Annual variation of protein concentration in biogenic component of atmospheric aerosol in Southwestern Siberia

A.N. Ankilov, A.M. Baklanov, B.D. Belan, A.I. Borodulin, G.A. Buryak, A.L. Vlasenko, Yu.V. Marchenko, S.E. Ol'kin, M.V. Panchenko, V.V. Penenko O.V. P'yankov, I.K. Reznikova, A.S. Safatov, A.N. Sergeev, and E.A. Tsvetova

Scientific Research Institute of Aerobiology
at the State Scientific Center of Virology and Biotechnology "Vektor," Novosibirsk Region
Institute of Chemical Kinetics and Combustion,
Siberian Branch of the Russian Academy of Sciences, Novosibirsk
Institute of Atmospheric Optics,
Siberian Branch of the Russian Academy of Sciences, Tomsk
Institute of Computational Mathematics and Mathematical Geophysics,
Siberian Branch of the Russian Academy of Sciences, Novosibirsk

Received November 29, 2000

Late in 1998 monitoring of the biogenic component of atmospheric aerosol in the Southwestern Siberia has been started. The data obtained show pronounced seasonal variability of the total content of protein in atmospheric aerosol. Yearly changes in the total protein concentration are characterized by strong height correlation, but no time-correlation was observed. Analysis of back trajectories of air masses showed that the protein component of atmospheric aerosol at the measurement point was formed by several independent sources located far from this point.

Earlier, in Refs. 1 and 2, we have presented some results of the tentative study of biological component of atmospheric aerosol in the Southwestern Siberia. In 1998 the marked total amount of protein and wide variety of living microorganisms were found in the near-ground atmospheric layer. The atmospheric aerosols of biological origin can travel at long distances and may reach high altitudes,[3,4] with the microorganisms contained in them keeping their vitality.[5–8] Therefore, to study thoroughly the properties of the biological component of atmospheric aerosol and to evaluate its sources, the ground-based measurements should be complemented with high-altitude ones.

In this paper, we present some results of high-altitude measurements of the protein concentration in atmospheric aerosol over forests of the Southwestern Siberia. These measurements have been conducted at the Scientific Research Institute of Aerobiology at the State Scientific Center of Virology and Biotechnology "Vektor" and at the Institute of Atmospheric Optics, Siberian Branch of the Russian Academy of Sciences. High-altitude measurements were complemented with ground-based ones that were performed at the Institute of Aerobiology in cooperation with the Institute of Chemical Kinetics and Combustion in the same region.

Materials and methods

Sampling at high altitude was performed from aboard of Optik–E airborne laboratory (AN–30 aircraft). The aircraft flew in the twentieths of every month starting from December 1998. Figure 1 shows schematically the place of the experiments. The 50-km long flight path went over the Karakansky forest on the right bank of the Ob River.

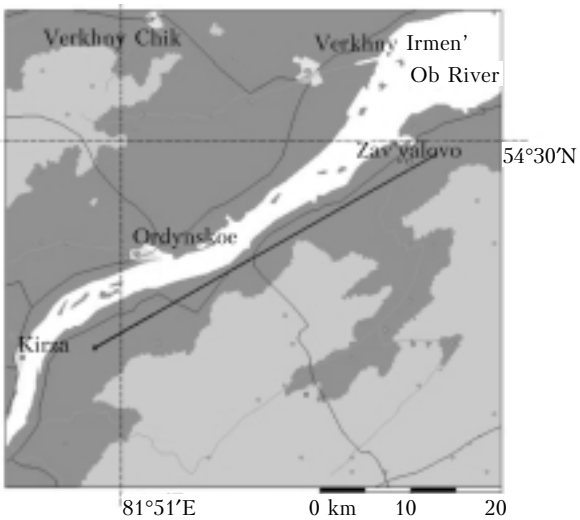

Fig. 1. Region over which the experiments have been conducted. The straight line shows the aircraft flight line.

Within the given path, the aircraft flew sequentially at the altitudes of 7000, 5500, 4000, 3000, 2000, 1500, 1000, and 500 m in daytime. At each altitude, one sample of air was taken to an AFA-KhA filter[9] for 10–20 min. The volume of an air sample was usually about 2 m^3.

