Variability of biogenic component of atmospheric aerosol over forested areas of Western Siberia

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The annual variability of the biogenic component of the atmosphere at the altitude of 500–7000 m over forested areas of Southwestern Siberia is studied, and the results are presented. The seasonal dependence of total atmospheric protein, as well as variations of the specific composition and amount of living micro-organisms has been found in this region for the first time. Besides, the strong altitude correlation of total protein has been revealed. The obtained data are important for better insight into processes of transport of biogenic aerosol in the atmosphere, identification of its possible sources, and estimation of the impact of unfavorable environmental factors (surely, biogenic aerosols are among them) on human health in the region under study.

Introduction

The tentative results of studying the biological component of the atmospheric aerosol in Southwestern Siberia are presented in Ref. 1. The noticeable amount of total protein and the great variety of living micro-organisms have been found in the samples of near-surface air in different seasons. It is well-known that biological aerosols in the ground atmospheric layer can be transported for great distances conserving their viability.[2–5] Naturally, as this takes place, they rise through significant heights.[6,7] Consequently, for more reliable detection of possible sources of bioaerosols, ground-based and high-altitude measurements should complement each other. The first results of such measurements of concentration and composition of bioaerosols above forests of Western Siberia are presented in this paper.

Materials and methods

Airborne sensing of the atmosphere was conducted from aboard the Optik–E airborne laboratory (AN–30 aircraft) equipped with both remote and contact measuring devices. During a flight over forested and marshy territories of the Novosibirsk Region at the end of every month for an year, navigation characteristics (flight altitude, wind speed and direction relative to the ground), meteorological parameters (temperature, relative humidity, parameters of solar radiation, etc.), concentration and size spectrum of aerosol, and concentration of soot and some gases were measured, and air was sampled for further analysis. To study the protein component of the atmospheric aerosol, the air was sampled onto AFA–KhA filters; for detection of living micro-organisms, the air was flown through standard impingers[8] with a flow rate of 50 l/min and sorbing liquid volume of 50 ml.

Sample analysis. The total protein content in the samples was determined by the Bradford method.[9] This method is characterized by the accuracy of about 30% and sensitivity of 0.1 μg/ml of a sample.

To detect the microbiologic component in the samples of the atmospheric bioaerosol, the following culture media were used[10]: LB with addition of agar up to 1.7% (LBA), agarized depleted LB (solution 1:10), Saburo and Chapek media (pH = 6.5) for detection of protofungi and yeast, starch-ammonium medium (KAA) for detection of actinomyces, and soil agar.

The aerosol samples under study were put on Petri dishes filled with the culture media (if necessary, the samples were successively diluted) and incubated in a thermostat up to 14 days. The morphologic peculiarities of detected micro-organisms were examined both visually and by means of light microscopy. To do that, the fixed Gram-stained specimens of cells and preparations of living cell suspensions were prepared. They were examined by the method of phase contrast. The detected micro-organisms were taxonomically identified only to genus.

Results and discussion

Table 1 summarizes the monthly distributed data on the concentration of atmospheric protein at the altitudes from 500 to 7000 m.

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Table 1. Altitude variability of the protein concentration in the atmosphere, in μg/m^3

Altitude, m	Month of sampling										
	12.98	01.99	02.99	03.99	04.99	05.99	06.99	07.99	08.99	09.99	10.99
500	0.29	0.92	–	0.52	n.d.	0	2.36	3.29	4.90	3.55	1.06
1000	0.20*	0.33	–	0.70	1.23	1.49	n.d.	2.48	2.87	0.53	1.33
1500	0.69	0.30	–	n.d.	n.d.	1.36	1.41	n.d.	2.10	4.94	1.42
2000	0.16*	0.21*	–	0.68	1.32	1.34	1.43	3.18	2.89	0.82	3.45
3000	0.17*	0.17*	–	0.37	1.19	1.33	2.08	3.64	4.67	4.20	1.35
4000	0.15*	0.14*	–	0.29	1.31	0.49	2.99	2.89	3.57	3.36	0.96
5500	0.18	0.24	–	0.67	0.54	1.40	3.04	1.18	2.48	4.57	1.55
7000	0.18	0.68	–	0	1.58	0.78	2.00	2.06	3.84	4.44	1.18

N o t e . Asterisk (*) means that the actual value does not exceed the tabulated one, n.d. means no data available.

