DYNAMICS OF MICROPHYSICAL CHARACTERISTICS OF THE NEAR–GROUND AEROSOL IN THE CITY OF BARNAUL

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The experimental results are presented of the study of diurnal, weekly, and monthly dynamics of the microphysical characteristics of the near-ground aerosol in the city of Barnaul. The features of their behavior depending on meteorological conditions are discussed.

The problem of air pollution becomes more and more urgent in connection with the increasing influence of the industrial activity on the environment. The main sources of pollution are every-day domestic, industrial and natural processes emitting, into the atmosphere, contaminating substances in the form of gaseous mixtures and aerosols.

In parallel with the study of chemical composition of aerosol substance, very important is the problem of determination of the aerosol microphysical parameters. The disperse composition of aerosol governs many atmospheric properties such as the transmission for optical radiation, photosynthesis in green leaves and so on. A number of papers[1–4] are devoted to the analysis of the urban atmospheric pollution. However, they discuss investigations of the aerosol component only occasionally.

This paper is devoted to the problem of implementing a complex approach to the study of aerosol component of the near-ground atmospheric layer under the conditions of a city with a highly developed industry and transport by the example of Barnaul.

From the standpoint of solving this problem, such aerosol characteristics as the dynamics of mass and number density depending on meteorological conditions, particle size distribution, particle shape and phase composition are of interest.

To determine these parameters, we used the instrumentation complex including 1) PKZV–906 serial device, 2) impactor setup, 3) aspiration setup, 4) automated complex for the measurement data processing. Collection of samples and determination of the medium-dispersed aerosol number density were carried out by means of the PKZV–906 device. The data were recorded in seven size intervals: 0.3–0.4, 0.4–0.5, 0.5–1, 1–2, 2–5, 5–10, and 10–100 μm. The results of measurements obtained during 15–20 min were averaged. Since the device has a rough resolution for the particles greater than 1 μm, coarse aerosol fraction was studied by means of an impactor and aspiration setups, depending on the parameter to be studied. The data on the number density can be obtained by means of the microphotography of the impactor glass plates or the AFA–VP–20 filter preliminary exposed and lightened. The results were averaged over several aerosol particle samples obtained in different areas of plate or filter.

The images of particles microphotographs have been scanned and then processed using special software on a "Robotron" complex giving the protocols on the particles parameters. Then the file obtained was processed by means of the electron tables "Excel," the "Windows" application, on an IBM–PC/AT–386 computer.

In addition to saving time, the automated data processing allows one to avoid subjective estimations of the data on the number density and extends the possibilities of increasing information capacity of the measurements in estimation of such microphysical parameters as the area of the particle images, deviation of their shapes from spherical, etc.

Both these sampling techniques lead to the mutually confirming results. However, one should keep in mind that the aspirator gives an error in the case of a liquid cover around a particle (it cannot be fixed on the filter). In its turn, the impactor distorts the result because of a leakage of fine particles with the air flow.

Such characteristics as the particle shape and phase composition of aerosol were studied by means of microimages of particles collected on the impactor plate, though, if to speak about the shape of the condensation nuclei, the pictures of lightened filters may be used. Mass concentration was determined by means of weighing filters before and after the exposition.

To study the dynamics of some aerosol properties, the samples were simultaneously collected for the medium-size and coarse aerosol fractions at the reference sites situated on the windward side of large sources of anthropogenic pollution (the building of the Physical Department of Altai State University) during different periods of time.

The data on diurnal behavior of the number density $N_{\rm n}$ and mass concentration $N_{\rm m}$ of aerosol are shown in Fig. 1, as well as the values δ_{50} and σ that are the parameters of lognormal distribution characterizing the median diameter and the material polydispersion.[5]

