Biogenic Component of Atmospheric Aerosol in the South of West Siberia

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Abstract

Results of 3 year-long studies of the biogenic component of the atmospheric aerosol in the south of West Siberia using terrestrial measurements and aircraft monitoring of the atmosphere and analysis of collected snow cover samples are presented. The seasonal dynamics of the content of components of this biogenic component has been obtained, their possible local and remote sources have been determined. It has been demonstrated that maximal and minimal values of concentration of total protein in the atmosphere differ by about an order, and the concentration of microorganisms does so by more than 2 orders. At the same time, the found values are quite consistent with literature data for other regions. On the basis of the data obtained, it is hypothesized that the main contribution to the biogenic component of the atmospheric aerosol even during the spring-summer period is made not by local, but by remote sources of bioaerosols. Mathematical models are proposed which permit making definite conclusions about the localization of these sources. It is demonstrated that the greatest influence on this region is exerted by the sources situated in Middle Asia and North-West Kazakhstan.

INTRODUCTION

The published data and our studies demonstrate that the biogenic component is an extremely important part of the atmospheric aerosol. In some cases, as much as 95 % of all the particles in the atmosphere with a diameter of more than 2 μm have biogenic nature [1, 2]. Apart from the "usual" influence on the climate [3] and on the ecosystems, such particles can contain living microorganisms and products of their life activity, which can lead to transmission or provocation of infectious diseases.

However, it is just the biological component of atmospheric aerosol that has received up to now, in our opinion, insufficient attention. Indeed, despite the fact that aerobiological studies of the atmosphere were carried out as long ago as the last century (see, *e. g.* [4], cited from [5]), they have not up to now been systematic. An exception are the rather long-term observations of bacterial flora in Sweden [5], Canada [6], and the USA [7–9], mold fungi in Finland [10], and plant pollen in Siberia [11]. These studies were dedicated only to one kingdom – plants and did not touch upon other ones. Data on systematic studies of the macromolecular composition of bioaerosols are not available in the literature.

Earlier, in [12, 13] results of a preliminary study of the biogenic component of the atmospheric aerosol in the south of West Siberia were presented. It was demonstrated that in the ground surface layer of the atmosphere at an altitude of up to 700 m, there was a noticeable amount of total protein and a great diversity of culturable microorganisms. Atmospheric aerosols, including bioaerosols, can propagate over large distances [10, 14–18], and therefore, together with monitoring of the biological component of the atmospheric aerosol and estimation of its influence on the population of the region, the search for sources of bioaerosols is extremely important. Knowing the characteristics of such sources (their situation, type and power), one can estimate those doses of various parts of the biogenic component which are received by the population in the process of life activity.

The most important parts of the biological component of the atmospheric aerosol, from our point of view, are protein – the basis of all the living matter on the Earth – and microorganisms that are the most significant from the point of view of epidemiology and ecology. That is why we paid the main attention to the study of these elements of the biological component of the atmospheric aerosol. The present work summarizes the comprehensive 3 year-long studies of the biological component of atmospheric aerosol in the south of West Siberia.

MATERIALS AND METHODS

Beginning from 1998, studies of the biogenic component of atmospheric aerosol has been carried out which included monthly aircraft probing of the atmosphere (since December 1998), on-ground sampling in the sites described herein below, and snow sampling.

High altitude samples were taken with the help of the laboratory "Optic-E" assembled on the basis of an airplane AN-30. Flights were performed on the 20th days of every month. The 50 km long flight trace passed above the Karakan forest situated on the right bank of the Ob' river. Within the limits of the indicated trace, the laboratory aircraft flew regularly at the daytime over the forest massif at the heights of 7000, 5500, 4000, 3000, 2000, 1500, 1000, and 500 m. For each height, one air sample was taken onto a AFA-HA filter [19] during 10–20 min. Usually, the volume of the sampled air amounted to about 2 m^3. Besides, air samples were taken into impingers [19] filled with 50 ml of physiological saline, with the volume rate of 50 l/min.

On-ground air samples were collected onto the same filters and impingers in the sites situated in the territory of the Research Center "Vector", Institute of Chemical Kinetics and Combustion, SB RAS, and in the settlement Klyuchi of the Novosibirsk Region. Besides, in the vicinities of Novosibirsk in late February of 2000 and 2001, snow samples were studied. For this, snow samples were taken in sterile conditions at the whole depth of the snow cover from an area of 1 dm^2, then they were thawed and analyzed for the content of total protein and viable organisms.