Table 2. Time and altitude correlation coefficients for the data on concentration of atmospheric protein

1998	1999										
XII	I	II	III	IV	V	VI	VII	VIII	IX	X	
1	0.10	–	0.18	−0.17	0.11	−0.50	0.16	−0.41	0.39	−0.11	XII
	1	–	−0.27	0.45	−0.68	−0.05	0.02	0.50	0.16	−0.32	I
		–	–	–	–	–	–	–	–	–	II
			1	−0.61	0.43	0.01	−0.04	−0.48	−0.59	0	III
500	1			1	−0.49	−0.58	0.54	0.50	−0.25	0.01	IV
1000	0.66	1			1	−0.35	−0.28	−0.65	−0.21	−0.06	V
1500	0.62	0.09	1			1	−0.49	0.19	0.27	−0.53	VI
2000	0.71	0.98	0.21	1			1	0.67	−0.27	−0.34	VII
3000	0.94	0.69	0.79	0.75	1			1	0.12	−0.21	VIII
4000	0.94	0.65	0.71	0.69	0.94	1			1	−0.53	IX
5500	0.66	0.19	0.90	0.24	0.75	0.80	1			1	X
7000	0.91	0.45	0.86	0.50	0.93	0.91	0.85	1			
	500	1000	1500	2000	3000	4000	5500	7000			
Flight altitude, in m											

The peculiarity of these data is that their altitude scatter significantly exceeds the estimated error of the method in winter and approaches it in summer. This points to the statistical character of the spread of atmospheric admixtures. Therefore, it seems impossible to obtain the reliable concentration profiles of atmospheric protein, especially, for the winter period.

Nevertheless, we can assume that the vertical distribution of protein is approximately homogeneous. Such a concentration profile of an atmospheric admixture must be observed in the case of an extended ground-based source under the conditions of intense or long turbulent mixing. It should be noted that the altitude variations of the protein concentration correlate markedly, whereas no time correlation is observed (Table 2).

It is seen from Fig. 1 that the total amount of atmospheric protein is minimum in winter. In spring, when flora and fauna awake, the protein concentration monotonically increases and reaches its maximum in summer with the value an order of magnitude exceeding the winter one. The analysis of the obtained data shows also that in summer we can reveal the tendencies in formation of the vertical profile of atmospheric protein. Thus, we should expect a distinct height-distributed annual cycle of variation of the protein component in the atmosphere. Obviously, revealing the vertical profiles of protein concentration and characteristics of its seasonal variability will call for particular attention in the future.

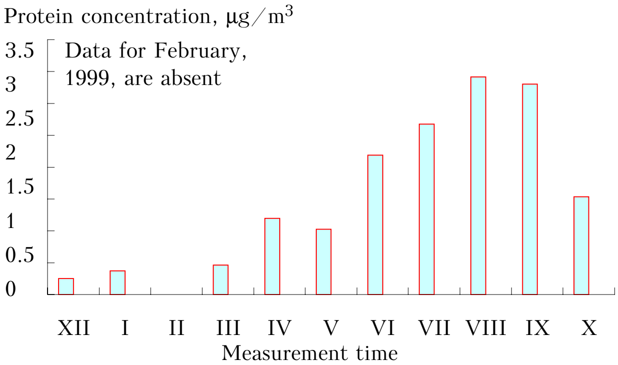

Fig. 1. Annual dynamics of the total protein concentration averaged over altitudes of 5–7 km (Roman numerals denote months of 1999).

The obtained data on the total concentration of atmospheric protein were compared with the observed concentration of aerosol particles (Figs. 2 and 3 show typical related altitude dependences for six of eleven months of observation). As is seen, no correlation between the concentration of aerosol particles measured with an optical counter and that of atmospheric protein was found, although under certain conditions the biogenic particles in the atmosphere constitute from 10 to 95% (Refs. 11–13). No correlation was also found between the total protein concentration and the concentrations of some atmospheric gaseous constituents (carbon dioxide, ozone).