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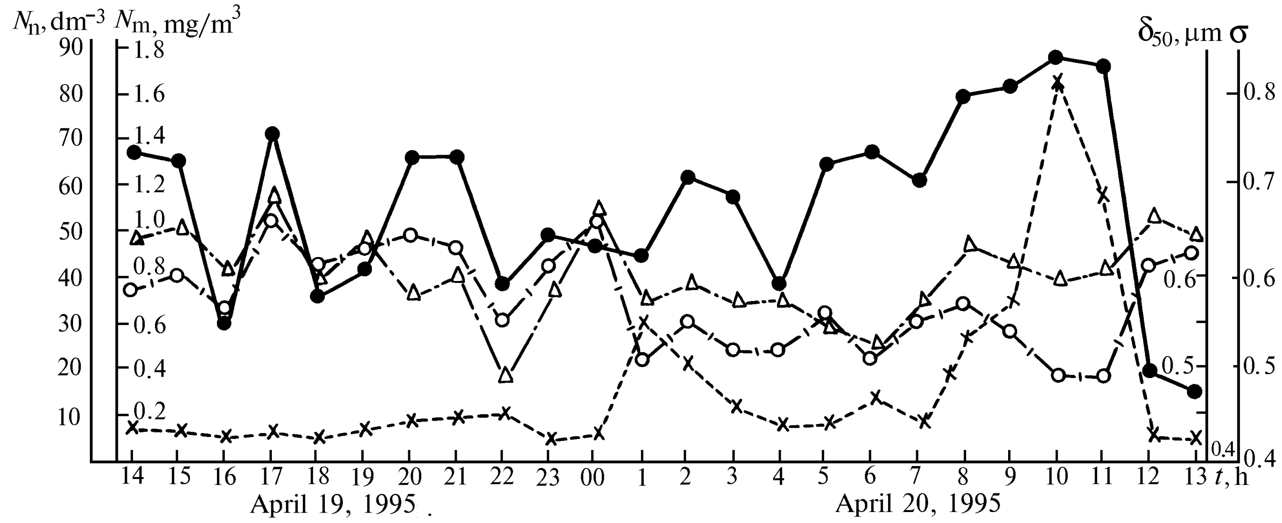

FIG. 1. Diurnal behavior of microphysical characteristics of urban aerosol: number density, $N_n(t)$ (×), mass concentration, $N_m(t)$ (•), degree of polydispersion, $\sigma(t)$ (Δ), median diameter, $\delta_{50}(t)$ (○).

This distribution was selected for the approximation of experimental values of the linear size of particles resulting from the analysis of numerous empirical curves and some analytical functions using different probability grids. Measurements were carried out from 2:00 p.m. of April 19, 1995, till 2:00 p.m. of April 20, 1995. Temperature variation during this time was from 1 to 9°C. The values of mass concentration and number density varied within the ranges 0.37 to 1.76 mg/m^3 and $3.37\cdot10^3$ to $8.21\cdot10^4$ dm^{-3}, respectively, during a day. The median diameter varied from 0.49 to 0.66 µm.

As is seen from Fig. 1, the value of N_n was practically stable [$(4-11)\cdot10^3$ dm^{-3}] during the first part of the experiment (from 2:00 p.m. till midnight of April 19, 1995), while the value of N_m varied within a narrow interval 0.7 to 1.4 mg/m^3, and δ_{50} varied from 0.3 to 0.5 µm. The peak of the aerosol number density $N_n = 3.44\cdot10^4$ dm^{-3} was observed from midnight till 3:00 a.m. of April 20, 1995, at $\delta_{50} = 0.5-0.55$ µm, and the degree of aerosol polydispersion also decreased as compared to the average value from 2:00 p.m. till midnight of April 19, 1995. Such an increase in the content of fine particles was caused by the night emission of pollutants from the Heat and Power Station No. 3. The stable increase of $N_n(t)$ and $N_m(t)$ was observed from 7:00 a.m. till 11:00 a.m. due to an increase in the traffic intensity and operation of domestic heating installations.

These values achieved their maxima at 10:00 a.m., while δ_{50} decreased to ≈ 0.49 µm. Meteorological conditions changed from noon to 1:00 p.m., it rained, and the curves $N_n(t)$ and $N_m(t)$ reached their maxima at $\delta_{50} = 0.61 \div 0.62$ µm. We revealed a sharp decrease of the particle number density during precipitation earlier in the experiment on May 15, 1994. The results showed that the volume concentration of the near-ground aerosol changed from 36 200 to 15 100 particles per 1 dm^3 due to wash out process (Fig. 2) during 50 min rain with the intensity of 10–14 mm.

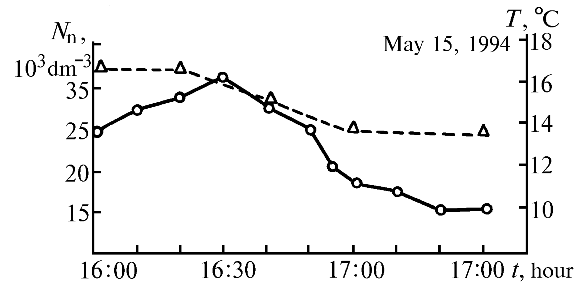

FIG. 2. Dynamics of the number density and temperature during a rain: $N_n(t)$ (°) and $T(t)$ (Δ).

Aerosol was sampled at the reference site from onboard a mobile laboratory at the altitude of 2.1 m from the ground surface. The sampler channel was protected from droplets. The rain intensity was determined by an improved technique using a water measuring bucket and a glass. It is interesting that during the initial period of the rain, in the near-ground layer the aerosol number density and δ_{50} increased. Such a variation may be explained by the appearance of liquid particles, in addition to the solid ones, under the conditions of high humidity.

