DYNAMICS OF SMOKE AEROSOL ACCUMULATION IN THE LOW PARTS OF BARNAUL CITY

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We discuss here data on the near-ground aerosol particle number density collected from a whole day round measurement in Barnaul under unfavorable meteorological conditions of the early October, 1997. The atmospheric situation in Barnaul during this period was characterized by high pollution of the atmosphere with smoke aerosol from the forest fires. The results obtained are indicative of aerosol accumulation in the central part of the city, on the side of the river valley, under conditions of inversion layer formation at night. The data collected enabled us to calculate the median diameter of aerosol particles and the polydispersity parameter of the aerosol. Their connection with the processes in the ground atmospheric layer is discussed.

The summer-fall period of 1997 at the southern territory of the West Siberia was characterized by long-term domination of alternating stable anticyclones. This fact, along with prodigious drought, gave rise to very unfavorable ecological and hygienic situation, especially in the industrial centers, in particular, in the city of Barnaul. The situation became extremely severe in the later half of September and in October. In this period, inversion layers were formed in the ground atmospheric layer almost every night. Under such conditions, pollutants emitted by heat power plants of industrial plants and public services, as well as heat and power stations practically did not dissipate in the atmosphere, but they were accumulated near ground in regions adjacent to the emission sources.[1] Long absence of precipitation turned off one of the mechanisms of aerosol removal from the atmosphere.[2] Gaseous pollutants compiled in the air under cloudless conditions has resulted, several times, in formation of the photochemical smog. Local bodies of the Russian State Hydrological and Meteorological Committee have repeatedly recommended restricting emissions into the atmosphere, however, no desired result has been achieved.

The situation in the forestry was very catastrophic. Spontaneous fires appeared almost everywhere, and in some cases they developed into large forest fires emitting large amount of smoke aerosol into the atmosphere. The situation was especially severe in the Altai Region, where about 550 km^2 of forest have been burnt away. One of the most powerful fires occurred in the first week of October in the Ob flood plain near Kalmanka village. Then it covered the territory of right-bank forest area to the south-east of Barnaul. On October 7 the smoke cloud from this fire covered the city. The visually estimated visibility range on this day did not exceed 2 km.

The experiment aimed at measurement of the aerosol particle number density in the atmosphere over the city was conducted on October 4. As the measurement site, we have chosen the region between Krasnoarmeiskii Avenue and Partizanskaya Street. This region is subject to pollution from such sources as heat power plants of the Altai Assembling Plant and “AltaiagropromstroiB reinforced concrete works, the bituminous concrete plant, a great number of private houses with stove heating, and heavy traffic. The region is situated near the city center on a slope of the Barnaulka river valley. The absolute height level of this region is almost the lowest one in the city. These factors cause the enhanced level of the anthropogenic pollution of the atmosphere in the area of newly built, during the last 15 years, sleeping blocks. The contamination level is especially high under calm weather in the presence of near-ground temperature inversions. The measurement site was situated far from highways well inside the area of sleeping blocks at the altitude about 20 m (sixth floor) above the ground.

The particle number density was measured in five size ranges (0.3–0.4, 0.4–0.5, 0.5–1, 1.0–2, and 2.0–5 μm) in the beginning of every hour with a PKZV–906 photoelectric particle counter. Simultaneously, we have measured the temperature of the ambient air. The meteorological situation during measurements was the following: slightly cloudy sky, gentle wind of a variable direction, low humidity because of no rains for a long time, air temperature from 5 to 23°C.

The experimental data have been estimated assuming the particle size-distribution to be lognormal for the urban aerosol, according to Refs. 3 and 4. The

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results of our measurements of the number density of the medium-disperse fraction of the near-ground aerosol also confirm the validity of this distribution. From the experimental results processed, we have derived the time behaviors of such aerosol microphysical characteristics as the particle number density N (dm^{-3}), the median diameter δ_{50} (μm), and the aerosol polydispersity parameter σ (see Fig. 1). During the experiment, the parameters under study varied within the following ranges: $N \in [330;\ 177170]$ dm^{-3}; $\delta_{50} \in [0.45;\ 0.49]$ μm; $\sigma \in [1.27;\ 1.49]$. The minimum $N(t)$ value occurred at 16:00 while the function $\sigma(t)$ reached its maximum at this same time (Fig. 1*b*). At that time the air temperature also reached the maximum in its diurnal behavior. Then the inversion layer began to form over the city due to the temperature decrease and calm weather. As a conseCuence, the particle number density had increased by the night-time. As suspended particles had been being accumulated in the atmosphere, the number of larger particles also increased. However, from 00:00 to 03:00 a.m. a fall off of $N(t)$ down to 32170 dm^{-3} was noticed. This is most likely connected with the sedimentation of large particles, what is confirmed by the corresponding behavior of $\delta_{50}(t)$ (Fig. 1*a*).

