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GENERAL BIOLOGY

Variability of the Content of Live Microorganisms in the Atmospheric Aerosol in Southern Regions of Western Siberia

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The results of preliminary studies on the biological component of atmospheric aerosol and annual dynamics of the total atmospheric aerosol protein concentration in the southern regions of Western Siberia were considered in the preceding works [1, 2]. Live microorganisms contained in atmospheric aerosols can be transferred over large distances and to high altitudes without loss of viability [3–7]. Therefore, the properties of the biological component of atmospheric aerosols and sources of their origin should be studied not only near the ground, but also at high altitudes. In this work, we describe the results of measurements of the concentrations of live microorganisms and the compositions of atmospheric aerosols above large forests in the southern regions of Western Siberia.

Air samples were collected using an Optik-E laboratory mounted aboard an AN-30 aircraft. The flights were performed in the last ten days of each month from March 1999. The schematic map of the sampling sites was published in [2]. During the daytime, the aircraft laboratory flew sequentially along the airway at altitudes of 7000, 5500, 4000, 3000, 1500, 1000, and 500 m. Air samples were collected using impingers [8] at an air flow rate of 50 l/min. The following culture media were used for detecting live microorganisms from atmospheric aerosol [9, 10]: LB depleted (dilution, 1 : 10) agar medium; starch–ammonia medium for detecting actinomycetes; and soil agar, Saburo (pH 5.4), and Czapek (pH 6.5) media for detecting lower fungi and yeasts. The samples collected were inoculated onto Petri dishes with nutrient media (samples were preliminarily diluted if necessary) and incubated in a thermostat for 14 days. Specific morphological features of microorganisms were studied visually using a light microscope. Cell preparations were fixed and Gram stained. Live preparations of cell suspensions were studied using phase-contrast microscopy. The microorganisms detected were taxonomically identified accurate to genus.

The total concentrations of microorganisms collected at different dates and altitudes and grown in four types of culture media are shown in Fig. 1. Two-factor ANDVA of these data showed that there is a stable statistically significant dependence of the concentration of live microorganisms in atmospheric aerosol on the month of sample collection (the factor was statistically significant at the 0.1% level). On the other hand, the concentration of live microorganisms in atmospheric aerosol was found to be practically independent on the altitude of sampling (significance level, 20%). In other words, there was a "frozen" altitude profile of concentrations of live microorganisms in atmospheric aerosol, the amplitude of the profile being a subject of seasonal variation (Fig. 2).

Analysis of specific features of bulk air flows under the actual environmental conditions showed that such profiles of the concentrations of atmospheric admixtures are generated by vast, remote, and flat sources, provided that the turbulent mixing is intense and sufficiently prolonged. Inverse Lagrange trajectories [11] of bulk air movement at the sites of sample collection were calculated to test the validity of these conclusions. A set of semispherical models of air transfer in the coordinate system bound to the actual ground relief was used in these calculations. Conjugated problems were solved in 30-day-long inverse time coordinates. The calculation algorithm was based on a combination of

