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Space-Time Variability of the Characteristics of Aerosol in the City–Suburbs System (for Novosibirsk as Example)

T. S. SELEGEY[1], K. P. KOUTSENOGII[2], N. N. FILONENKO[1], S. A. POPOVA[2] and T. N. LENKOVSKAYA[1]

[1]*Siberian Regional Research Hydrometeorological Institute, Ul. Sovetskaya, 30, Novosibirsk 630099 (Russia)*

E-mail: selegey@sibnigmi.ru

[2]*Voevodskiy Institute of Chemical Kinetics and Combustion, Siberian Branch of the Russian Academy of Sciences, Ul. Institutskaya 3, Novosibirsk 630090 (Russia)*

E-mail: koutsen@kinetics.nsc.ru

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Abstract

Analysis of average monthly, maximal and minimal values of the mass concentration of aerosol in Novosibirsk and at its south-east outskirts during the years 2005–2008 was carried out. It was revealed that the levels of atmospheric air pollution with aerosol in the city and in the suburbs are formed non-equivalently. A trend for a more stable character of air pollution in the city is observed along with the higher variability in the suburbs.

Key words: city–suburbs system, mass concentration of aerosol, maximal, minimal and average values, annual variation, interannual variability, weather pattern, the level of atmospheric pollution

INTRODUCTION

At present, there are only scarce data on air pollution over suburban areas of large cities, and the data on simultaneous measurements of pollutant concentrations in the city and on its outskirts are almost completely absent. However, the suburban areas are recreation sites for urban population, and any information on air pollution of these areas is very interesting.

The goal of the present work was to study the dynamics of changes in the mass concentrations of atmospheric aerosol in Novosibirsk and its south-east outskirts. Along with ozone, atmospheric aerosol is the main danger for the health of population, and it cannot be excluded that during some time intervals the atmospheric air in suburban areas can be more polluted than the air in the city.

EXPERIMENTAL

We used the averaged data on the mass concentration of aerosol (C_{mass}) (daily averaged aerosol concentration) to measure the spatio-temporal variability of atmospheric aerosol in Novosibirsk and its suburbs. The observations were carried out by the Institute of Chemical Kinetics and Combustion of the SB RAS in Novosibirsk and the Klyuchi settlement during the years 2005–2008 while working on the programme of the Aerosol of Siberia [1].

The observation site for the mass concentration of aerosol in Novosibirsk in 2005–2008 was located in the Leninskiy District of the city, near Municipal Hospital No. 34. In 2008, the observation site was moved to the Zayeltsovskiy District, which had interrupted the homogeneity of observations in the city: the distance between these observation sites is about 7.3 km, and these sites are affected by different sources of pollution [2].

Klyuchi, a settlement situated at a distance of 30 km to the south-east from the centre of Novosibirsk (12 km to the east from Akademgorodok), was chosen as a suburban district. Locations of observation points of aerosol mass concentration are shown in Fig. 1.

