RESULTS OF CLIMATIC-ECOLOGICAL MONITORING AT THE TOR STATION. IV. ESTIMATION OF THE EFFECT OF URBAN ENVIRONMENT

B.D. Belan, E.V. Pokrovskii, T.M. Rasskazchikova, and G.N. Tolmachev

Institute of Atmospheric Optics,
Siberian Branch of the Russian Academy of Sciences, Tomsk
Received July 21, 1994

The possible effect of the urban environment of Tomsk on the air composition monitored at the TOR station has been estimated. For this purpose, an experiment was performed in July of 1993 to measure the same parameters under background conditions. It has been demonstrated that the urban environment affects only some parameters as compared with the background conditions. Data of monitoring at the TOR station were unaffected by industrial emissions.

The preceding papers of this series presented results of annual monitoring of the meteorological parameters and gas and aerosol composition of the atmospheric air at the TOR station located in the Tomsk Akademgorodok.[1] When interpreting these results, we were not always able to explain correctly one or another fact revealed in the course of data processing.[2–4] On the one hand, this is due to complexity of atmospheric processes which in most cases were governed by superposition of different mechanisms. On the other hand, due to the urban environment of an industrial center, Tomsk, a possible anthropogenic effect of industrial emissions on one or another process must be constantly kept in mind when interpreting results. The present paper is devoted to the estimation of a possible effect of urban environment on measurement data.

For practical implementation of this task, simultaneous measurements were performed at the Scientific Base of the Institute of Atmospheric Optics in Kireevsk and at the TOR station in July of 1993. During a comparative experiment, the same parameters were monitored in Kireevsk and at the TOR station. In addition, aerosol samples were taken at the same intervals as in Ref. 4 to analyze the particle composition. Recall, that Kireevsk is 60 km west of Tomsk, on the river Ob' bank. In the vicinity of Kireevsk, there are no large industrial centers. It may be suggested that the air mass passed through Kireevsk arrives then in Tomsk. The effect of urban environment can be estimated based on an increment in the concentration.

First we turn our attention to the temporal variability of the meteorological parameters at the above-indicated stations, shown in Fig. 1. As is seen from Fig. 1, the air temperature and humidity at both stations varied practically synchronously. Only the amplitudes of daily variations were different. They were slightly larger in Kireevsk. Evidently, this is due to a well-known effect of urban environment as an "island of heat."[5] The trends of seasonal variations also coincide. The daily variations of the air humidity and temperature were opposite. Thus, the temporal variations of temperature and humidity in Kireevsk and Tomsk support the assumption that air masses pass in turn through the stations.

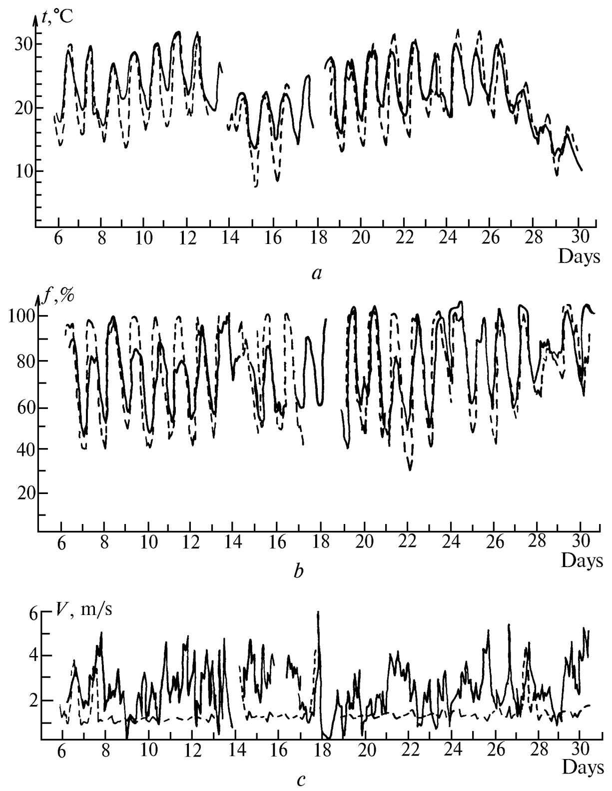

FIG. 1. Variations of the meteorological parameters in Tomsk (———) and Kireevsk (— — —) in July of 1993: a) temperature, b) humidity, and c) wind velocity.