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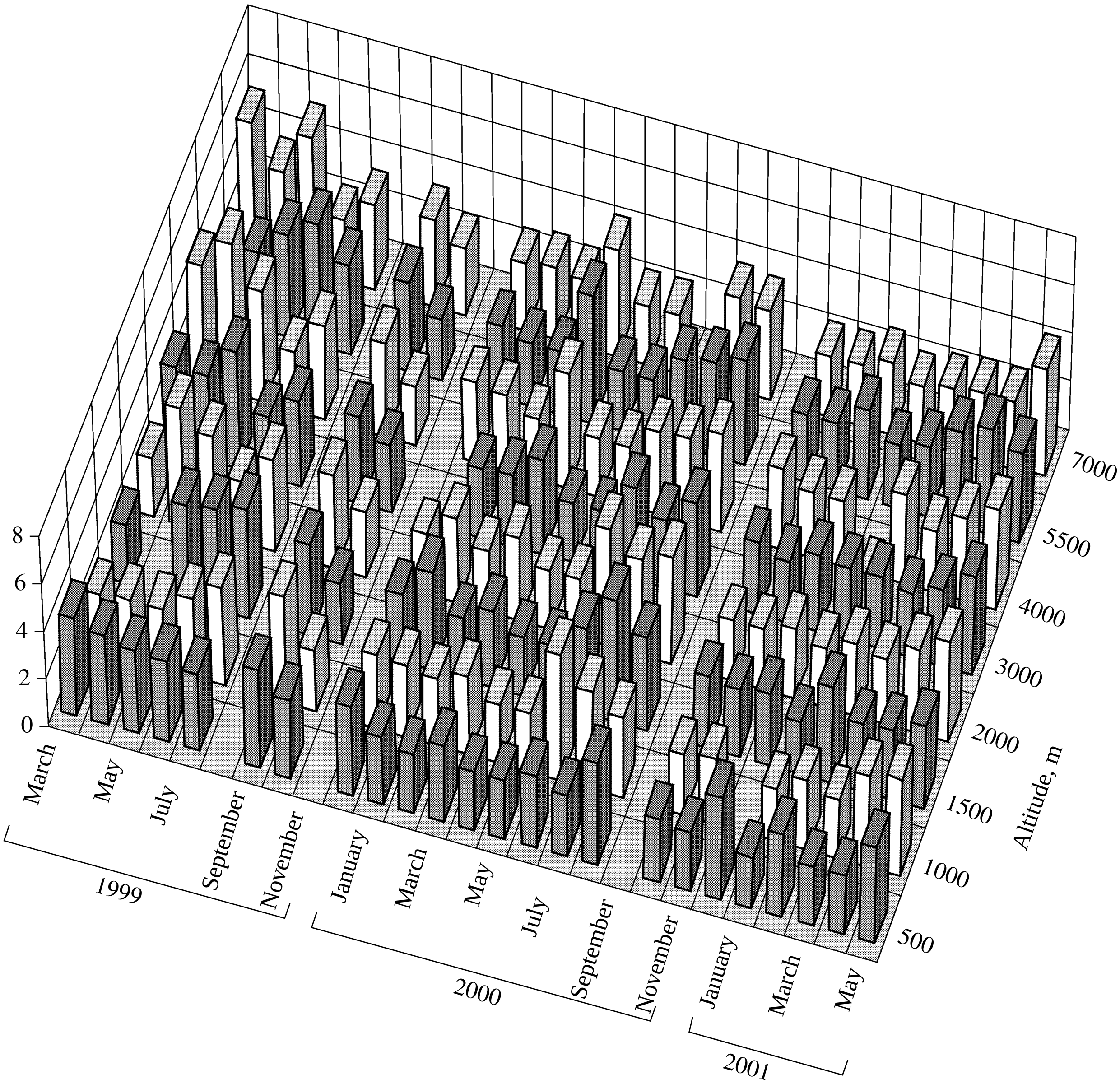

Fig. 1. Total concentrations of living microorganisms collected at different altitudes in the southern regions of Western Siberia from March 1999 to May 2001. Here and in Fig. 2, ordinate shows the logarithm of microbial cell count per m^3. No data were obtained in November 1999 and September 2000.

the Lagrange and Monte-Carlo methods. The spatiotemporal structure of atmosphere circulation was calculated with a time step of 30 min using the Reanalysis NCEP/NCAR databank. Different prehistories of bulk air components at the site of sampling was a specific feature of the calculation of the atmosphere circulation trajectories. Before these components were mixed with each other near the sampling site, they had travelled at different altitudes and above different regions of the earth surface (in some cases, above different continents and oceans). Therefore, aerosol particles generated by quite different sources might be found at the sampling site. Because aerosol particles several micrometers in size may be suspended in atmosphere for a long time, they may travel with bulk air over large distances. Before reaching the sampling site, propagation of air flows is accompanied by movement from one altitude to another, contacts the earth's surface (probably, at the sites of contact with the ground, air flows become contaminated with biological aerosols), and intense mixing (each inverse trajectory is characterized by its own specific places).