Analysis of total protein

The total protein content in all the samples was assayed under laboratory conditions by one of two methods: firstly, according to Bradford [20] which sensitivity was 0.1 μg/ml of washout from the filter, and the concentration measurement error did not exceed 30 %; secondly, by fluorescence method using the dye described in [21]. The sensitivity of this technique was about 0.01 μg/l, and the concentration measurement error was less than 20 %.

Analysis of microorganisms' content

For detection of microorganisms, the collected samples were sown on Petri dishes containing the following agarized nutrient media: LB [22] and impoverished LB (diluted 1 : 10) – for detection of saprophyte bacteria; starch-ammonium medium KAA [33] – for detection of Actinomycetes; Sabouraud and Czapek media [23] – for detection of lower fungi and yeast. If necessary, successive dilutions of samples were used. The sowings were incubated in a thermostat at the temperature of 30 °C for 3–14 days. Morphological properties of the detected microorganisms were studied visually with the help of light microscopy. For this, fixed Gram-stained cell preparations and live preparations of cell suspensions were made which were observed by the phase contrast method. Taxonomy of the detected microorganisms was determined to the genus [24, 25]. Calculation of the number of viable microorganisms in the samples was made according to standard methods [26], the number of microorganisms being averaged by 2–3 parallels scattered in 4–5 different culture media.

In some cases, for an indirect estimation of pathogenicity of the detected microorganism cultures, in *in vitro* experiments their plasmocoagulative activity was measured [27]. For this, dry citrate rabbit plasma was diluted 1 : 5 with sterile physiological saline and poured out into tubes, 0.5 ml each. The one day-old culture was suspended in diluted blood plasma and incubated for 1, 2, 3 or 24 h at 37 °C. Thickening of plasma in the mixture with the culture under study, irrespective of the plasma coagulation degree, was considered as positive reaction. As control, experiments with test strains of staphylococci having or not having positive reaction, were run simultaneously.

Estimation of localization of possible remote sources of bioaerosols

Detection of possible remote sources of bioaerosols is a typical inverse problem of "detector – source" type. Estimation of localization of possible sources was carried out by two approaches. The first one was performed in Eulerian manner and consisted in solving the classical conjugate task of turbulent diffusion. A result of solution of this task are Green functions for conjugate equations [28]. Values for the Green functions at points outside the detector represent values of the function of sensitivity that show what contribution to the concentration of the admixture observed at the detector point is made by various points of sources. The second approach was performed in Lagrangian manner. For this, unlike the Eulerian approach, which permits obtaining the functions of sensitivity, single conjugate trajectories going out of the detector point in inverse time flow were modeled.

At the first stage, the solution of this task consisted in integrating the system of equations of movement of particles entrained by the movement of air masses, taking into account the rate of their gravitational sedimentation. At the second stage, a local approximation of the operator of "frozen coefficients" type model [29] was used. With such assumptions, each local task admits separation of variables and therefore the Green function for it may be represented as a product of Green functions for one-dimensional equations along coordinate directions. These functions are identical to the probability density of Gaussian chance quantities with a zero mean value and an unknown standard deviation.

Just like in the Eulerian approach, for the Lagrangian variant we used numerical schemes of second order with respect to time. Introduction of chance characteristics into the computation algorithm at the stage of taking into account the turbulence presupposes the use of statistical modeling technique on ensembles of particles. In this way, the transfer algorithm used by us represents a combination of determined transfer of particles along the trajectory of air masses movement and of the Monte-Carlo method for taking into account the turbulent exchange.

In both types of calculation, hemispherical basic models of admixture transport in the atmosphere in a hybrid coordinate system described in [30] were used: isobaric in free atmosphere and relief-tracking in the lower layers of the atmosphere. The calculations carried out in Eulerian and Lagrangian approaches were subsequently compared with each other. In order to increase the reliability of calculations, hydrometeorological situations were reconstructed by factual information from the database Reanalysis NCEP/NCAR USA [31] with the help of the system described in [32]. Calculations were carried out for 30 days with a step of 30 min in the reverse time direction from the moment of the end of observations. Some calculation results are discussed herein below.

Determination of the characteristics of local sources contaminating the snow cover

For estimation of long-term (a month, a season, a year) pollution of a locality by local sources by the observation data, the following regression equation [33, 34] was proposed and tested:

$$p(r, \varphi, \vec{\Theta}) = \Theta_1 g(\varphi + 180°) r^{\Theta_2} \exp(-c / r) \quad (1)$$

where p is the specific content of the admixture under consideration in the snow (soil, air); r, φ are polar coordinates of the calculated point with the origin in the site of the source location; $g(\varphi)$ is the climatic repeatability of wind for the time period under consideration; c is a quantity dependent on the altitude of the source, temperature and volume of the ejected admixture and wind velocity; $\vec{\Theta}(\Theta_1, \Theta_2)$ is vector of unknown parameters.

