Study of the biogenic part of atmospheric aerosol accumulated in snow cover nearby some aerosol sources

I.S. Andreeva, A.I. Borodulin, G.A. Buryak, S.E. Ol'kin, V.A. Petrishchenko, V.F. Raputa,[1] I.K. Reznikova, and A.S. Safatov

State Scientific Center of Virology and Biotechnology "Vektor," Kol'tsovo, Novosibirsk Region
[1] Institute of Computational Mathematics and Mathematical Geophysics, Siberian Branch of the Russian Academy of Sciences, Novosibirsk

Received November 27, 2001

We present some results of the study of biogenic atmospheric aerosols accumulated in the snow cover near Novosibirsk in 2001. It was found that the total protein concentration in snow decreased as the distance from the sources of both organic and inorganic aerosols increased. Such dependence was not found for living microorganisms in the snow. The data on microorganism content in snow are presented as well. Possible ways of deposition of aerosol particles containing protein and microorganisms onto the snow cover are discussed.

Introduction

In our previous paper,[1] we demonstrated the possibility of using snow cover samples for analysis of the biogenic component of atmospheric aerosol in Novosibirsk region. As a good accumulator of atmospheric pollutants in winter, the snow cover was earlier used to study pollution with polyaromatic compounds, radionuclides, and heavy metals.[2–6] Some microbiological characteristics of the snow cover were studied as well.[7–9]

In this paper, we assess in a more thorough way the biogenic component of the atmospheric aerosol within the framework of comprehensive ground-based and high-altitude measurements.[10–14] The uniqueness of the results obtained consists in the fact that other methods can hardly estimate correctly the concentration of aerosol emitted and reconstruct source characteristics from it, because of discontinuous source operation, stochastic character of aerosol spread in the atmosphere, and difficulty of simultaneous sampling at many points under the emission plumes. Unlike soil, snow does not contain large amounts of biogenic components, therefore it can be used to study the biogenic component of atmospheric aerosol.

Materials and methods

Samples were taken both near and far from powerful anthropogenic sources. A specialized sampler took samples with the base area of 1 dm^2 for the whole depth of the snow cover. Five samples taken within an area of 1 m^2 were then united into a single one. A sample was melted under sterile conditions and divided into several parts for analysis of total protein and living microorganisms.

The total protein content was analyzed in a laboratory by one of the two methods: the Bradford method,[15] whose sensitivity was 0.1 μg/ml and the measurement error for the concentration did not exceed 30%, and the fluorescent method with a dye described in Ref. 16; the sensitivity of the latter was about 0.01 μg/ml and the measurement error for the concentration was less than 20%.

The following nutrient media were used to detect living microorganisms in atmospheric aerosol samples: LB agarized full and depleted (1:10 dilution) medium; starch-ammoniac medium to reveal actinomycete; soil agar, Saburo (pH 5.4) and Chapek (pH 6.5) media to reveal lower fungi and yeasts. The studied samples were sowed on a Petri dish with nutrient media (whenever needed, sequential dilutions of samples were prepared) and incubated in a thermostat for up to 14 days. Morphological peculiarities of detected microorganisms were analyzed visually and with the use of optical microscopy. For this purpose, we prepared fixed Gram-stained cell specimens and supravital cell suspension specimens observed by the method of phase contrast. Found microorganisms were identified accurate to genus.[17,18] In our classification, the group called "non-spore-forming bacteria" included various microorganisms not forming endospores: Gram-variable and Gram-positive coccus bacilli, various non-spore-forming bacilli stainable Gram-negatively (among them, pseudomonases, intestinal bacteria, etc.). This conditional group also included bacteria, whose cells had an irregular shape, for example, mycobacteria, nocardin. Some extra tests were conducted as well.[17,18]

The amount of living microorganisms in samples was calculated by the standard methods,[19] and the amount was averaged over 2 to 3 parallels of samples scattered over 4 to 5 different media.

0235-6880/02/05–06 425-04 $02.00

To assess the long-term pollution of a territory by a local source from the observations, the regression dependence proposed in Refs. 20 and 21 and attested in Ref. 1 was used. This approach allows assessment of characteristics of local pollution sources.