Consider the sum Euler function of sensitivity of a functional as an example. Let the functional be used to

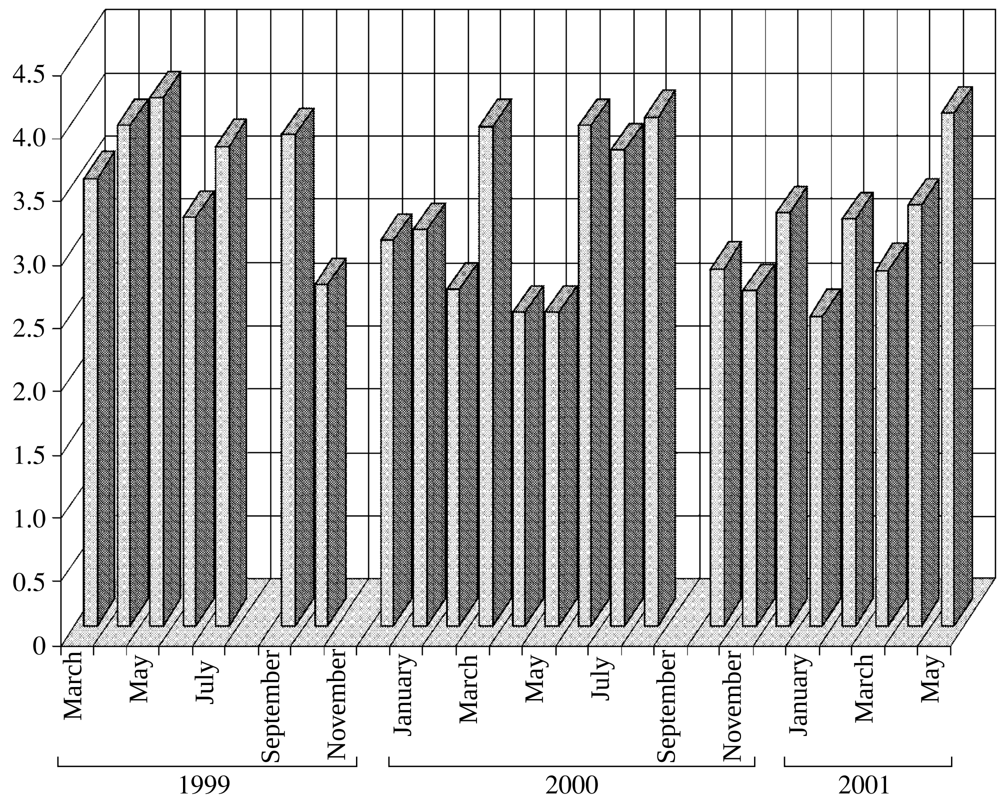

Fig. 2. Seasonal dynamics of the concentration of live microorganisms averaged over all altitudes of the atmosphere in the southern regions of Western Siberia.

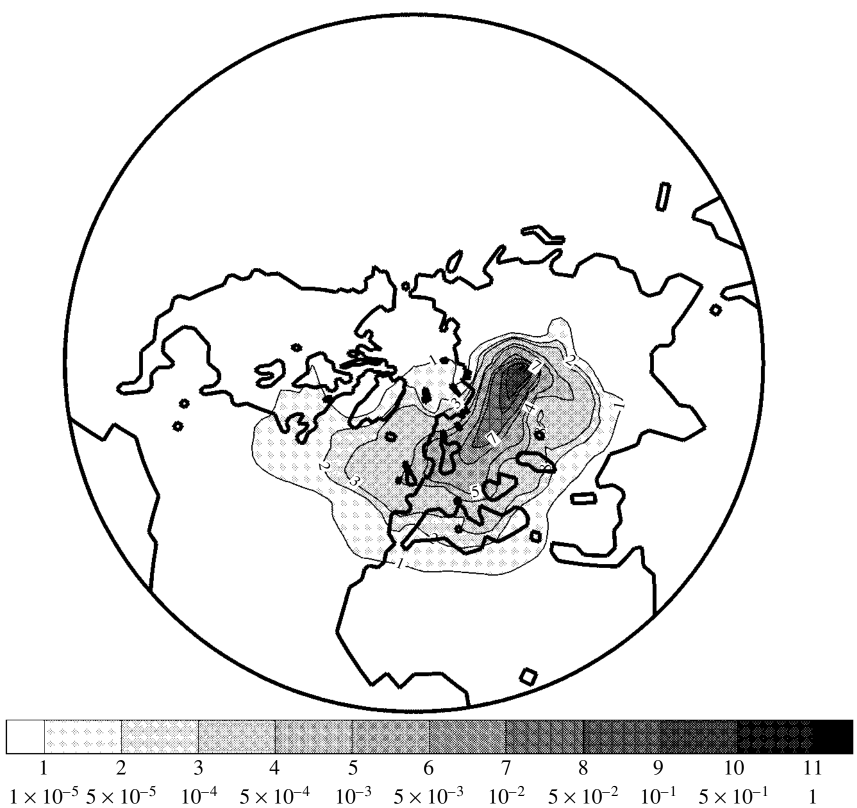

Fig. 3. Lagrange trajectories touching the earth's surface and averaged over the whole ensemble of air particles. The isolines correspond to the probability that the aerosol particles generated at a given site of the earth's surface were collected at the sampling site.

