Biogenic component fraction in the atmospheric aerosol of Southwestern Siberia

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The data on the biogenic component fraction of the atmospheric aerosol in Southwestern Siberia have been obtained from ground-based and high-altitude monitoring. It was found that the fraction of total protein does not exceed approximately 10% of the total aerosol mass in the surface layer of the atmosphere. The concentrations of total protein and viable microorganisms in the atmosphere are constant at the altitudes from 500 to 7000 m. So, the fraction of the biogenic component of atmospheric aerosol increases with height. The tentative results on the total protein distribution over different size ranges of atmospheric aerosol particles were obtained with a low-pressure multistage impactor.

Introduction

We have been carried out combined investigations into the biogenic component of atmospheric aerosol in Southwestern Siberia since 1998. In particular, it has been shown that the atmospheric layer up to the altitudes of 7000 m contains marked amount of total protein and wide diversity of viable microorganisms.[1–3] However, we have not yet considered what is the fraction of the biogenic component in the atmospheric aerosol. Besides, in the literature there are data available only on the fraction of bacteria viable in one nutrient in different size fractions of atmospheric aerosol.[4] The information about the fraction of total protein (the sum contribution of protein molecules and viable microorganisms) in various-size aerosol particles is lacking as well.

This paper analyzes our results on the concentration of total protein and viable microorganisms. The object of analysis is the fraction of the biogenic component in the total mass of atmospheric aerosol depending on size of aerosol particles.

Materials and methods

High-altitude samples have been collected in the last decade of every month with the airborne laboratory Optik-E mounted onboard an AN-30 aircraft. In daytime the airplane consecutively flew over a forest at the altitudes of 7000, 5500, 4000, 3000, 2000, 1500, 1000, and 500 m. Air samples were collected onto AFA-KhA filters with the flow rate of about 250 l/min and impingers with the flow rate of 50 l/min. Surface samples were collected round-the-clock nearby Klyuchi village in the vicinity of Novosibirsk Akademgorodok for one month in different seasons using identical filters and impingers with the flow rate of 50 l/min. Besides, during one day in the middle of a month four samples were additionally collected on the testing ground of the SRC VB "Vector" in order to reveal the diurnal behavior of the measured characteristics. To analyze the total protein in aerosol particles of different size fractions, sampling onto a low-pressure five-stage impactor was carried out.[5]

The total protein content was analyzed under laboratory conditions using one of the two methods: the Bradford protein assay,[6] whose sensitivity was 0.1 μg/ml and the concentration measurement error did not exceed 30%, and the fluorescent method with a color reagent,[7] whose sensitivity was about 0.01 μg/ml and the concentration measurement error was less than 20%.

To find viable microorganisms, the samples were placed onto Petri dishes containing the following agarized nutrient media: LB medium[8] and LB depleted medium (1:10 dilution) for detection of

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saprophytic bacteria, starch-ammoniac medium (SAM)[9] for detection of actinomycetes, soil agar, Sabouraud medium[9] for detection of lower fungi and yeast. Whenever necessary, sequential dilutions of the samples were prepared. Then the samples were incubated in a thermostat at the temperature of 30°C for 3 to 14 days. Morphological features of isolated strains were studied visually and using optical microscopy. For this purpose, fixed Gram-stained cell specimens and vital specimens of cell suspensions observed by the phase contrast method were used. All microorganisms were identified only up to genus.[10,11]

Viable microorganisms in the samples were counted by the standard techniques,[12] and the number of microorganisms was averaged over 2 to 3 parallels of samples placed into 4 to 5 different media. The group we call nonsporiferous bacteria incorporates various microorganisms that do not form endospores: gram-variable and gram-positive coccobacilli, various non-spore-forming gram-negative-stained bacilli, including pseudomonases, bacteria of the intestinal group, and others. This conditional group includes also the bacteria, whose cells have an irregular shape, for example, mycobacteria and nocardia. The number and combination of microorganism cells in different samples varied widely.