0235-6880/95/09 721-04 $02.00

At the same time, the wind regime at both stations turned out to be substantially different (Fig. 1*c*). The wind velocity in Kireevsk was found to be much lower than in Tomsk. Only on 6, 7, 9, 14, 18, and 27 of July its values at both stations were commensurate. This fact may be explained alternatively: first, by different heights of installation of anemometers, namely, 6 m height in Kireevsk and 6 m height above the roof of a three-storied building in Tomsk that, taking into account large gradients in the ground layer, results in such differences between the wind velocities; second, by the circulation of breeze type developed in the vicinity of large rivers, which is disturbed only with the air mass change.[6] When comparing Figs. 1*a* and *c*, this assumption is also confirmed. The increase of wind velocity in Kireevsk coincides in time with the change of sign of the air temperature trend, what is characteristic of the air mass change.[7]

Synchronous character and close values of the amplitudes of variations at both stations also have been recorded for the aerosol number density and carbon monoxide concentration. Plots of variations of these parameters are not shown here due to slight differences between their values in Tomsk and Kireevsk.

We dwell on those air components that differ greater.

At first, we consider the plots of temporal variations of ozone concentration shown in Fig. 2. It can be seen from Fig. 2 that the ozone concentration in the ground atmospheric layer in Tomsk is much higher (by a factor of 2 to 7) than in Kireevsk. In this case, the variations of the ozone concentration are synchronous. These results indicate that the air masses coming to this region are enriched with ozone in the region of Tomsk. The average increase for July is 3.2 times. It is evident that ozone generation occurs along the path of air motion from Kireevsk through Tomsk to the TOR station. Whether ozone is generated in the town or in its environs, will be considered below.

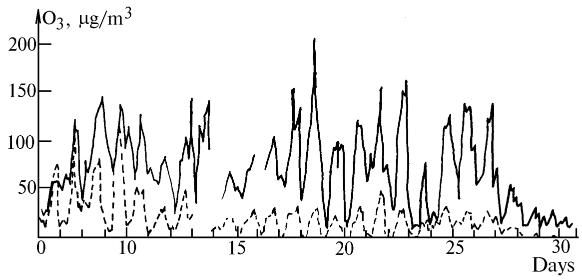

FIG. 2. Temporal dynamics of the ozone concentration in Tomsk (———) and Kireevsk (— — —) in July of 1993.

Synchronous variations of gas concentration with aerosol number density indicates that the spatial scales estimated in Refs. 3 and 4 are valid at the distance from Kireevsk to Tomsk being equal to 60 km.

Particle samples make it possible to identify the elements with which the aerosol particles are enriched in the process of their transfer from Kireevsk to Tomsk.

It is clear from Table I that, on average, for a month the mass aerosol concentration in Tomsk is higher than in Kireevsk by a factor of 1.42. The enrichment can be noted for most of the components being determined. At the same time, the K^+ concentration decreased by a factor of 3, the As concentration decreased almost by a factor of 3, the Si concentration − more than by a factor of 3, the Mo concentration − more than by a factor of 2, and the Cu concentration decreases by a factor of 6.5. The concentration of Cl^-, Br^-, SO_4^{2-}, Zn^{2+}, Hg^{2+}, Ti, U, and Ca remained almost unchanged. This is indicative of the absence of intense sources of the above components on the path of air mass transport.

TABLE I. Chemical composition of aerosol (μg/m²) in Kireevsk and Tomsk in July of 1993.