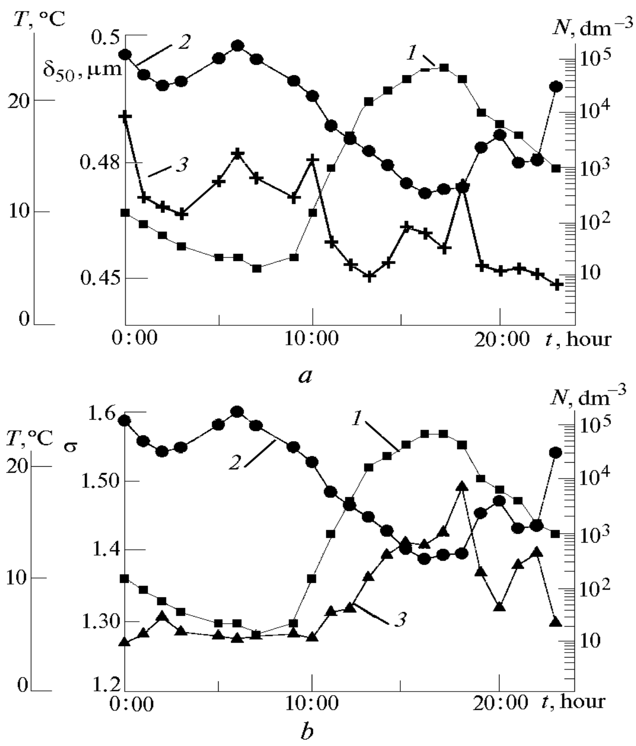

FIG. 1. Diurnal behavior of the microphysical characteristics of the ground urban aerosol (the city of Barnaul, October 4, 1997): (a) temperature T(t) (curve 1), particle number density N(t) (curve 2), median diameter $\delta_{50}(t)$ (curve 3); (b) temperature T(t) (curve 1), particle number density N(t) (curve 2), polydispersity parameter $\sigma(t)$ (curve 3).

At the further decrease in the temperature and increase in the air humidity, the number density of particles and their median diameter grew. In the morning, when the air temperature reached its minimum, the $N(t)$ and δ_{50} approached their maximum values. Such a behavior can, most likely, be explained by condensation of water vapor on particles that leads to their growth in size. This, in turn, results in an increase of the number density of particles in the size range under study, because small particles, which were too small to be recorded, grew to medium-disperse particles when covered with water. Besides, at this time the temperature inversion in the ground layer was most pronounced and the smoke aerosol from operating heat power plants of the neighboring plants and from forest fires in the suburbs was intensely accumulated in the river valley. Then we observed a common decrease in both the number density and median diameter of aerosol particles against the background of the increasing degree of aerosol polydispersity. Such a behavior of the parameters under study is Cuite clear, because the inversion layer has been broken up by the intense convective mixing with increasing temperature what favors the decrease in aerosol particle number density. The increase in the median diameter of particles and the degree of polydispersity up to its maximum value is also caused by this process.

Peaks in the particle number density at nighttime and early morning hours were also observed in other experiments and the degree of aerosol polydispersity usually behaves similarly, that is, takes its lowest values at that time. However, the absolute values of the particle number density detected in the observed situation may characterize it as extremely severe, from the ecological point of view. As compared to similar studies conducted in the same period of 1995 during a month of bringing up the city heating systems to full power,[2] the maximum values of the particle number density recorded in 1997 turned out to be an order of magnitude, on the average, higher.

This situation is similar to the situation observed earlier in the city of Gorno-Altaisk.[5] It is evidently typical of cities having coal burning heat and electric power plants.

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