Results and discussion

As was already noted based on the results of three-year airborne measurements,[12] the profiles of the total protein concentration and the concentration of viable microorganisms are almost constant on the average at the altitudes from 500 to 7000 m, but their amplitudes vary in different seasons (Figs. 1 and 2).

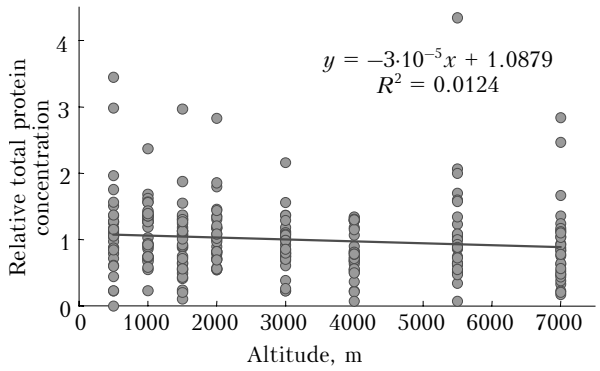

Fig. 1. Three-year average vertical profiles of the total protein concentration in atmospheric aerosol at the altitudes of 500–7000 m in Southwestern Siberia.

This fact allows us to consider the altitude average characteristics rather than individual data for every flight at all the altitudes (Fig. 3). In the plots, we can see the annual regularities in the behavior of the total protein concentration and the concentration of viable microorganisms in the atmosphere. Normalization of the characteristics to their annual mean values for every year makes these regularities more obvious. Three-year average variations of the total protein concentration and the concentration of viable microorganisms in the atmosphere are depicted in Figs. 4 and 5.

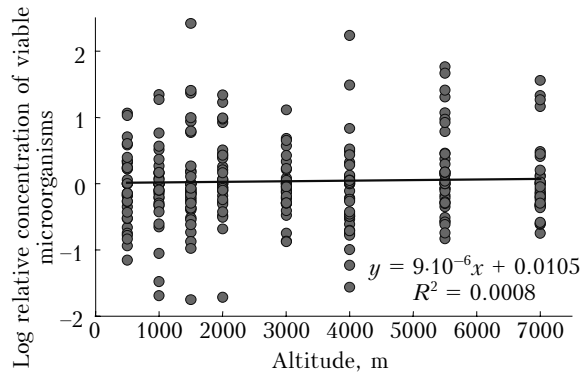

Fig. 2. Three-year average vertical profiles of the concentration of viable microorganisms in atmospheric aerosol at the altitudes of 500–7000 m in Southwestern Siberia.

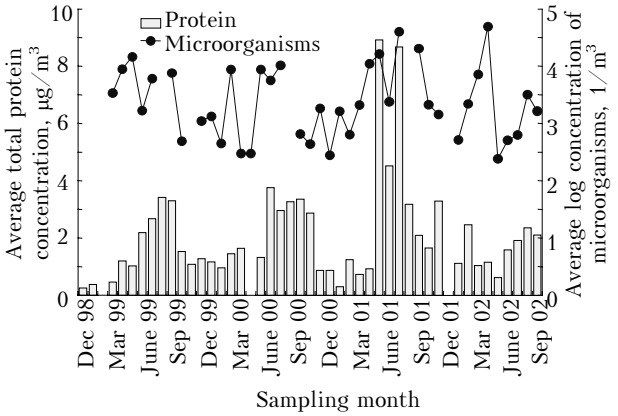

Fig. 3. Variation of the altitude-mean (500–7000 m) total protein concentration and concentration of viable microorganisms in the atmosphere in Southwestern Siberia.

