Tropospheric Bioaerosols of Southwestern Siberia: Their Concentrations and Variability, Distributions and Long-term Dynamics

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Abstract The paper is devoted to the results of the eight-year study of the biogenic components of tropospheric aerosol in Southwestern Siberia at the altitudes up to 7,000 m. The most important among them are: the total protein as an indicator of all substances of biological origin and culturable microorganisms as a component, which is most harmful to man. The eight-year dynamics of mean annual values of the above concentrations, their annual variations and altitude profiles are presented. Possible sources of the observed bioaerosols are discussed.

Keywords Bioaerosols, tropospheric aerosols, long-term trends

Introduction

The knowledge of characteristics of the biogenic components of atmospheric aerosol is required for solving the problems of ecology, meteorology, climatology and applied microbiology. Biogenic components traced by two main components of bioaerosols: the total protein and culturable microorganisms at the attitudes up to 7,000 m [1–3]. The work presents the results of the eight-year study of atmospheric bioaerosols in Southwestern Siberia.

Materials and Methods

Sampling was performed at 8 altitudes from 7,000 to 500 m in the daytime over the forest at the distance of 50 km to the south from Novosibirsk with "Optic-E" laboratory mounted on an Antonov-30 airplane during the last 10 days of each

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month. Air samples were collected on filters of AFA-HA type at a flow rate of approximately 250 L/min and impingers at a flow rate of 50 L/min. On-land samples were collected on a day in the middle of the month to reveal daily variations of the measured values.

The total protein concentration in samples on filters was analyzed in a laboratory using a fluorescent dye described in [4]; the method sensitivity was 0.1 μg/ml of the sample, the determination error did not exceed 20%.

The following nutrient media were used to detect culturable microorganisms on Petri dishes: LB [5] and depleted LB (medium diluted 1:10 to prevent the influence of neighboring colonies on microorganism growth) were used to detect saprophyte bacteria; starch-ammoniac medium [6] was used to detect actinomycetes; soil agar and Sabourau medium [6] were used for low fungi and yeast. The seedings were incubated in thermostats at 30°C for 3–14 days. Morphological characteristics of the grown microorganisms were studied visually and with light microscopy. For this purpose, Gram-stained fixed and live preparations of cell suspensions were prepared and observed with the phase contrast method. Taxonomic groups the microorganisms referred to were determined up to the genus [6–8]. Microorganism concentrations in the sample were calculated with standard methods [9] by averaging 2–3 parallel seedings on 4–5 different media. The number and representation of microorganisms varied in different samples. More detailed analysis of detected bacteria was performed with biochemical methods and genotyping.

Results and Discussion

Altitude profiles and annual dynamics of variations of the total protein and culturable microorganisms concentrations at the altitudes up to 7 km were revealed. Figure 1 presents the data on these concentrations standardized for each flight (to compensate for their time dynamics). The total protein and culturable microorganisms concentrations nearly do not decrease with the altitude, whereas the concentration of aerosols with the diameter of more than 0.4 μm decreases at the altitude of 7 km by more than an order of magnitude as compared with that in the near-ground layer [10]. Such profiles of atmospheric pollutants can be formed by very powerful remote sources such as large woodlands, water surfaces and soil. Aerosols from such sources rising to considerable altitudes are mixed up and transported for long distances, creating the observed profiles as the particles deposit.

Weak dependence of the observed concentrations on the altitude allows us to sum up data for all the altitudes for constructing annual dynamics of the total protein and culturable microorganisms concentrations [11]. An expressed annual variation of the total protein and culturable microorganisms concentrations in the atmosphere of Southwestern Siberia was revealed. Mean annual concentrations of these values in the region at the altitude of 500–7000 m were also determined, Figure 2. It presents the observed tendency to a decrease in bioaerosol mass in the atmosphere, but, however, it is not statistically significant.