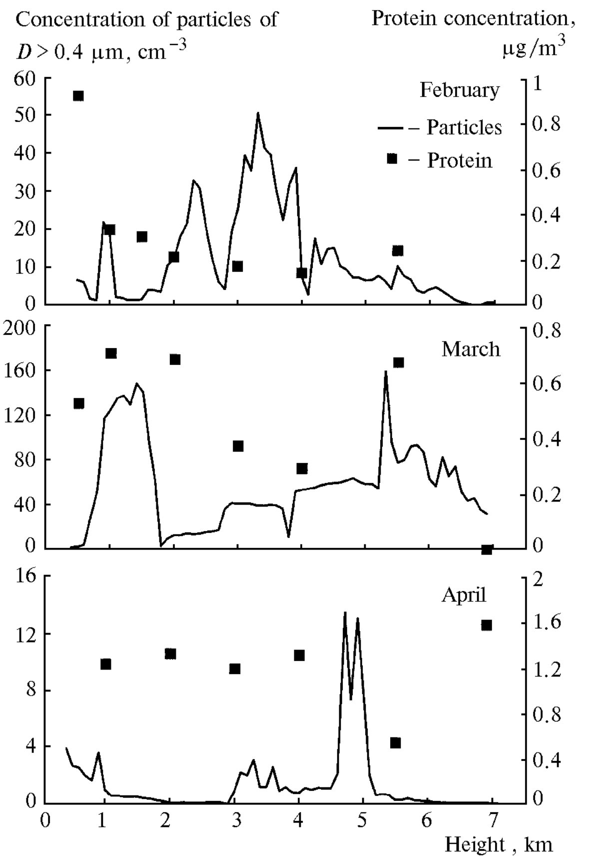

Fig. 2. Altitude dependence of the concentrations of aerosol particles and total protein in the atmosphere in February–April 1999.

Analysis of atmospheric air samples for living micro-organisms has shown some seasonal variability of their specific composition (Tables 3 and 4). In summer period, the atmospheric amount of micro-organisms nascent on soil agar increases, whereas the number of micro-organisms grown in the Saburo medium varies insignificantly. To illustrate the observed variety of micro-organisms, we give the data on their percentage in the atmosphere in June and September of 1999 (Table 5). On the whole, the results obtained for the time of observations allow no reliable conclusions on regularities in the atmospheric variability of micro-organisms of different kinds. No correlation was found between the concentration of micro-organisms in the atmosphere and the concentrations of protein, aerosol particles, and gaseous constituents.

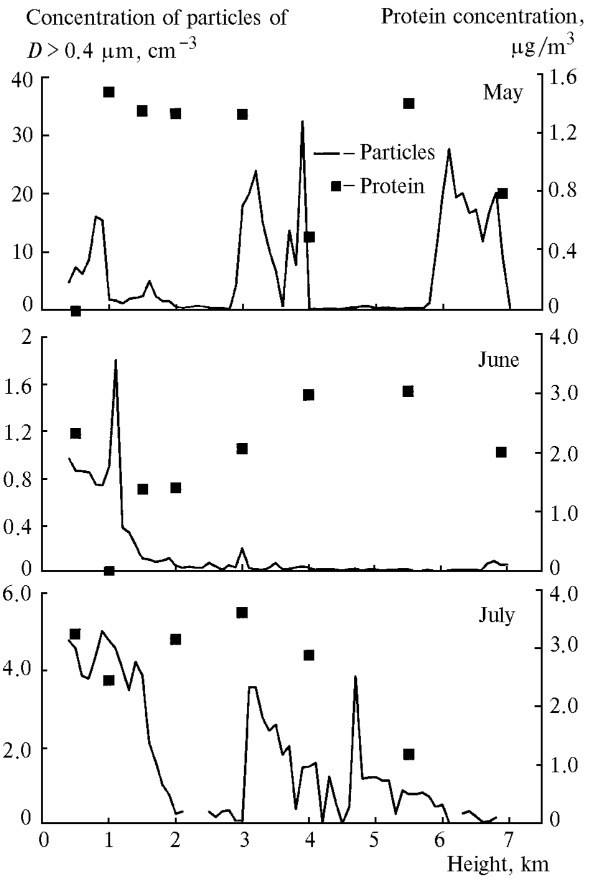

Fig. 3. Altitude dependence of the concentrations of aerosol particles and total protein in the atmosphere in May–July 1999.