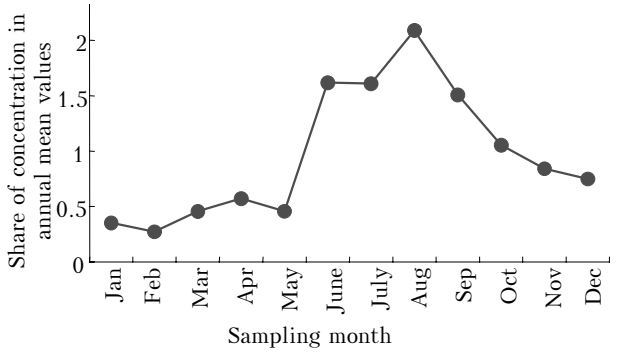

Fig. 4. Annual variation of the total protein content in atmospheric aerosol at the altitudes from 500 to 7000 m in Southwestern Siberia.

Thus, our observations reliably prove the presence of the annual dynamics in variations of the total protein concentration and the concentration of viable microorganisms in the atmosphere over Southwestern Siberia.

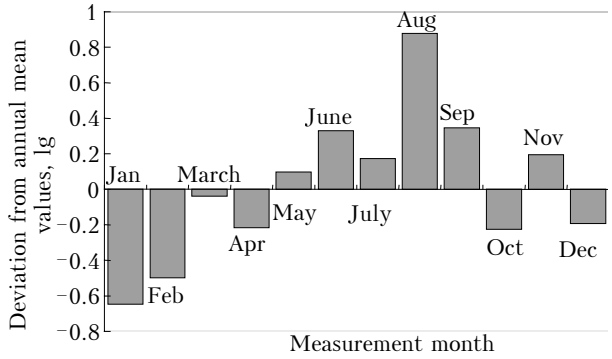

Fig. 5. Annual variation of the content of viable microorganisms in atmospheric aerosol at the altitudes from 500 to 7000 m in Southwestern Siberia.

Let us consider in a more detail the revealed altitude dependence of the total protein concentration and the concentration of viable microorganisms in the atmosphere. In Ref. 13 we mentioned that such concentration profiles are formed in the atmosphere as a result of long turbulent mixing as an admixture spreads from remote sources. The absence of systematic month correlation in the atmospheric protein concentration means that various independent sources (plant tracts, water bodies, erosive soil, etc.) take part in the formation of the vertical profiles. Of interest is the fact that the total number of aerosol particles in the atmosphere decreases with height,[14] while the fraction of bioaerosols increases. This can take place only in the case that the main sources of bioaerosols are located very far from the observation point. Analysis of these results is considered in a more detail elsewhere.[1–3]

The technique of our ground-based measurements allows us to estimate the fraction of the biogenic component in the total mass of atmospheric aerosol. The typical dynamics of the diurnally mean mass concentration of particles and the fraction of total protein is shown in Fig. 6. The mean values of the total particulate mass of atmospheric aerosol, the total protein mass, and the fraction of protein in the total aerosol mass for different seasons of 2001–2002 are tabulated below. We can see that the protein fraction does not exceed 5%.

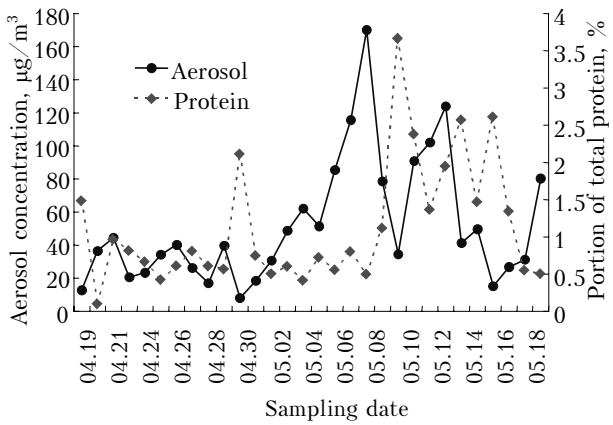

Fig. 6. Dynamics of mass concentration of aerosol particles and total protein in the atmosphere near Novosibirsk in April–May 2002.