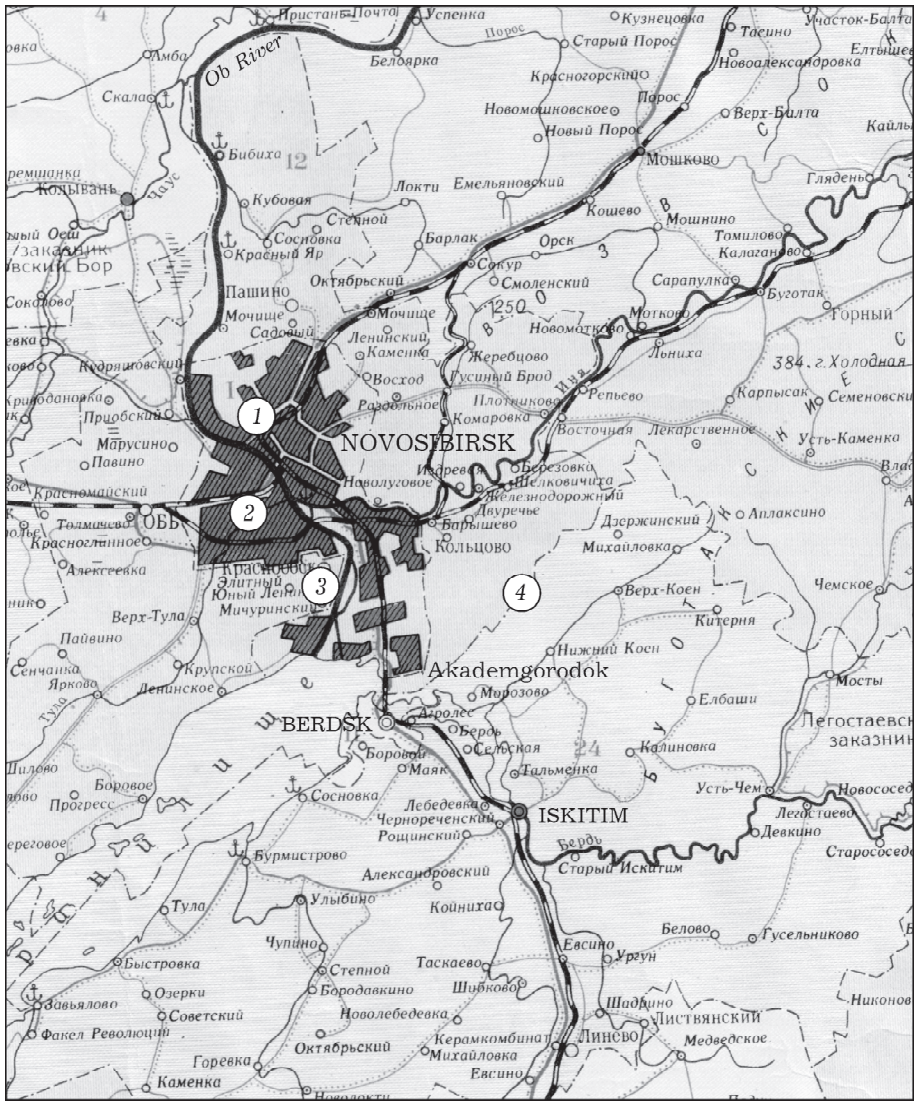

Fig. 1. Locations of observation sites of aerosol mass concentration in Novosibirsk and it the suburban area: *1* – Lineynaya str., 33; *2* – Municipal Hospital No. 34; *3* – Ogurtsovo meteostation; *4* – the settlement of Klyuchi.

Aerosol was sampled on fine fibrous aerosol filters AFA-KhA-20 through the filtration set-up pumping air at a rate of 13 m^3/h for 24 h. All measurements in Novosibirsk and in Klyuchi were carried out in series of 30 days, separately by seasons (winter, spring, summer, autumn), often non-synchronously, which affected the statistic reliability of the results.

RESULTS AND DISCUSSION

To study the annual variations of the mass concentration of aerosol in the system city–suburbs, we determined monthly averaged (C_{av}), maximum (C_{max}) and minimum (C_{min}) values of the mass concentration of aerosol, averaged over the period 2005–2007 (Table 1).

The annual variation of monthly averaged aerosol concentration is shown in Fig. 2 separately for Novosibirsk and Klyuchi. The monthly mean values for C_{av} were restored by extrapolation for those months when observations were missing.

It follows from the data shown in Table 1 and in Fig. 2 that the monthly averaged aerosol mass concentration in Novosibirsk was 1.5–2.0 times higher than that in Klyuchi, because the city is an environment with higher dust level. The highest monthly mean concentrations of aerosol in Novosibirsk were observed in

TABLE 1

Monthly averaged, maximum and minimum values of the mass concentration of aerosol in Novosibirsk and in the settlement Klyuchi (2005–2007), μg/m^3

Parameters	Months of the year											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
	Novosibirsk (Hospital No. 34)											
C_{av}	53.8	51.2	50.7	122.2	84.5	104.6	73.2	71.1	71.3	81.6	–	–
C_{max}	97.4	100.3	73.4	180.8	128.2	150.6	104.8	104.5	113.1	122.4	–	–
C_{min}	26.0	26.3	38.5	49.4	42.3	62.5	14.7	28.5	39.1	26.9	–	–
N	19	42	7	16	45	16	45	11	17	49		
	Klyuchi settlement											
C_{av}	31.7	35.2	–	46.8	71.0	41.8	35.3	–	30.0	33.3	–	–
C_{max}	64.1	98.0	–	138.8	297.3	91.0	116.3	–	90.3	135.0	–	–
C_{min}	10.2	10.4	–	15.5	5.1	8.5	9.8	–	4.9	4.2	–	–
N	35	54		33	56	33	56		23	57		

Notes. 1. N is the number of measurements. 2. Dash – no data.

April, due to soil erosion and evaporation of dust particles from the surface of the earth, not covered by grass yet. In the suburban area (Klyuchi settlement), the peak of monthly averaged values of aerosol mass concentration is in May. Obviously, this is due to delayed snow melting and as a result later baring of soil and plant flowering.

The maximum concentrations of aerosol for individual days for Novosibirsk during the whole year (except May) are also higher than or comparable to similar data for suburban areas. The aerosol concentration in the city is 2.5 times lower than in suburbs in May. Especially large differences in the maximum concentrations of aerosol were recorded in the first and second decades of May. Apparently, this is because during this period the territory of the city is already cleaned and starts to get covered with grass, while in the suburbs a significant amount of dust is carried into the air from bare soil after snow melting.