The near-ground sampling was done to the identical filters. Sampling was performed at two sites: territory of the Institute of Chemical Kinetics and Combustion (1.5 m above the ground level) and in the State Scientific Center of Virology and Biotechnology

0235-6880/01/06–07 473-05 $02.00

"Vektor" (20 m above the ground level). Besides, some samples were taken in Tomsk and Kireevsk (Tomsk Region). The total protein content in all samples was analyzed under laboratory conditions by the Bradford method.[10] The sensitivity of the method was 0.1 μg/ml sample wash-out from the filter. The measurement error in concentration did not exceed 30%.

Results and discussion

Figure 2 shows the dependence of the protein concentration at different altitudes on the month of observation. A peculiarity of the results presented is that in winter the concentration is at the level of minimum concentration measurable reliably by this method, and the spread in the data is relatively wide.

In summer, the absolute concentration of protein increases, but the spread remains wide. On the one hand, this may be indicative of a significant effect of the statistical nature of atmospheric aerosol spread on the amount of protein sampled. Actually, because of large fluctuations of the aerosol concentration even at a limited sampling time, the measured concentrations in samples differ widely. On the other hand, we can assume that the mean protein concentration varies homogeneously, smoothly along the vertical.

These profiles of an atmospheric admixture concentration result from extended remote area sources (such as large forestlands, water bodies, erosive soil, etc.) at intense and long turbulent mixing. However, in this case, large fluctuations of the concentration must be observed against the background of smoothly varying mean values. The altitude-average concentrations shown in Fig. 3 indicate that the second assumption is more likely closer to reality.

Let us consider the data collected in June 2000 in a more detail. The altitude-average protein concentration does not differ from that in winter period. This can be explained by large fluctuations of the protein concentration (whose values were less than the expected ones in all measurements), however the ground-based measurements in June 2000 show that the protein concentration in the near-ground atmospheric layer was low during all this month (Fig. 4).