The data obtained show that the contribution of viable microorganisms to the total protein mass is relatively low. The fraction of such microorganisms is from 0.02 to 10.6% (Ref. 15). Thus, the estimated contribution of microorganisms to the observed total protein concentrations in the atmosphere should be considered quite representative. In February–March and June of 2002 the data were obtained on the size of total protein particles near ICKC SB RAS and in Kireevskoe village of Tomsk Region (Figs. 7 and 8).

In nine experiments, it was found that the largest number of protein molecules is in the fraction of particles with the aerodynamic diameter from 0.16 to 0.4 μm. At the same time, the mass protein fraction is maximum for the 2.1–10 μm size fraction and equal roughly to 0.3%.

These data are tentative, since they are not statistically confident. Nevertheless, they agree well with the results reported in Ref. 4, where it was shown that the atmospheric aerosol fraction with the particle diameter > 2 μm is richest in microorganisms (which always contain marked amount of protein).

Note that mechanical destruction of dead biogenic matter (residuals of plants, animals, their cells) into very small parts requires rather high energy.

Period-averaged mass of atmospheric aerosol, total protein mass, and the protein fraction in the total particulate mass *

Measurement date	Total mass of particles, μg/m³	Mass of total protein in particles, μg/m³	Mass fraction of total protein, %
January–February 2001	26.98 ± 10.87	0.007 ± 0.004	0.003 ± 0.024
April–May 2001	61.47 ± 37.87	0.096 ± 0.10	0.16 ± 0.11
June–July 2001	34.24 ± 12.47	0.24 ± 0.14	0.76 ± 0.40
September–October 2001	31.05 ± 16.58	0.085 ± 0.009	0.24 ± 0.26
January–February 2002	21.68 ± 5.39	0.075 ± 0.043	0.36 ± 0.21
April–May 2002	52.01 ± 38.26	0.56 ± 0.59	1.21 ± 0.83
June–July 2002	25.86 ± 10.06	0.31 ± 0.09	1.30 ± 0.60
September–October 2002	37.79 ± 19.13	0.29 ± 0.14	0.78 ± 0.31

* Mean values ± standard deviations

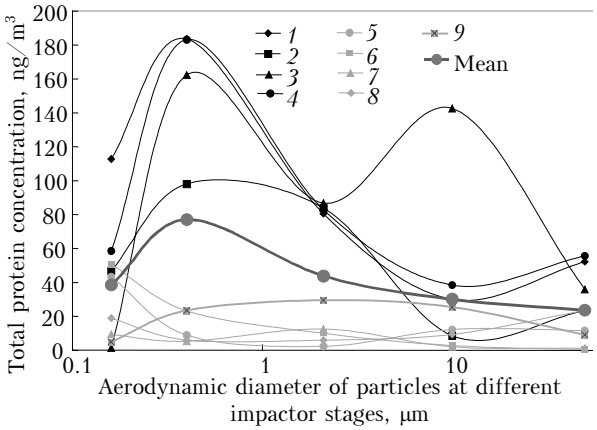

Fig. 7. Total protein distribution over atmospheric aerosol fractions in the atmospheric surface layer, as measured in February–March 2002 on the testing ground of ICKC SB RAS, Novosibirsk (curves *1–4*) and June 2002 in Kireevskoe village (curves *5–9*).

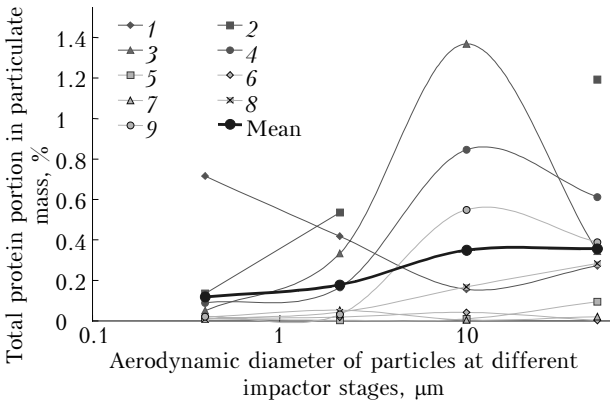

Fig. 8. Total protein distribution in atmospheric aerosol particulate mass in the atmospheric surface layer as measured in February–March 2002 on the testing ground of ICKC SB RAS, Novosibirsk (curves *1–4*) and June 2002 in Kireevskoe village (curves *5–9*).