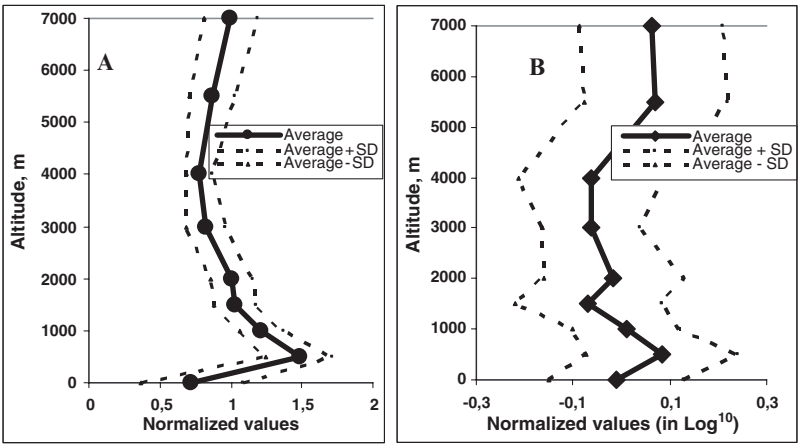

Figure 1 Standardized altitude profiles of the total protein (A) and culturable microorganisms (B) concentrations in Southwestern Siberia

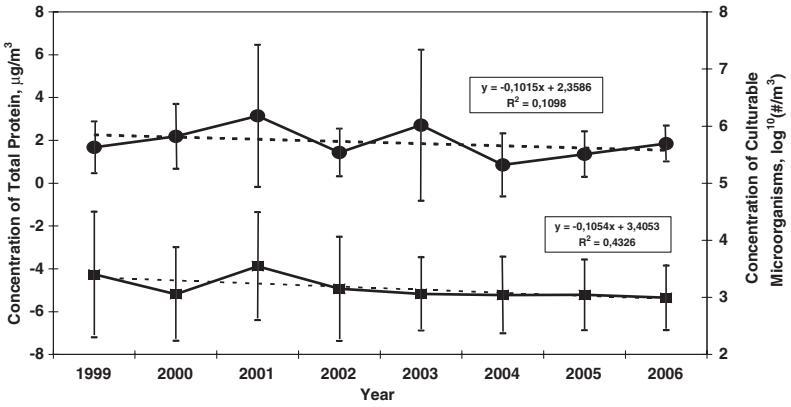

Figure 2 Eight-year variations of mean annual concentrations of the total protein (•) and culturable microorganisms (■) in the atmosphere of Southwestern Siberia at the altitudes of 500–7000 m

No statistically significant differences were revealed in the daily variations of on-land concentrations of the total protein and culturable microorganisms in the atmosphere. No considerable variation in the representation of different culturable microorganisms in samples collected during 24 h was revealed either.

An important characteristic of bioaerosol is its portion in the total mass of atmospheric aerosol. The data of [11] for different seasons revealed the portion of the total protein making up 0.1%–10% of the mass of aerosol particles determined with gravimetrical method though, according to the data of [12], the mass portion of bioaerosol in the vicinity of Lake Baikal makes up from 10%–80% of the total aerosol mass during the year, and according to [13], the portion of the biogenic

particles can reach 95%. Estimates performed taking into account that the portion of culturable microorganisms in their total number makes up 0.02–10.6% according to [14] point to the considerable contribution of the detected number of culturable microorganisms to the observed total protein concentrations.

Previously it was shown that the maximal number of protein molecules is in the fraction of particles with aerodynamic diameters 0.16–0.4 μm [11]. The mass portion of the total protein in all particles is maximal in the fraction of 2.1–10 μm. These results agree with the data of [15], which showed that the fraction of atmospheric aerosol with particle diameters exceeding 2 μm is most rich in microorganisms (always containing a considerable amount of protein). Note that mechanical destruction of non-living biological material (remains of plants and animals and their individual cells) to submicron-sized particles requires considerable energy expenses. That's why, naturally, particles with diameters exceeding 0.1 μm are most rich in biogenic components.

Microorganisms referring to a wide range of genera and species were detected in the analyzed samples. Microorganism strains, which cannot be classified under any of the known taxons by their phenotypic characteristics, were also detected. On the whole, the percentage of microorganisms in samples varies with the altitude and between measurements (both at the ground level and at different altitudes). However, at present the obtained data are insufficient for constructing seasonal and altitude dependences for individual microorganisms as was done for their total number.

Conclusion

The performed research work allowed us to determine the dynamics of the mean annual values of the total protein and culturable microorganisms concentrations, their annual variation, altitude profiles and long-term trends. However, the obtained data is insufficient for predicting the variations of these concentrations. Also, they are insufficient for reliable determination of possible sources of the observed atmospheric bioaerosols. That is why observations of atmospheric bioaerosols in the region should be continued.

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