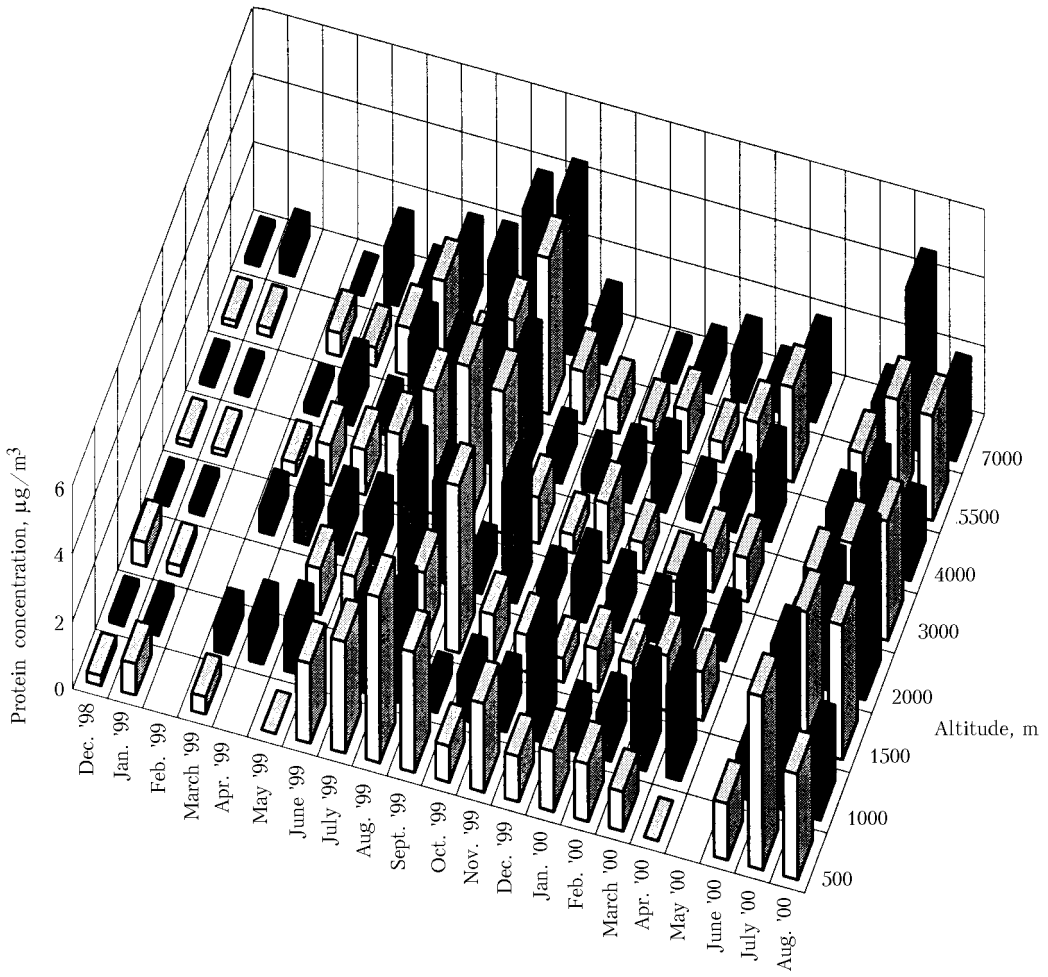

Fig. 2. Altitude dependence of the total protein concentration in the atmosphere. The data for different altitudes are shown alternately by light and dark-color bars.

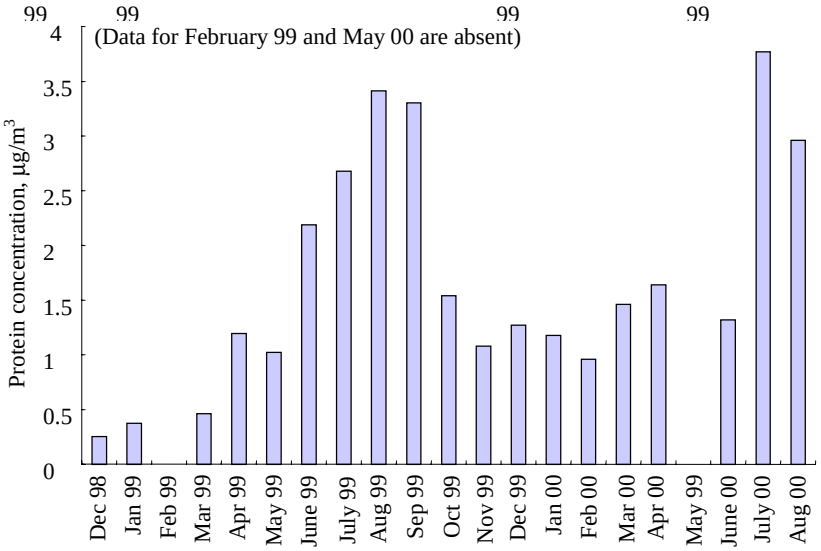

Fig. 3. Protein concentration in the atmosphere averaged over the altitudes from 500 to 7000 m.

