Dynamics of the microphysical parameters of the near-ground aerosol in Barnaul

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Received January 22, 2004

This paper is devoted to the problem of realizing a combined approach to the study of the main microphysical parameters of the surface urban aerosol in the city of Barnaul. The data on microstructure of the urban aerosol since 1991 until 2003 are presented. The dynamics is studied of such parameters as aerosol mass, number concentration, and mean radius of particles.

Such aerosol characteristics as the dynamics of mass and number concentration depending on the time of a day and meteorological conditions, as well as the peculiarities of the aerosol particle size-distribution are of doubtless interest in solving the problem of monitoring of the near-ground aerosol in an industrial center.

Such investigations are useful for objective estimation of the role of the near-ground aerosol as a climate-forming factor in an industrial center, as well as have a sanitary and hygienic significance. In breathing in a polluted air, the toxicants contained in it, stay long in the respiratory path of a human being, and the following dependence between the particle size and the depth of their penetration is revealed. Up to 70 or even 90% of particles with the diameter of 7 to 10 μm settle in the upper respiratory path and do not penetrate to deep parts of the lungs. Particles of a smaller size (1 to 3 μm) penetrate to the alveolus parts of the lungs, 30 to 35% of them are detained and then, being dissolved, go directly to blood. Smaller particles of the diameters less that 0.1 μm are less dangerous, because the majority of them is breathed in and out and is not detained in lungs.

To estimate the degree of air pollution by aerosol particles and, hence, the quality of the atmosphere and their influence on the human health, it is necessary to know different quantitative aerosol characteristics, including the mass and number concentration as well as the particle size. Particles of the size from 0.3 to 0.5 μm are related to the most dangerous respirable fraction.[1]

The instrumentation complex used for investigations consisted of the setup for aerosol sampling on paper filters, photoelectric aerosol photometer FAN, and the device for observation of the air turbidity PKZV–906. In order to determine the mass concentration of the intermediate aerosol fraction, the samples were collected on the filters of the AFA–KhA–20 type weighed before and after the exposure. The data were recorded in 7 channels with the boundary size of 0.3–0.4; 0.4–0.5; 0.5–1; 1–2; 2–5; 5–10; 10–100 μm; and the measurement errors were 30% in the second and third channels and 40% in the fourth and fifth channels, respectively. The data were averaged over 20-minute intervals. The mean radius of the aerosol particles suspended in the near-ground atmospheric air was determined by means of the aerosol photoelectric photometer FAN with the measurement error no more than 15%.

The diurnal behavior of the mass concentration of aerosol particles N_m is shown in Fig. 1.

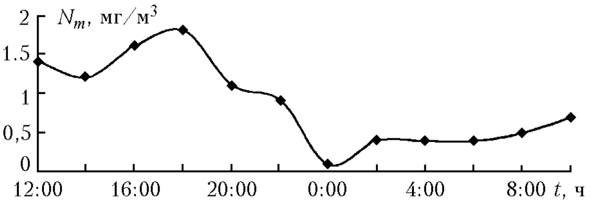

Fig. 1. Diurnal behavior of the mass concentration on May 7–8, 2003.

Measurements were carried out on May 7, 2003 since 12:00 till 24:00 and on May 8, 2003 since 0:00 till 10:00 in Krasnoarmeyskii ave., 90. This district is situated in the business center of Barnaul near the cross of two great thoroughfares of the city, Molodezhnaya str. and Krasnoarmeyskii ave. Overall, 600 liters of air were pumped through each of the filters at the height of 10 m above the ground surface. The value of the mass concentration varied during a day within the range from 0.1 to 1.75 mg/m^3, its maximum value was obtained at 18:00, and minimum at 0:00.

Such a behavior of the aerosol mass concentration is caused, obviously, by the following factors: the nearby streets (Krasnoarmeyskii ave., Sotsialisticheskii ave., Molodezhnaya str.), which are among the largest thoroughfares, at the end of working time (17:00–18:00) are overfilled with the motor vehicles, the exhausted gases from which essentially affect the state of the near-ground aerosol near the measurement site. Taking into account the fact that atmospheric air is sufficiently heated by 18:00 (see below the dependence of the mass concentration on the air temperature), these factors explain the peak in Fig. 1.

From the above reasoning, the minimum observed at 0:00 is quite clearly understood. At this time there is practically no motor vehicles in the business center of the city, temperature is low, that causes the value of the mass concentration close to the background

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one. As is seen in Fig. 2, by the beginning of the working time (7:00–9:00), as vehicles appear on the streets and air temperature increases, the mass concentration increases again.

