the standard values. The content of heavy metals in the urban air did not exceed MPC.

In September 2002, the air pollution remained to be the highest (in the city) in the Tsentral'nyi, Kalininskii, and Kirovskii districts.

Thus, the investigations and analysis of the synoptic situation and weather conditions, as well as the plots and the Tables illustrating the variation of meteorological parameters and atmospheric pollution indices, have revealed the main features and causes of atmospheric air pollution in St. Petersburg under conditions of the critical ecological situation. In addition, the results obtained allow us to draw some general conclusions concerning the organization and conduction of environmental monitoring at the level of a megalopolis, namely:

1. The system for monitoring of the environment in general and atmospheric air in particular should be many-level, with convenient circular and fast information exchange top–down and information acquisition down–top.

2. Every station should be equipped with communication facilities (better, mobile and computer) for organization of the fast exchange of information.

3. A minimum set of sensors should include analyzers for express measurements of the concentrations of SO_2, NO_x, CO, soot, O_3, and dust.

4. It is necessary to develop devices responding to empyreuma and the smoky odor and capable of determining quantitatively the degree of air pollution, disturbing the human comfort and causing the sharp increase in the number of asthma attacks.

The organization of such a system will exclude the unexpected occurrence of critical ecological situations, similar to that which took place in St. Petersburg on September 1–10 and, especially, on September 5 of 2002 and will actually serve to protect the human health under conditions of severe pollution.

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