Results and discussion

Snow samples collected late in February of 2001 from regions adjacent to the Berdsk Chemical Plant (BCP) and Novosibirsk Electrode-Making Plant (NEMP) were analyzed by the methods described in the previous section. It was found that the total protein concentration in snow obeys a certain law, as a function of distance from an aerosol source. At the same time, no similar dependence on the distance was found for living microorganisms (Figs. 1 and 2). It should be noted that high value of the total protein concentration in Fig. 1 at the distance of 500 m from the source may be caused by foreign biological pollution. The regression models describing the observed dependences were constructed in accordance with the method described in Refs. 1, 20, and 21. This dependence for the BCP is shown in Fig. 3. For the NEMP we failed to construct an adequate model.

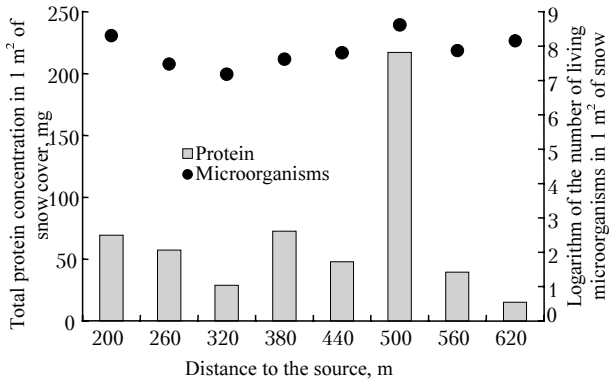

Fig. 1. Concentrations of total protein and microorganisms in snow cover in 2001 as functions of the distance to BCP smokestack.

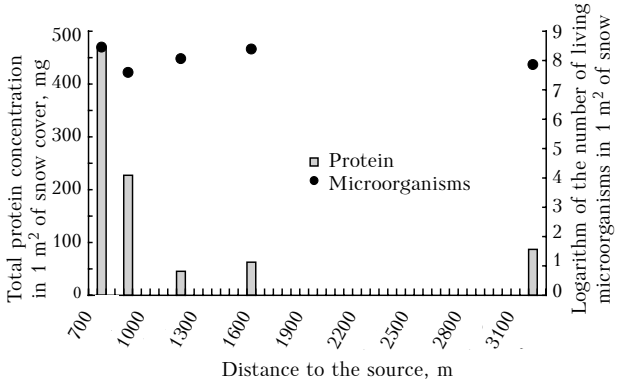

Fig. 2. Concentrations of total protein and microorganisms in snow cover in 2001 as functions of the distance to NEMP smokestack.

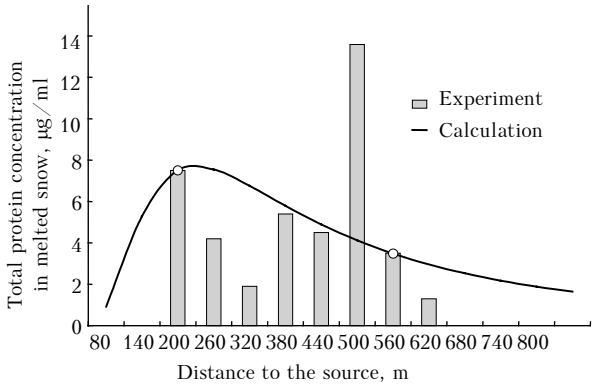

Fig. 3. Experimental and calculated data on the protein content in snow cover as a function of the distance to the BCP smokestack. Reference points used for estimation of the regression function are shown on the calculated curve.

Let us compare the estimates of the total protein emission from the BCP in winter 2000/01 with the data obtained for the BCP in 2000 and for the Novosibirsk Capacitor-Making Plant (NCMP). As follows from the data in Table 1, the emission rates and the size spectrum of aerosol from the BCP are similar. At the same time, according to our data, the NCMP is not a source of protein. However, the protein concentration in the snow cover near the NCMP is also described by the dependence similar to that shown in Fig. 3 of Ref. 1. Considerable part of protein coming to snow from the atmosphere is likely scavenged from the atmosphere by coarse aerosol particles, rather than directly coming from anthropogenic sources. This assumption is also confirmed by the fact that the total protein concentration observed in the atmosphere in winter period is rather high, and the presence of protein in our region is mostly caused by very distant powerful sources.[11–13]