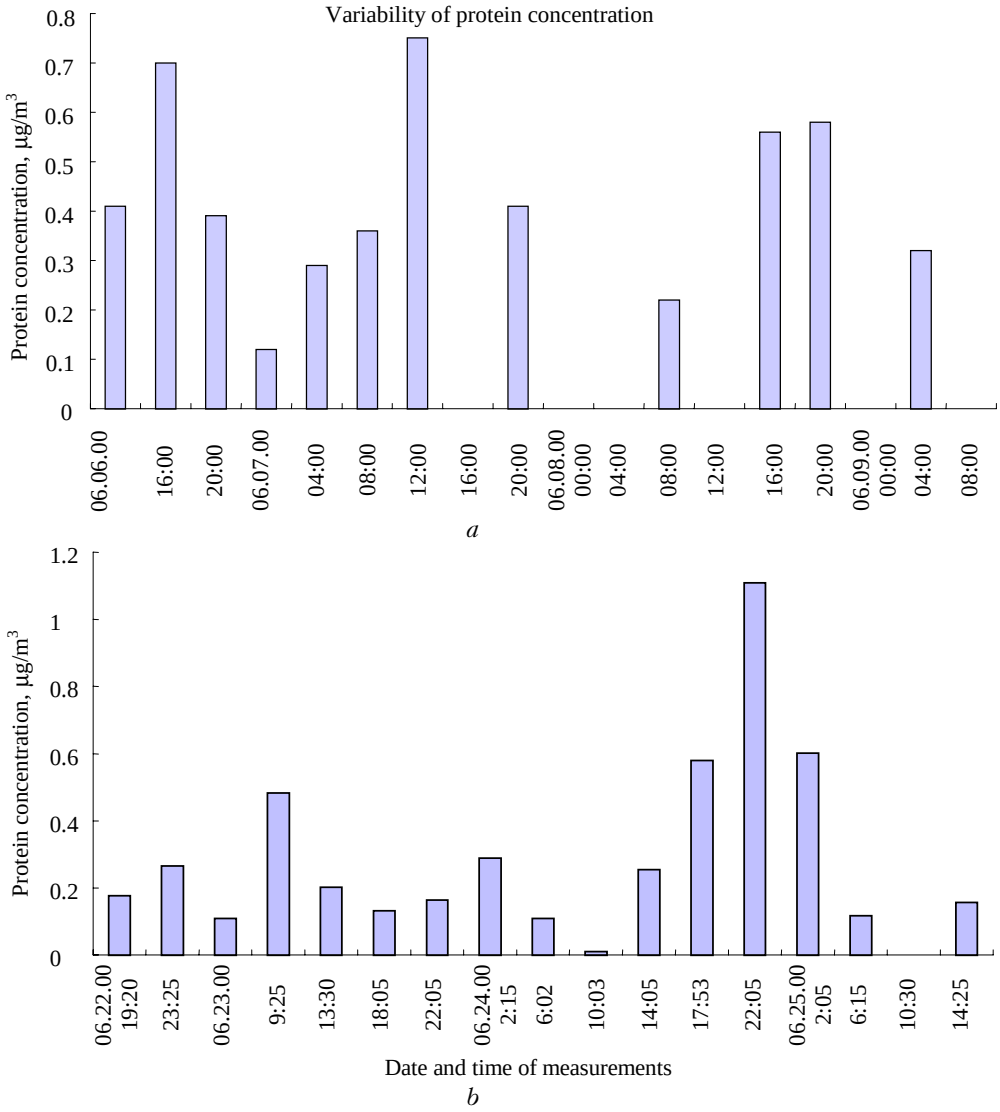

Fig. 4. Variability of the total protein concentration near the ground surface: "Vektor" (*a*) and Institute of Chemical Kinetics and Combustion (*b*).

Peculiarities of the atmospheric circulation in the Southwestern Siberia in this month have likely prevented the atmospheric masses rich in biogenic particles to reach this region.

Correlation analysis proves to be rather efficient for analysis of the data array similar to that shown in Fig. 2. The results of this analysis are tabulated in Table 1, which gives the correlation coefficients of the protein concentration obtained from analysis of samples of the data shown in Fig. 2 (a total of 463 measurements conducted in different time). It is worth noting the fact that the concentration of protein has significant height correlation (thus, the mean value of the pair correlation coefficient is 0.67, and with the probability of 95% this mean falls within the interval from 0.61 to 0.72), whereas no significant time correlation is observed. From this we can conclude that during a year the profiles of protein concentration in the atmosphere have, on the average, similar shape.

Actually, the Pearson 5% significance criterion does not reject the hypothesis that all pair coefficients of height correlation belong to one general set with the mean value of the coefficient shown above. This argument confirms the hypothesis that the concentration profiles of the atmospheric protein are formed in the process of long turbulent mixing from extended and remote sources. The absence of systematic (i.e., with the same sign) time correlation in the concentration of atmospheric protein means that different and statistically independent aerosol sources take part in the formation of vertical profiles of the protein concentration.

This hypothesis is confirmed by our numerical estimates. We have calculated the back trajectories of air mass from the sampling point with the semi-spherical model in the coordinate system following the surface terrain. Inverse problem was solved for 30 days back. The computational algorithm is based on the combination of Lagrange approach and the Monte Carlo method. The NCEP/NCAR Reanalysis data were used to reconstruct the spatiotemporal structure of atmospheric circulation with the step of 30 min.

The peculiarity of the trajectories computed is that the air masses coming to the sampling point have different history: in the process of their motion they were at different altitudes over different regions (often even different continents and oceans), and only as they approach the sampling point, their trajectories converge to a common point. Consequently, aerosol particles from different sources can actually come to the sampling point. Since the micron-size aerosol particles can rest in the atmosphere for rather long time,[10] they can reach the sampling point together with the air masses. It should be noted that in the process of motion the air masses move from one height to another, they can touch the surface (where they are probably enriched with bioaerosols), mix intensely at some places (for each backward trajectory these places are different), and only then approach the sampling point.