Table 3. The presence of different micro-organisms nascent on soil agar in the atmosphere in 1999

Altitude, m	March	April	May	June	July	August	September	October
500	n.f.	n.f.	0	1000	1500	0	86	0
1000	n.f.	0	0	500	6500	0	690	0
1500	0	n.d.	0	n.f.	7000	0	160	0
2000	0	0	n.f.	500	6500	0	0	0
3000	0	0	0	n.f.	6000	670	0	0
4000	n.f.	n.f.	0	n.f.	5500	0	100	0
5500	0	0	2900	n.f.	2000	0	130	0
7000	0	0	n.f.	n.f.	2000	0	40	0

N o t e : n.f. means not found, n.d. means no data.

Table 4. The presence of different micro-organisms nascent in the starch-ammonium medium in the atmosphere in 1999

Altitude, m	March	April	May	June	July	August	September	October
500	0	0	1200	0	2000	860	0	5
1000	0	0	n.f.	0	2500	170	120	5
1500	0	n.d.	4100	2000	112000	15	20	0
2000	0	900	n.f.	0	4500	330	20	0
3000	0	0	n.f.	n.f.	2500	100	0	0
4000	200000	n.f.	18000	0	3000	n.d.	40	0
5500	1000	0	3600	0	3000	315	0	0
7000	13000	1000	6900	n.f.	500	50	0	0

Note: n.f. means not found, n.d. means no data.

Table 5. The presence of different micro-organisms nascent in the agarized depleted LB medium, in %, in the atmosphere

Altitude, m	June 1999	July 1999
500	Absent	Actinomyces – 0.03 Bacilli – 34.75 Cocci – 32.79 Diplococci – 31.15 Nonsporogenous bacteria – 1.00
1000	Bacilli – 66.7 Nonsporogenous bacteria – 6.7 Cocci – 16.7 Fungi – 9.9	Actinomyces – 8.33 Bacilli – 12.5 Cocci– 8.33 Diplococci – 66.67 Nonsporogenous bacteria – 4.17
1500	Cocci – 100	Bacilli – 3.85 Cocci – 96.15
2000	Cocci – 87.5 Bacilli – 12.5	Actinomyces – 7.69 Bacilli – 3.85 Cocci – 73.08 Diplococci – 15.38
3000	Bacilli – 100	Actinomyces – 2.00 Bacilli – 7.67 Cocci – 79.00 Diplococci – 11.33
4000	Cocci – 100	Actinomyces – 0.80 Bacilli – 14.29 Cocci – 23.02 Diplococci – 61.90
5500	Cocci – 50 Nonsporogenous bacteria – 25 Actinomyces – 25	no data
7000	Cocci – 60 Nonsporogenous bacteria – 30 Bacilli – 10	Cocci – 81.23 Nonsporogenous bacteria – 18.77

Conclusions

The short-term (less than an year) period of observations and the great body of the obtained information hinder generalization and explanation of the results. Nevertheless, we can draw some tentative conclusions.

1. The complex systematic study of the biogenic component of the atmospheric aerosol in Western Siberia has been started with the help of the airborne laboratory. The study is accompanied by measurements of a wide spectrum of physical and chemical characteristics of the atmosphere and atmospheric aerosol, such as air temperature and humidity, wind direction and velocity, size spectrum and chemical composition of the atmospheric aerosol, presence of some important gaseous constituents in the atmosphere, etc.

2. The seasonal variability of the total protein concentration in the atmosphere has been found. Its altitude variation turns out to be almost uncorrelated with the measurement time, whereas its correlation with the altitude is high.

3. The following micro-organisms were found in the atmosphere of Southwestern Siberia at the altitude

of 500–7000 m: bacteria (first of all, different bacilli and cocci and, to lesser degree, actinomyces) and protofungi. The seasonal variability of micro-organisms in the atmosphere has been revealed with certainty.

4. No significant correlation between the concentrations of micro-organisms and background protein in the atmosphere, as well as with aerosol particles and gaseous constituents has been found (the maximum coefficient of correlation between micro-organisms and atmospheric protein is lower than 30%).

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