Table 1. Estimated regression parameters and total protein emissions

Source, year	Estimated parameters		Total emission, kg
	θ_1	θ_2	
BCP, 2001	2.22	−2.62	16.2
BCP, 2000	1.06	−3.68	24.7
NCMP, 2000	0.73	−5.84	15.4

Note. The data for 2000 are borrowed from Ref. 1. The parameter θ_1 is proportional to the emission rate and depends, rather in a complex way, on the climatic characteristics of wind velocity, turbulent exchange coefficients, source height, and the aerosol deposition rate. The parameter θ_2 depends on the aerosol deposition rate, coefficient of vertical turbulent diffusion at the height of 1 m, and the exponent in approximation of the horizontal component of wind velocity by a power-law function.

As was noted above (see Figs. 1 and 2), although it was shown that the total protein concentration depends on the distance from the possible pollution source, we failed to find similar dependence for the concentration of living microorganisms in snow. This

fact indicates that sources of microorganisms and total protein are independent in our case and have different origin. Besides, the hypothesis of scavenging of the aerosol containing total protein suggests the following conclusion: the living microorganisms found and a large fraction of total protein is brought by particles of different size. It is natural that large particles containing atmospheric microorganisms[22] almost do not interact with coarse particles of anthropogenic emissions, while smaller particles containing total protein are scavenged from the atmosphere by coarse particles of aerosol emissions, thus forming snow depositions, which are described by models of emissions from sources with the characteristic particle size about one micron diameter. Besides, some snow particles may directly contain microorganisms, because they, as known,[23–25] may serve as nucleation centers for a new phase, which then forms snowflakes.

Let us consider now the results on the biodiversity of microorganisms in the snow cover. As follows from Table 2, the fractions of different kinds of microorganisms differ even at neighboring points, although this difference is not so pronounced as that at neighboring heights in the atmosphere (see Ref. 14). This situation is rather expectable, because the snow cover, accumulating deposited particles and keeping them for the whole winter, makes natural integration of existing time variations of the diversity of atmospheric microorganisms. It should also be noted that the data obtained on the concentration and fraction of microorganisms in snow cover samples agree with those for other regions.[7–9,26]

Table 2. Percentage of microorganisms in snow samples

Sampling site, year	Distance to the source, m	Bacilli	Cocci	Non-spore-forming bacteria	Fungi	Actino-mycetes
BCP, 2000	250	28.76	47.32	21.34	2.58	–
	300	2.27	81.82	6.82	9.09	–
	350	–	54.05	27.03	18.92	–
	400	2.55	73.98	10.20	13.27	–
	450	–	40.91	47.73	11.36	–
	500	2.22	64.44	14.44	18.90	–
	550	19.69	59.08	17.90	3.33	–
	600	18.33	10.18	71.27	0.22	–
	650	3.50	–	92.82	3.68	–
BCP, 2001	200	30.55	30.55	34.36	4.54	–
	260	39.72	1.87	29.44	28.97	–
	320	38.98	20.34	23.73	16.95	–
	380	12.27	44.61	24.16	18.96	–
	440	3.01	51.10	31.66	14.23	–
	500	–	48.58	48.58	2.84	–
	560	1.71	32.93	28.66	36.70	–
	620	2.01	3.90	91.61	2.48	–
NCMP, 2001	750	4.51	66.35	10.53	18.61	–
	900	17.58	46.15	13.19	21.98	1.10
	1200	1.59	3.58	94.16	0.67	–
	1600	3.88	3.11	92.52	0.49	–
	3200	0.91	14.61	76.14	8.34	–

Thus, the study of the snow cover yields the very important information about the biogenic component of atmospheric aerosol and its possible local and remote sources in our region.