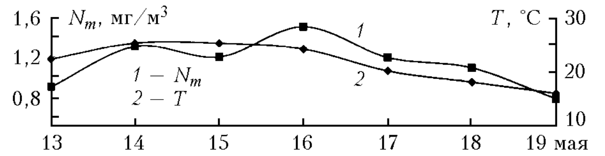

Fig. 2. Temporal behavior of the mass concentration N_m and air temperature T on May 13–19, 2003.

Aerosol samples for observation of the time behavior of the mass concentration were collected every day at 18:00 since May 13 until May 19, 2003 (Fig. 2). Measurements were carried out at the same height the volume of pumped air was 900 liters.

Mass concentration in this period took the values from 0.8 to 1.5 mg/m^3, the air temperature varied within the limits from 18 to 25°C.

The data on the dynamics of the mean radius of aerosol particles obtained on June 2 until 8 of 2003 by means of the photoelectric aerosol photometer FAN are shown in Fig. 3.

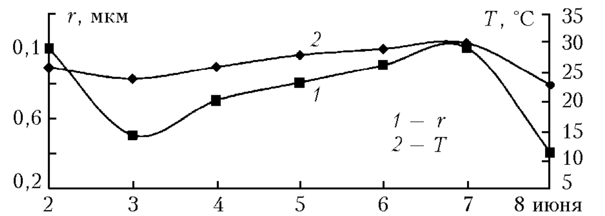

Fig. 3. Time behavior of the mean radius of aerosol particles (*1*) and the air temperature (*2*) on June 2–8, 2003.

The mean radius varied in these measurements from 0.04 to 1 μm. The measurements have been carried out every day since 18:00 until 18:30, the air temperature varied from 23 to 30°C.

The results obtained evidence of some dependence of the mean radius of particles and the aerosol mass concentration on the air temperature, which is to be studied. One can assert at this stage, that hotter air has larger kinetic energy that allows the convective airflows to lift larger particles from the underlying surface (soil, asphalt pavement).

The main criteria of the quality of the atmospheric air are the maximum permissible concentrations (MPC) for inhabited areas. According to the State Standard GOST 17.2.1.04-77, the MPC means the maximum concentration of an admixture in the atmosphere, which is related to certain time of averaging, and does not affect human health at periodic effect or during the whole life, including remote consequences for the medium as a whole.[2]

The maximum one-time MPC of dust is 2.96 mg/m^3 for the cities with population from 500 thousand to 1 million people (population of Barnaul is about 600 thousand); the annual mean MPC (Ref. 2) is 0.24 mg/m^3. The values of the mass concentration obtained during our experiments (0.1 to 1.75 mg/m^3) do not exceed the maximum one-time MPC.

The experiments on measuring the number density of aerosol particles suspended in the atmospheric air were carried out at the same site since December 22 until December 29, 2003. The diurnal (Fig. 4) behavior and the dynamics (Fig. 5) of the number density have been analyzed.

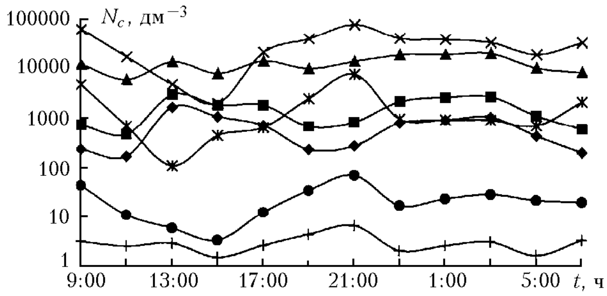

Fig. 4. Diurnal behavior of the number density of particles of different fractions on December 24–25, 2003 ◆ 0.3–0.4; ■ 0.4–0.5; ▲ 0.5–1; × 1–2; ✱ 2–5; ● 5–10; + 10–100 μm.

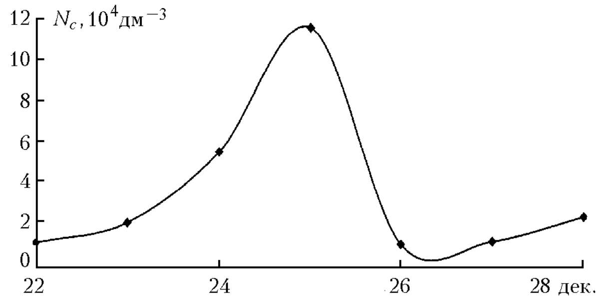

Fig. 5. Time behavior of the total number density of particles on December 24–25, 2003.