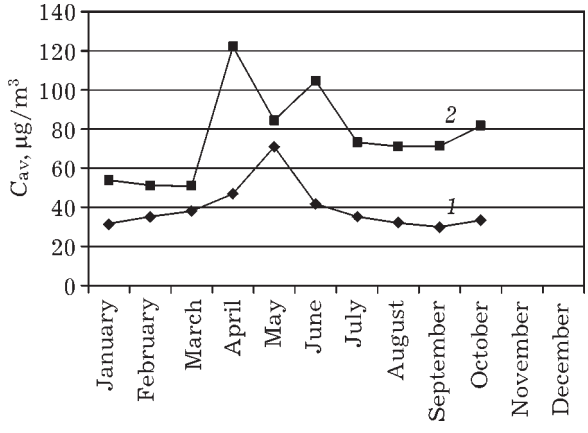

Fig. 2. Annual variation of monthly averaged values of mass concentration of aerosol in the Klyuchi settlement (*1*) and in Novosibirsk (*2*) during the years 2005–2007.

Over the period of 2005–2007, the average minimum daily aerosol concentration in Novosibirsk was 35 μg/m^3 with fluctuations during some months from 14.7 to 62.5 μg/m^3. Minimum aerosol concentration in Klyuchi for individual days decreased to 4–10 μg/m^3, only in April (in years with early spring), they were at a level of 15.5 μg/m^3.

The annual amplitude of daily aerosol concentrations (maximum/minimum) in Klyuchi was 293 μg/m^3, in Novosibirsk only 166 μg/m^3. This indicates a more stable character of the formation of the mass concentration of aerosol in the city compared to the suburbs. Obviously, suburban areas are under stronger influence of various factors that lead to a sharp increase in aerosol mass concentration and its rapid decline during short time. In this regard, the following should be noted: Klyuchi is affected by the transport of pollutants emitted from three industrial cities. Novosibirsk is situated to the north-west from the settlement; Iskitim is situated at a distance of about 20 km to the south-southeast, Berdsk lies at a distance of 13 km to the south-west. All these cities have well-developed industry and significant thermal power

complex, so they can affect the formation of the air pollution level in the settlement of Klyuchi.

Dates of detection of the minimum and maximum concentrations of aerosol in the city and its suburbs are not the same, which also indicates that different factors determine the mass concentration of aerosols in these areas, including the delay or acceleration of the processes leading to an increase in the mass concentration. So, it is even more interesting to analyze the episodes of simultaneous increases in aerosol concentration in the air of both the city and the suburb. Thus, the analysis of the sampled days with aerosol concentration not less than 100 μg/m^3 in at least one of the sites under consideration showed that in most cases the high concentrations of aerosols in the atmosphere of the city were not accompanied by an equally significant increase in their concentrations in the atmosphere of the suburban area. However, in rare cases, this phenomenon was still the case. For example, for the period 2005–2007, there were three such episodes: May 16–19, 2006, April 22–26, 2007 and May 2–4, 2007 (Table 2).

It was established that in the first case (the period of May 16–19, 2006) a trough elongated from north to south (axis Almaty–Omsk) was passing over the territory of Novosibirsk. As it passed through the Novosibirsk Region, wind direction changed from south-east to north-west, wind speed (u_{av}) was about 3 m/s (average). Obviously, the north-west streams transferred all industrial and other pollutants from the city to the south-eastern periphery, where the concentrations of aerosol were 1.5–2.5 times higher than the average value for the city. As soon as the wind changed its direction on the 20th of May to the south-west, inflow of polluted air from Novosibirsk to the settlement Klyuchi stopped and aerosol concentration decreased to 60–80 μg/m^3.

The second case (April 22–26, 2007) was observed on the background of anticyclone weather type with weak winds (1.0–1.5 m/s) and almost motionless atmosphere up to about 750 m (AT-925 kPa). These conditions contributed to a large accumulation of pollutants over the city and its suburbs within at least 30 km. In the centre of the city, aerosol concentration was 1.5–2.0 times higher than in suburban areas. With a change of the synoptic situation (approaching cyclone), intensification of turbulence occurred, and aerosol concentration decreased to 60–80 mg/m^3. Long stay of the anticyclone weather type, according to [3], leads to an increase in surface air concentrations of aerosol particles approximately by a factor of 1.5. The considered episode confirms the validity of this conclusion.