References

1. I.S. Andreeva, A.I. Borodulin, G.A. Buryak, V.V. Kokovkin, S.E. Ol'kin, V.A. Petrishchenko, V.F. Raputa, I.K. Reznikova, A.S. Safatov, and E.V. Stepanova, Atmos. Oceanic Opt. **14**, Nos. 6–7, 497–500 (2001).
2. V.F. Raputa, A.P. Sadovskii, S.E. Ol'kin, and N.A. Lapteva, Atmos. Oceanic Opt. **11**, No. 6, 521–523 (1998).
3. V.F. Raputa, T.V. Khodzher, A.G. Gorshkov, and K.P. Koutsenogii, Atmos. Oceanic Opt. **11**, No. 6, 562–564 (1998).
4. V.F. Raputa, A.P. Sadovskii, S.E. Ol'kin, V.V. Kokovkin, S.V. Morozov, and A.I. Vyalkov, Atmos. Oceanic Opt. **12**, No. 6, 521–524 (1999).
5. Yu.A. Izrael', A.S. Volkov, and A.F. Kovalev, Meteorol. Gidrol., No. 5, 5–12 (1995).
6. A.I. Akulov and I.F. Mingazov, *State of the Environment and Human Morbidity in Novosibirsk* (VO Nauka, Novosibirsk, 1993), 97 pp.
7. T.P. Vinogradova, V.L. Chugai, M.V. Kazakova, S.V. Beloborodova, and G.P. Koroleva, in: *Abstracts of Reports at the Conference on Biodiversity of Microorganisms in Eastern Siberia and Their Scientific and Practical Use* (Irkutsk, 1999), pp. 15–17.
8. G.P. Koroleva, A.G. Gorshkov, T.P. Vinogradova, E.V. Butakov, I.I. Marinaite, and T.V. Khodzher, Khimiya v Interesakh Ustoichivogo Razvitiya **6**, No. 3, 327–337 (1998).
9. A.B. Kul'ko and O.E. Marfenina, Mikrobiologiya **67**, No. 4, 569–572 (1998).
10. 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, 488–493 (1999).
11. 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).
12. B.D. Belan, A.I. Borodulin, Yu.V. Marchenko, S.E. Ol'kin, M.V. Panchenko, O.V. P'yankov, A.S. Safatov, and G.A. Buryak, Dokl. Ros. Akad. Nauk **374**, No. 6, 827–829 (2000).
13. 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, Atmos. Oceanic Opt. **14**, Nos. 6–7, 473–477 (2001).
14. I.S. Andreeva, B.D. Belan, A.I. Borodulin, G.A. Buryak, V.A. Zhukov, M.V. Panchenko, V.V. Penenko, V.A. Petrishchenko, and A.S. Safatov, Dokl. Ros. Akad. Nauk **381**, No. 2, 1–5 (2001).
15. A. Darbe, ed., *Practical Protein Chemistry. A Handbook*, (John Wiley & Sons, New York, 1986).
16. W.W. You, R.P. Haugland, D.K. Ryan, and R.P. Haugland, Annal. Biochem. **244**, No. 2, 277–282 (1997).
17. M.P. Starr, H. Stolp, H.G. Truper, A. Balows, H.G. Scchlegel, eds., *The Prokaryotes: A Handbook on*

Habitats, Isolation, and Identification of Bacteria (Springer-Verlag, Berlin, Heidelberg, New York, Tokyo, 1981), 2596 pp.
18. *Methods of Experimental Micology* (Naukova Dumka, Kiev, 1982), 550 pp.
19. I.P. Ashmarin and A.A. Vorob'ev, *Statistical Methods in Microbiological Investigations* (Gos. Izd. Med. Lit., Leningrad, 1962), 180 pp.
20. V.F. Raputa, A.P. Sadovskii, and S.E. Ol'kin, Meteorol. Gidrol., No. 2, 33–41 (1997).
21. V.V. Kokovkin, V.F. Raputa, and O.V. Shuvaeva, Khimiya v Interesakh Ustoichivogo Razvitiya **5**, No. 7, 477–483 (1999).
22. Y. Tong and B. Lighthart, Aerosol Sci. Technol. **32**, No. 5, 393–403 (2000).
23. R.C. Schnell and G. Vali, J. Atmos. Sci. **33**, No. 8, 1554–1564 (1976).
24. G. Vali, M. Christensen, R.W. Fresh, E.L. Galyan, L.R. Maki, and R.C. Schnell, J. Atmos. Sci. **33**, No. 8, 1565–1570 (1976).
25. J. Lindeman, H.A. Constantinidou, W.R. Barchet, and C.D. Upper, Appl. Environ. Microbiol. **44**, No. 5, 1059–1063 (1982).
26. S. Gruber and R. Jaenicke, J. Aerosol Sci. **31**, Suppl. 1, S737–S738 (2000).