Observation of the diurnal behavior of the number density of particles of different fractions was carried out on December 24–25, 2003. During these days temperature varied from –8 to –16°C, the total number density took the values from $1.3 \cdot 10^4$ dm^{-3} (at 15:00 on December 24) to $1.1 \cdot 10^5$ dm^{-3} (at 21:00 on December 24). It is seen from Fig. 4 that maxima and minima of the number densities of the fractions 0.3–0.4; 0.4–0.5; and 0.5–1 μm coincide, as well as the peaks of the number densities of particles of the size 1–2; 2–5; 5–10; and 10–100 μm. The maximum of fine aerosol (0.3 to 1 μm) coincides with the minimum of the coarse fraction (1 to 100 μm) and *vise versa*.

To obtain time behavior of the total number density, samples were collected every day since December 22 until December 28 at 20:00 (Fig. 5). The atmospheric air temperature varied in this period within the limits from –7 to –14°C. The maximum of the number density ($1.1 \cdot 10^5$ dm^{-3}) was observed on December 25, 2003 under conditions of clear windless weather without precipitation at a temperature of –14°C and the pressure of 748 mm Hg. One should note that the characteristic smog was observed this evening near the observation site. Minimum of the number density ($0.93 \cdot 10^4$ dm^{-3}) was observed on December 22, 2003 under conditions of cloudy weather with small precipitations of snow, at a temperature of –7°C, westward wind of 8 m/s speed and the pressure of 737 mm Hg.

It is interesting to compare the obtained results with the results of experiments on measuring the number density of particles by means of PKZV–906 carried out in 1991 and 1995. The measurements of the disperse composition of urban aerosol were carried out both during a full day (every 1 hour) and once a day. Let us consider the results of some measurements. The round-the-clock experiment at Gogol str., 85 was carried out on April 17–18, 1991. This district, the lowest in the city, strongly undergoes pollution from numerous enterprises, boiler-houses, motor vehicles, chimneys of houses, etc. The daily mean total number density of particles was $2.5 \cdot 10^5$ dm^{-3}, the minimum value ($2.4 \cdot 10^3$ dm^{-3}) was observed at 11:20 on April 17, 1991 at south-eastward wind of 1–2 m/s speed, temperature of 6°C, relative humidity of 90%, and the maximum value ($9.4 \cdot 10^5$ dm^{-3}) was observed at 23:10 on April 17, 1991 at south-eastward wind of 0–1 m/s speed, temperature of 5°C, and relative humidity of 45%.[3]

Diurnal dynamics of the mass concentration and the total number density was also followed during a day on April 19–20, 1995 at Krasnoarmeyskii ave., 90. This district is situated, as previous one, in the business center of the city. It is a little bit higher than the previous region. It undergoes not less pollution from enterprises, boiler-houses, motor vehicles, and chimneys of houses. It is also characterized by sandy soil and more intense motion of air masses.

The measurements were carried out since 14:00 on April 19, 1995 until 14:00 on April 20, 1995. The values of the mass and number concentrations varied during the day within the ranges from 0.37 to 1.76 mg/m^3 and from $3.37 \cdot 10^3 - 8.21 \cdot 10^4$ dm^{-3}, respectively, the minimum of the total number density was observed at 23:00 on April 19, 1995, and the maximum at 10:00 on April 20, 1995. The temperature variation in this period was 1 to 9°C.[4]

Let us consider the results of round-the-clock experiment carried out on October 4, 1997 not far from the previous site at the cross of Krasnoarmeyskii ave. and Partizanskaya str. The values of the total number density varied during this experiment within the range from $3.3 \cdot 10^2$ to $1.7 \cdot 10^5$ dm^{-3}, the maximum was observed at 16:00, and the minimum at 6:00. Temperature during this day varied from 5 to 23°C. One should note that these investigations were carried out under conditions of enhanced pollution of the city by smoke aerosol.

The value of the mass concentration on May 7–8, 2003 at the site on Krasnoarmeyskii ave. varied within the range from 0.1 to 1.75 mg/m^3, and the observation of the time behavior of the number density during the day on 24–25 of December 2003 showed the change of the number density within the range from $1.3 \cdot 10^4$ to $1.1 \cdot 10^5$ dm^{-3}.

Thus, one can note the following regularity of the behavior of the total number density of the near-ground aerosol in the city of Barnaul. The tendency toward a decrease of the maximum values of the concentration was observed in the period since 1991 until 2003, while the minimum values increased from year to year. Besides, the important peculiarity is the increase of the total number density during these years by 5 times.

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