Table 1. Correlation coefficients of the total protein concentration in the atmosphere as calculated from the data shown in Fig. 1. The upper part of the table corresponds to the time correlation, and the lower one corresponds to the height correlation

Dec 98	Jan 99	Feb 99	Mar 99	Apr 99	May 99	June 99	July 99	Aug 99	Sep 99	Oct 99	Nov 99	Dec 99	Jan 00	Feb 00	Mar 00	Apr 00	May 00	June 00	July 00	
1.00	0.10		0.18	−0.17	0.11	−0.50	0.16	−0.41	0.39	−0.13	0.24	−0.24	0.21	0.32	0.12	−0.22		−0.12	0.30	Dec 98
	1.00		−0.27	0.45	−0.68	−0.05	0.02	0.50	0.16	−0.32	0.99	−0.19	0.25	0.83	−0.38	−0.52		0.15	0.83	Jan 99
																				Feb 99
			1.00	−0.61	0.43	0.01	−0.04	−0.48	−0.59	0.47	0.18	0.59	0.23	−0.03	0.83	0.04		0.30	−0.02	Mar 99
				1.00	−0.49	−0.58	0.54	0.50	−0.25	0.01	−0.48	0.04	−0.37	0.43	−0.22	−0.50		−0.63	0.28	Apr 99
					1.00	−0.35	−0.28	−0.66	−0.21	0.43	−0.65	0.28	−0.65	−0.47	0.62	0.52		−0.47	−0.29	May 99
						1.00	−0.49	0.19	0.27	−0.53	0.04	−0.12	0.35	−0.20	−0.43	0.51		0.52	−0.23	June 99
							1.00	0.67	−0.27	0.14	0.07	0.40	0.18	−0.07	0.01	−0.72		0.34	−0.17	July 99
								1.00	0.12	−0.34	0.39	0.08	0.15	0.08	−0.56	−0.56		0.54	0.08	Aug 99
									1.00	−0.53	0.09	−0.77	0.15	−0.15	−0.74	−0.03		0.16	−0.08	Sep 99
	Height, m									1.00	−0.29	0.10	−0.11	−0.24	0.46	−0.22		−0.31	−0.28	Oct 99
	500	1.00									1.00	−0.02	0.63	0.84	−0.15	−0.56		0.57	0.83	Nov 99
	1000	0.51	1.00									1.00	−0.21	0.05	0.74	0.07		0.17	0.09	Dec 99
	1500	0.68	0.34	1.00									1.00	0.21	−0.17	−0.46		0.68	0.00	Jan 00
	2000	0.54	0.67	0.35	1.00									1.00	0.06	−0.29		−0.10	0.95	Feb 00
	3000	0.75	0.46	0.73	0.60	1.00									1.00	0.23		−0.16	0.09	Mar 00
	4000	0.74	0.51	0.70	0.51	0.90	1.00									1.00		−0.37	−0.19	Apr 00
	5500	0.55	0.39	0.86	0.30	0.70	0.81	1.00												May 00
	7000	0.86	0.49	0.89	0.45	0.80	0.83	0.83	1.00									1.00	−0.14	June 00
		500	1000	1500	2000	3000	4000	5500	7000	Height, m									1.00	July 00

As an example, we present in Fig. 5 the total sensitivity function and the data (averaged over the ensemble of all Lagrange trajectories) for the measurement conducted at the point with the coordinates 54.23°N, 82.09°E at the altitude corresponding to the pressure level of 700 mbar (roughly 3 km). Isolines in this figure show the levels of probability of that the sampled aerosol particles started from a given point on the surface (in other words, only those trajectories that terminated on the surface in the inverse time are taken into account here). In particular, it is seen from Fig. 5 that particles from Northern Kazakhstan had the highest probability to be found in the samples.