At the same time, when studying the particle shape, it has been noticed that they are moistened at the humidity of 100%, then taking the spherical shape and growing up. Then, when temperature decreased, the particles grow due to the development of condensation and coagulation processes, and then they fall down due to gravitational sedimentation and are washed out by the rain droplets. When analyzing the weekly dynamics of the main characteristics of aerosol, we also have observed such a dependence of N_n and δ_{50} on the presence of precipitation. Minimum values of N_n and N_m were observed on April 18 and 20, 1995, when high humidity occurred (measurements were made 2–3 hours after a rain on April 19 and during the rain on April 20).

When analyzing the daily data on the coarse fraction, we did not reveal a universal analytical function of the size distribution for all samples. However analogous behavior of the δ_{50} curves of the medium-size and coarse fractions have been observed (i.e., when δ_{50} of the medium-size fraction increased, δ_{50} of the coarse aerosol fraction also increased). At the same time, the behavior of the total mass concentration only slightly depends on the number density of coarse particles. This is evidence of the fact that the medium-size aerosol, whose parameters variation mainly determine the dynamics of aerosol mass concentration, is the fraction that makes principal contribution to the total mass. For example, an increase in N_m was observed when the median diameter δ_{50} increased at a constant number density. On the other hand, a sharp increase of the number density at a small increase of δ_{50} only slightly affected the value of the mass concentration. Such a relationship between the values N_m, N_n and δ_{50} is caused by the fact[5] that $N_m \sim N_n (\delta_{50})^3$. Then an increase in N_n was observed at a decrease of the median diameter and the degree of aerosol polydispersion. However, these features are observed in the case of absence of extraordinary meteorological conditions (strong wind and precipitation).

A fragment of monthly dynamics of some parameters of the urban aerosol is shown in Fig. 3. The period of experimental investigations (from October 21 till November 5, 1995) was selected in order to estimate the change in the state of the near-ground atmospheric layer related to the beginning of the cold season. Rather quick decrease of daily mean temperature was observed during this period, and the urban heating systems were operated at full power. The number density variation was observed within the range from $6.51 \cdot 10^3$ to $9.85 \cdot 10^4$ dm^{-3}. Thus, the value of N_n increased by one order of magnitude, on the average, with respect to similar measurements carried out in early fall. One should note that the curve $N_n(t)$ took its minimum values ($N_n \approx 1.59 \cdot 10^4$ dm^{-3} on October 26; $N_n \approx 6.67 \cdot 10^3$ dm^{-3} on October 28; and $N_n \approx 6.51 \cdot 10^3$ dm^{-3} on November 2) at the points corresponding to experimental measurements during a snowfall. The mass concentration reached the value $N_m \sim 3$ mg/m^3.

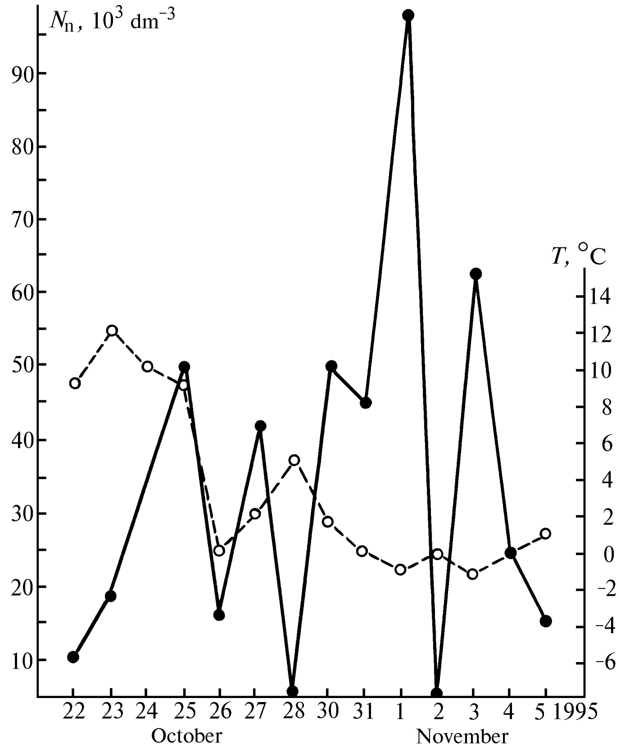

FIG. 3. Dynamics of the number density, $N_n(t)$, (close circles) and temperature, $T(t)$, (open circles) from October 21 till November 5, 1995.

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