Therefore, it is natural that the aerosol fraction with the particle diameter > 0.1 μm is richest in biogenic components. The above reasoning proves indirectly the validity of the results obtained with the low-pressure impactor.

In conclusion, we would like note another interesting aspect indirectly supporting the hypothesis on the prevalent role of remote powerful sources in the formation of biogenic component of atmospheric aerosol in Southwestern Siberia. More than one-year observations show that the total protein concentrations measured at the ground level are usually lower than that measured at the altitudes from 500 to 7000 m (Fig. 9).

For viable microorganisms these values are close (Fig. 10). This situation can take place only in the case that the biogenic component comes from the above to the atmospheric layer under study, which, taking into account its marked concentration, can be caused only by remote powerful sources, such as the above-mentioned: plants, soil, water bodies, etc.

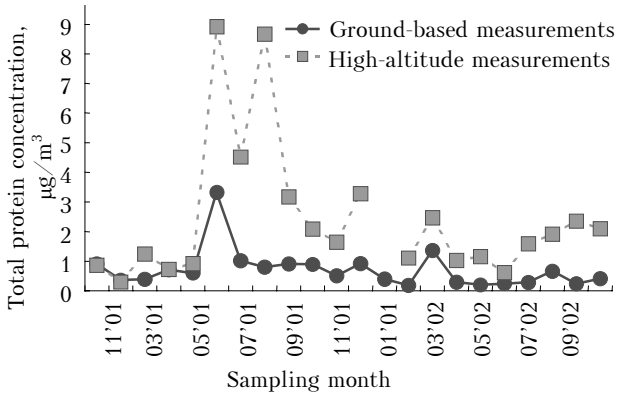

Fig. 9. Comparison of the dynamics of the surface total protein concentration and that averaged over the altitudes of 500–7000 m in atmospheric aerosol in Southwestern Siberia.

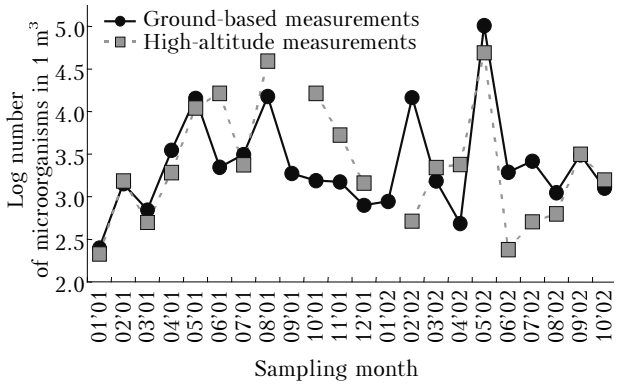

Fig. 10. Comparison of the dynamics of the surface concentration of viable microorganisms and that averaged over the altitudes of 500–7000 m in atmospheric aerosol in Southwestern Siberia.

If we take into account the long time needed for aerosol transport from remote sources to the observation point, then it becomes clear why the time behavior of the total protein concentration and the concentration of viable microorganisms differs from the typical seasonal activity of the animate nature in the Northern Hemisphere.

Thus, we have obtained the data on the concentrations of total protein and viable microorganisms concerning the fraction of the biogenic component in the total mass of atmospheric aerosol and its size distribution. The valuable information about the composition of atmospheric aerosol, its possible sources and their location has been obtained and analyzed.

Acknowledgments

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