In the last case (May 2–4, 2007), the recorded the maximum value of the mass con-

TABLE 2

Synchronous periods of aerosol concentration values ($C \geq 100$ μg/m^3) in the city–suburb system

Years	Date	C, μg/m^3		d_{925}*	u_{av}, m/s	Synoptic situation
		Novosibirsk	Klyuchi			
2006	16.05	119.2	222.6	SE	2.8	Trough to the south
	17.05	128.2	191.0	NW	2.8	Sedentary field
	18.05	82.1	195.6	NW	2.4	Saddle, haze
	19.05		168.3	NW	3.4	North periphery of anticyclone
2007	22.04	130.1	61.2	SE	1.5	North-west periphery of anticyclone
	23.04	159.9	114.9	SE	0.8	The same, haze
	24.04	180.8	96.8	SE	1.1	The same
	25.04	152.2	118.8	SE	1.5	Sedentary field
	26.04	154.8	138.8	SW	3.5	North-west periphery of anticyclone
	02.05	120.2	297.3	SW	4.0	Passage of a warm front
	03.05	92.3	103.3	W	7.6	Warm sector
	04.05	101.3	84.1	SW	3.6	« «

* Wind direction to AT-925 gPa.

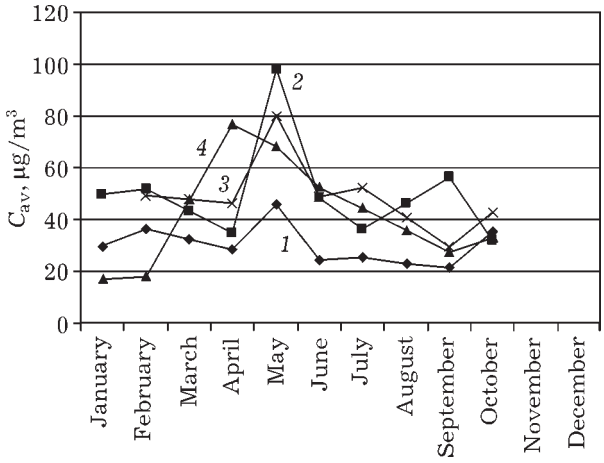

Fig. 3. Annual variations in monthly averaged aerosol concentrations in the settlement Klyuchi: *1* – 2005, *2* – 2006, *3* – 2007, *4* – 2008.

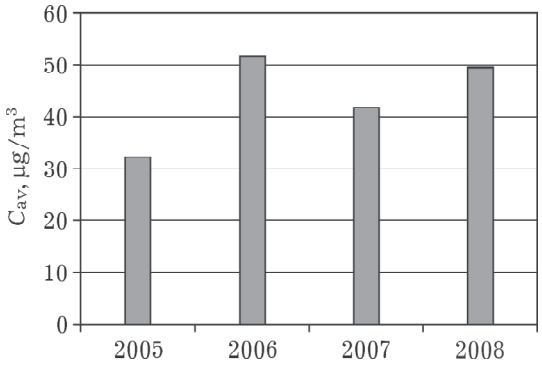

Fig. 4. Annual average concentrations of aerosol in the settlement Klyuchi.

centration of aerosol in the settlement Klyuchi (297.3 μg/m^3) was noted during the passage of a warm front. The front was accompanied by winds of 4–7 m/s, and was moving to the south-west. This case can be described as the flow of air polluted with dust from the south-west of the Novosibirsk Region.

The accumulated data on the mass concentration of aerosol in the settlement Klyuchi suggest interannual variability of this value (Figs. 3 and 4). At the same time, it was impossible to follow the interannual variability of monthly averaged values of aerosol mass concentration in Novosibirsk in the measurement site based on the Municipal Hospital No. 34 because of the small number of observations.

We showed (see Fig. 3) that the average monthly values of the mass concentration of aerosol in the settlement Klyuchi undergo significant not only seasonal but also annual variations. So, in 2005, the concentration of aerosol in the atmosphere was minimal and about 1.5 times less than that detected during other years. The highest concentration of aerosol in the air occurred in 2006 and 2008 (see Fig. 4).

The coefficients of correlation between the mass concentration of aerosol in the settlement Klyuchi and aerosol mass concentration in Novosibirsk, obtained from simultaneous observations, showed moderate closeness of relationship. As an average per year, the coefficient of correlation (r) between these values is equal to 0.40. And only in certain seasons (in summer) it decreased to 0.16, which was due to different time intervals necessary for the formation of the maximum concentrations of aerosil in the city and suburbs. Below we show the value of r for different seasons of the year:

Parameters	Winter	Spring	Summer	Autumn	Year
r	0.35	0.32	0.16	0.28	0.40
N	47	43	41	47	178

CONCLUSION

Thus, the level of air pollution with dust in the city and in the suburbs is formed non-uniformly. There is a tendency of more sustainable air pollution by dust in Novosibirsk and its large variability in the settlement Klyuchi, which indicates the presence of a number of factors influencing this process in the south-eastern suburbs of the city.

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