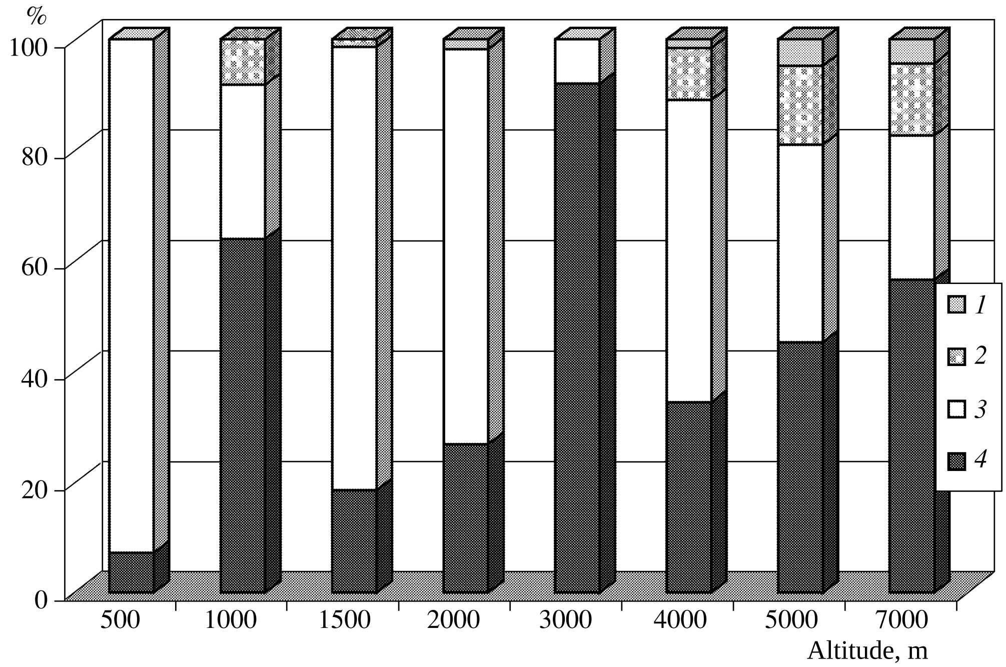

Fig. 4. Percentages of different groups of microorganisms in atmospheric air samples collected July 1999: (*1*) actinomycetes; (*2*) bacteria forming no spores; (*3*) cocci; and (*4*) bacilli.

describe the results of measurements performed in June 1999 at an altitude of about 1.5 km at the sampling site with the 54.23° N, 82.09° E (Fig. 3). The isolines in Fig. 3 were plotted by averaging over the whole ensemble of Lagrange trajectories of air particles. The isoline describes the probability that aerosol particles generated at given site of the earth's surface were collected at the sampling site. Our analysis showed that northwestern Kazakhstan was the most probable site of origin of the aerosol particles collected during this experiment.

It should be emphasized that abundance of different groups of microorganisms in the atmosphere significantly varies with altitude. This effect is distinctly observed even in the case of rather rough taxonomic identification of microorganisms (Fig. 4). Probably, a more accurate taxonomic identification of microorganisms would reveal more significant diversity. However, even the currently available pattern can be regarded as evidence in favor of the hypothesis that biological aerosols observed in the atmosphere of the southern regions of Western Siberia are generated by remote sources. This conclusion generally follows from the results of numerical simulation of atmospheric processes. It should also be noted that the atmospheric concentrations of living microorganisms determined in our experiments agree with the results obtained by other authors who studied the biogenic component of the atmosphere in other regions [3–7, 12–15].

Thus, systematic studies on the presence of live organisms in the atmospheric aerosol in the southern regions of Western Siberia have begun. Statistically significant data on the annual cycle of changes in the concentration of atmospheric microorganisms have been obtained. Preliminary analysis of these data showed that the biogenic component of atmospheric aerosol in the southern regions of Western Siberia is generated by several independent sources significantly remote from the site of observation. Some of these sources are probably located in the Middle Asia.

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