Element	Tomsk	Kireevsk	Ratio
pm	4.64 + 0.63	4.89 + 0.59	0.95
K^+	0.08 + 0.05	0.24 + 0.07	0.33
Na^+	0.60 + 0.22	0.05 + 0.06	12.00
Cl^-	0.01 + 0.003	0.01 + 0.01	1.00
Br^-	0.03 + 0.01	0.03 + 0.02	1.00
NO_3^-	0.05 + 0.03	0.02 + 0.01	2.50
NH_4^+	0.13 + 0.12	0.03	−
F^-	0.004	−	−
SO_4^{2-}	2.90 + 1.19	2.58 + 1.92	1.12
Zn^{2+}	0.01 + 0.006	0.009 + 0.006	1.11
Cd^{2+}	0.003 + 0.002	0.001 + 0.001	3.00
Hg^{2+}	0.001 + 0.001	0.0008 + 0.0006	1.25
As^{5+}	0.003 + 0.003	0.008 + 0.007	0.38
Mn	0.025 + 0.010	0.015 + 0.010	1.67
Fe	0.20 + 0.14	0.13 + 0.08	1.54
Cr	0.008 + 0.001	0.005 + 0.001	1.60
Pb	0.001 + 0.001	0.0006 + 0.0003	1.67
Mg	0.11 + 0.03	0.08 + 0.04	1.34
Ni	0.002 + 0.001	0.001 + 0.0004	2.00
Ti	0.04 + 0.02	0.05 + 0.02	0.80
U	0.0001 + 0.0001	0.0001 + 0.0001	1.0
Al	0.15 + 0.06	0.10 + 0.03	1.50
B	0.005 + 0.004	0.0025 + 0.0020	2.00
Ca	0.09 + 0.03	0.10 + 0.06	0.90
Si	0.14 + 0.57	0.48 + 0.40	0.29
Mo	0.0001 + 0.0001	0.0002 + 0.0001	0.50
Sn	0.0008 + 0.0001	0.0005 + 0.0002	1.60
Cu	0.0006 + 0.0005	0.004 + 0.002	0.15
	5.5926	3.9477	1.42

The concentration of the components Na^+, NO_3^-, Cd^{2+}, Ni, and B increases considerably. Since these components usually have anthropogenic origin, it is believed that synchronous variations of their concentration is indicative of the fact that it increases under the effect of urban environment.

We now turn our attention to Fig. 3, which shows the July dynamics of NO_3^- and SO_4^{2-} ions. It may be noted that these aerosol components at both stations behave similarly. However, they are not so synchronous as the plots of ozone, temperature, and air humidity (Figs. 1 and 2). It is possible that this is due to averaging when aerosol samples are taken and the daily variations are smoothed out. Nevertheless, as follows from Fig. 3*a*, the NO_3^- increase is nearly constant within a month that is definitely indicative of the effect of urban environment. The same can be said about Na^+, Cd^{2+}, Ni, and B.

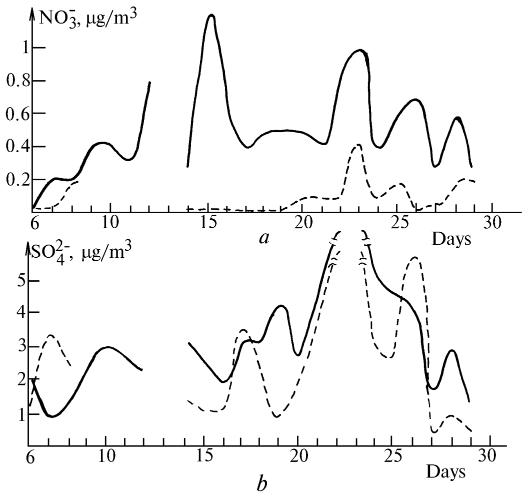

FIG. 3. Time dependence of the concentration of the NO_3^- *(a) and* SO_4^{2-} *(b) ions in Tomsk (———) and Kireevsk (— — —) in July of 1993.*