The Θ_1 value is proportional to the emission power and depends in a rather complicated way on the climatic characteristics – wind velocity, coefficients of turbulent exchange, altitude of the source and rate of sedimentation of the aerosol admixture. The second parameter Θ_2 depends on the rate of sedimentation of aerosol particles, coefficient of vertical turbulent diffusion at the height of 1 m and power in the approximation of the horizontal component of wind velocity by the power profile.

In some cases, *e. g.*, for weakly settling admixture, when there is information about the wind velocity and about geometrical and thermodynamic characteristics of the source, the quantity c can be calculated preliminarily taking into account the relation $c = 2r_{max}$ [35] or found by the results of observation of the ground surface concentration field for a weakly settling admixture (here, r_{max} is the point of maximal ground surface concentration for a weightless admixture). In opposite case, the quantity c must be considered as one belonging to estimable parameters of the model (1).

RESULTS AND DISCUSSION

Aircraft probing of the atmosphere

In Table 1, the observed concentrations of the total protein and the number of culturable microorganisms in samples of atmospheric air taken at various altitudes are presented.

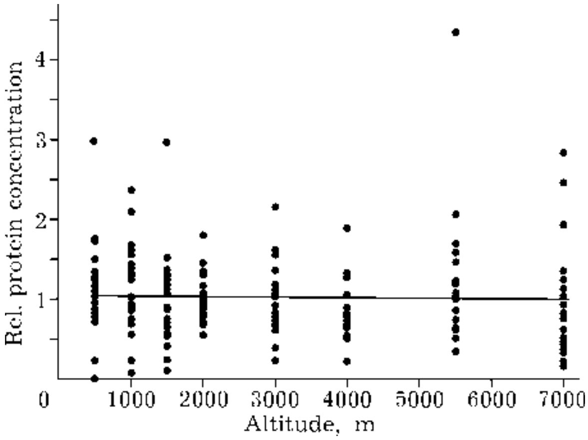


Fig. 1. Normalized altitude dependent profile of concentrations of the total protein in the atmosphere in the south of West Siberia: $y = -8\ 10^{-6}x + 1.0527$, $R^2 = 0.001$.

First of all, noteworthy is the fact that the profile of concentration dependence on the altitude normalized by the average value of concentrations for each month of measurement remains practically constant (Figs. 1 and 2).

The trend of concentration profiles in this case is not detectable. Two-factors variance analysis [36] of the data obtained shows that there exists a stable dependence of the concentration measured on the month of measurement (the factor is significant even at the confidence level of 0.1 %); at the same time, there is no dependence of these concentrations on the altitude (the confidence level is 20 %). This gives a reason to build the time course of change of the mean values for the concen-

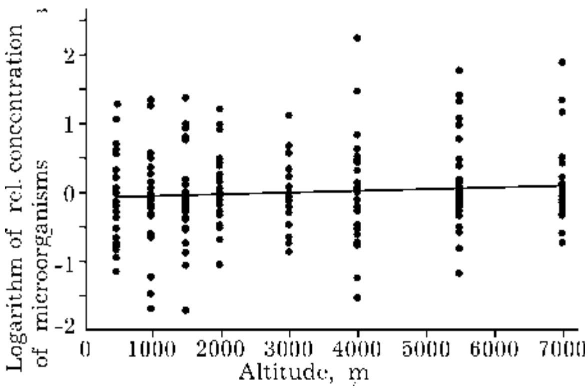


Fig. 2. Normalized altitude dependent profile of concentration of culturable microorganisms in the atmosphere in the south of West Siberia: $y = -2\ 10^{-5}x + 0.0708$, $R^2 = 0.0058$.