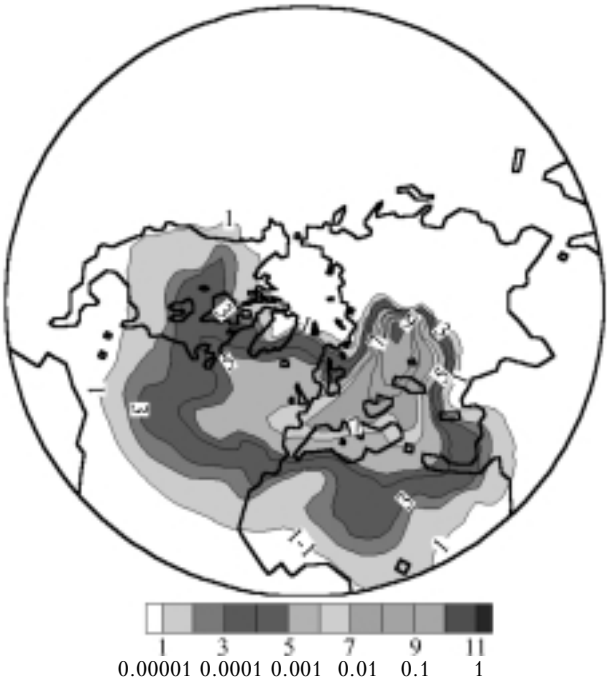

Fig. 5. Distribution of the probability that aerosol particles starting from different points on the surface reach the sampling point in Novosibirsk Region at the altitude of 3 km on October 31, 1998.

The obtained results and the above discussion allow us to draw the following conclusions.

The systematic study of protein component of atmospheric aerosol in the Southwestern Siberia has been started; the tentative results on the annual behavior of the concentration of atmospheric protein have been obtained. The measured concentrations of the biogenic component of atmospheric aerosol agree well with the measurement data collected in other regions.[11–16]

The tentative analysis of data shows that the protein component of atmospheric aerosols in the Southwestern Siberia is formed by several independent sources that are far from the observational sites, including sources in Central Asia.

Acknowledgments

The work was partially supported by the Russian Foundation for Basic Research, Project No. 00–05–72014.

References

1. A.N. Ankilov, A.M. Baklanov, A.I. Borodulin, G.A. Buryak, S.B. Malyshkin, S.E. Ol'kin, O.V. P'yankov, O.G. P'yankova, A.S. Safatov, and A.N. Sergeev, Atmos. Oceanic Opt. **12**, No. 6, 488–492 (1999).
2. I.S. Andreeva, B.D. Belan, A.I. Borodulin, G.A. Buryak Yu.V. Marchenko, S.E. Ol'kin, M.V. Panchenko, V.A. Petrishchenko, O.V. P'yankov, I.K. Reznikova, A.S. Safatov, A.N. Sergeev, and E.V. Stepanova, Atmos. Oceanic Opt. **13**, Nos. 6–7, 592–596 (2000).
3. D.J. Kushner, ed., *Microbial Life in Extreme Environments* (Academic Press, London, 1978).
4. P.H. Gregory, *Microbiology of Atmosphere* (Leonard Hill, London, 1961), 251 pp.
5. J. Gloster, R.F. Sellers, and A.I. Donaldson, Vet. Rec. **110**, No. 1, 47–52 (1982).
6. A. Bovallius, B. Bucht, R. Roffey, and P. Anas, Appl. Environ. Microbiol. **35**, No. 5, 847–852 (1978).
7. G.W. Hammond, R.L. Raddatz, and D.E. Gelskey, Rev. Infect. Dis. **11**, No. 3, 494–497 (1989).
8. C.S. Cox, *The Aerobiological Pathway of Microorganisms* (John Wiley & Sons, Chichester, 1987), 273 pp.
9. W.D. Griffiths and G.A.L. DeCosemo, J. Aerosol Sci. **25**, No. 8, 1425–1458 (1994).
10. A. Darbe, ed., *Practical Protein Chemistry. A Handbook* (John Wiley & Sons, Chichester, 1986), pp. 297–298.
11. K.Ya. Kondrat'ev, ed., *Aerosol and Climate* (Gidrometeoizdat, Leningrad, 1991), 444 pp.
12. P. Artaxo, H. Storms, F. Bruynseels, R. Van Grieken, and W. Maenhaut, J. Geophys. Res. **93**, No. D2, 1605–1615 (1988).
13. P. Artaxo, W. Maenhaut, H. Storms, and R. Van Grieken, J. Geophys. Res. D**95**, No. 10, 16971–16985 (1990).
14. S. Matthias-Maser and R. Jaenicke, J. Aerosol Sci. **25**, No. 8, 1605–1613 (1994).
15. S. Matthias-Maser, V. Obolkin, T. Khodzer, and R. Jaenicke, J. Aerosol Sci. **29**, Suppl. 1, S545–S546 (1998).
16. S. Mattias-Maser, V. Obolkin, T. Khodzer, and R. Jaenicke, Atmos. Environ. **34**, No. 22, 3805–3811 (2000).