The above-indicated decrease of concentration of K^+, As^{5+}, Si, Mo, and Cu accompanying the air mass transport from Kireevsk to Tomsk is likely to be connected with the change of the character of underlying surface. In particular, in the region of Kireevsk the sandy banks of the river Ob' may serve as a source of Si. And because Si forms the coarse-dispersed particles, they are rapidly removed from air flow due to sedimentation. This mechanism is supported by the estimated spatial scales of the coarse-dispersed aerosol fields given in Ref. 4.

To summarize, we note that at least in July of 1993 Tomsk contributed to the increase of concentration of some gaseous and aerosol components of the air. At the same time, synchronous measurements of the most of the parameters monitored in Kireevsk and at the TOR station indicate that general circulation processes were also recorded at the station.

The effect of urban environment on measurements at the TOR station should be manifested through the increase of concentration of one or another ingredient for definite wind directions. In particular, because the station is east of the town,[1] the effect of urban environment should be manifested primarily for winds with western component.

Analysis of the values of concentration of carbon monoxide and dioxide recorded at the TOR station for different wind directions did not reveal any significant dependence. The ozone and aerosol concentration turned out to depend more strongly on the air mass transport direction. In this case, the aerosol component appeared to be so variable that it was difficult to say about any regularities. For the aerosol component one preferable direction of transport is monthly revealed, which varies randomly during a year. The ozone behavior is more stable (Fig. 4).

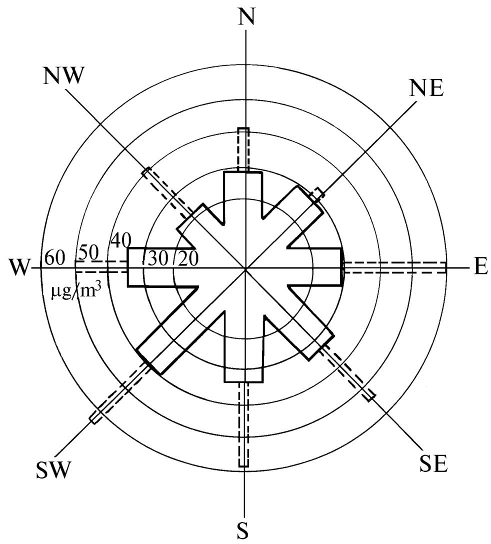

FIG. 4. Variations of the ozone concentration (μg/m³) as functions of the wind direction: [solid box] *, cold season;* [dashed box] *, warm season.*

Figure 4 shows that the maximum ozone concentration is observed in a cold season in southeast, southern, southwest and western directions. The minimum ozone concentration is observed in northwestern direction. In summer, the minimum values of concentration are observed for winds with northern components, and the maximum values of concentration are observed in southern quadrant and eastern direction.

Such a variation of the ozone concentration points to the fact that there is no correlation between the ozone concentration and the air mass transport through the city. Most likely we observe here the effect of general circulation processes. We established previously[8] that the ozone concentration in the atmospheric surface layer decreases sharply by thepassage of cold fronts and increases in the rear of warm fronts. Taking into account the well-known relationship between the front passage and the change of the wind direction,[7] namely, that the warm fronts have the southern component of the velocity and the cold ones have the northern component of the velocity, it is easy to interpret the data in Fig. 4.

Thus, analysis of variations of gaseous and aerosol components recorded at the TOR station as functions of the wind direction does not reveal correlation between industrial emissions and the concentration of the components. It is possible that the effect of urban environment turns out to be extended to distances larger than the distance from the outskirts of the town to Akademgorodok.

To summarize the entire cycle of investigations, we can draw the conclusion that our monitoring reveals the regional variability of the parameters under study.

Moreover, some characteristics indicate the effect of Tomsk environment and therefore must be interpreted with correction.

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