TABLE 1

Observed concentrations of the total protein (P, μg/m^3) and culturable microorganisms (M, logarithm of the number per 1 m^3) in the atmosphere at various heights

Month, year of measurement	Altitude, m															
	500		1000		1500		2000		3000		4000		5500		7000	
	P	M	P	M	P	M	P	M	P	M	P	M	P	M	P	M
12.98	0.3	–	0.2	–	0.7	–	0.2	–	0.2	–	0.1	–	0.2	–	0.2	–
01.99	0.92	–	0.3	–	0.3	–	0.2	–	0.2	–	0.1	–	0.2	–	0.7	–
02.99	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
03.99	0.5	4.2	0.7	2.3	–	2.5	0.7	2.5	0.4	3.5	0.3	5.0	0.7	3.0	0.0	5.4
04.99	–	3.8	1.2	2.5	–	–	1.3	4.9	1.2	3.5	1.3	6.2	0.5	3.1	1.6	3.7
05.99	0.0	3.5	1.5	2.5	1.4	4.0	1.3	4.1	1.3	4.8	0.5	4.7	1.4	4.2	0.8	5.5
06.99	2.4	3.4	–	3.2	1.4	4.2	1.4	2.5	2.1	2.5	3.0	2.5	3.0	5.0	2.0	2.5
07.99	3.3	3.2	2.5	4.1	–	4.6	3.2	3.8	3.6	3.5	2.9	3.9	1.2	3.7	2.1	3.5
08.99	4.9	–	2.9	–	2.1	–	2.9	–	4.7	–	3.6	–	2.5	–	3.9	–
09.99	3.6	4.1	0.5	4.4	4.9	3.8	0.8	4.9	4.2	3.6	3.4	3.9	4.6	3.7	4.4	3.6
10.99	1.1	3.3	1.3	2.5	1.4	2.5	3.4	2.7	1.4	2.8	1.0	2.5	1.5	2.5	1.2	2.7
11.99	2.6	–	1.1	–	1.1	–	0.7	–	0.5	–	0.6	–	1.0	–	–	–
12.99	1.3	3.7	3.0	3.0	0.7	2.8	1.5	2.6	1.7	–	1.1	3.4	0.6	3.0	0.2	2.9
01.00	1.8	2.8	0.8	3.0	1.3	4.1	1.2	3.5	0.9	2.9	1.5	3.2	1.3	2.6	0.7	3.0
02.00	1.7	2.5	1.3	2.8	1.1	2.5	0.7	2.5	0.2	3.0	0.7	2.5	0.6	2.5	1.3	2.8
03.00	1.2	3.2	2.4	3.3	1.6	3.2	2.0	3.4	1.2	4.0	1.1	4.8	1.5	5.2	0.7	4.4
04.00	0.0	2.5	2.7	2.5	1.4	2.5	0.9	2.5	1.3	2.5	2.2	2.5	2.8	2.5	1.9	2.5
05.00	–	2.5	–	2.5	–	2.5	–	2.5	–	2.5	–	2.5	–	2.5	–	2.5
06.00	1.7	3.0	1.2	5.3	1.2	3.6	1.2	4.9	1.5	3.8	1.4	3.4	1.4	3.6	1.0	–
07.00	5.1	2.6	4.8	4.1	4.1	5.1	3.1	4.0	2.6	2.9	2.6	3.5	3.3	3.9	4.7	3.9
08.00	3.1	4.3	2.2	3.4	4.0	3.9	4.3	4.5	3.5	3.9	1.6	4.0	3.1	4.4	1.9	3.7
09.00	4.2	–	1.8	–	2.1	–	2.7	–	3.6	–	4.4	–	3.0	–	3.4	–
10.00	3.0	2.7	2.9	2.6	2.5	3.0	3.6	2.5	7.3	3.0	4.3	3.3	2.2	2.9	1.1	2.5
11.00	3.7	2.5	5.0	2.7	0.4	2.8	2.7	2.5	3.5	2.6	1.9	2.7	–	2.8	9.4	2.5
12.00	0.2	4.3	0.8	–	1.0	3.0	0.6	2.9	0.2	3.2	0.2	2.7	3.8	3.7	0.2	3.0
01.01	0.2	2.2	0.2	2.2	0.5	2.2	1.1	2.5	0.9	3.0	0.6	–	0.9	2.6	2.5	2.3
02.01	–	3.6	0.2	2.9	0.4	4.0	0.4	3.0	–	3.0	0.4	3.7	0.1	3.0	–	2.6
03.01	0.9	2.5	2.0	2.5	3.7	2.8	0.7	2.8	1.4	2.7	0.3	2.5	0.6	3.9	0.5	2.7
04.01	0.8	2.5	1.0	3.9	0.5	2.9	1.3	3.5	0.5	3.2	0.6	3.4	0.6	4.3	–	2.7
05.01	2.8	4.1	1.4	4.1	0.2	3.5	0.6	4.2	0.7	4.1	0.5	4.1	0.6	3.7	0.5	4.5
06.01	11.2	4.8	9.2	3.9	11.1	3.3	7.1	5.2	5.4	5.3	5.7	3.4	14.3	3.7	7.4	4.0
07.01	5.3	2.5	5.7	3.3	6.2	3.0	4.4	3.3	6.2	3.6	3.1	2.9	3.4	4.8	2.0	3.6
08.01	7.6	4.9	8.1	–	3.6	2.9	10.2	5.8	6.8	4.4	7.0	3.1	17.9	5.4	8.1	5.7
09.01	2.7	–	4.6	–	2.3	–	3.2	–	4.9	–	4.1	–	2.0	–	1.5	–
10.01	1.8	4.3	0.2	5.6	2.5	3.8	2.2	4.7	2.5	5.0	2.7	3.1	2.5	3.7	2.4	4.3
11.01	1.7	–	2.1	–	1.5	3.7	0.9	5.2	1.6	3.8	1.9	5.3	1.5	5.5	1.9	3.2

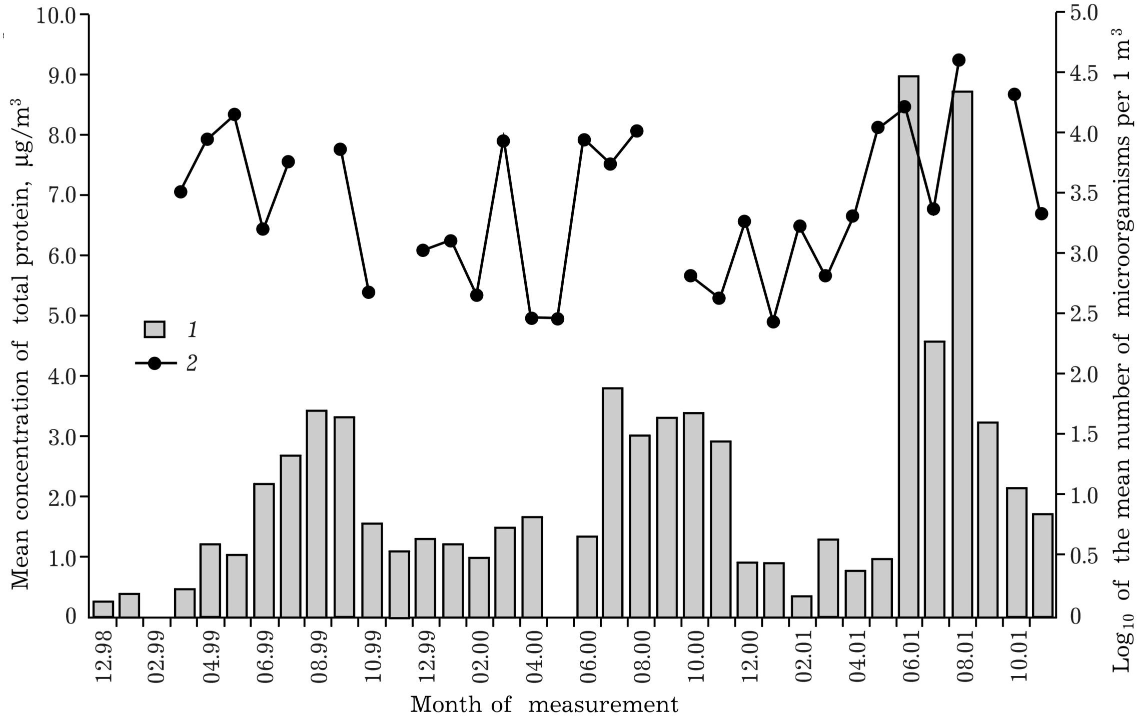


Fig. 3. Dynamics of the change of concentration of the total protein (*1*) and the numbers of culturable microorganisms (*2*) in the boundary layer of the atmosphere in the south of West Siberia.

tration and numbers across the altitudes of 0.5–7 km (Fig. 3).

As it follows from these graphs, there is a pronounced seasonal variability of the total protein concentration and of the number of culturable microorganisms in the atmosphere. At the same time, as it was noted above, there exists a kind of "frozen" altitude profile of these concentrations which amplitude varies smoothly from month to month. Such profiles of admixture concentrations in the atmosphere can be formed due to very powerful remote sources, such as large plant massifs, reservoirs, soil. Aerosol particles from these sources, rising to a considerable altitude, are mixed and transported all over the northern hemisphere, creating the observed profiles as the particles settle. This hypothesis is favored also by the data on the culturable microorganism composition in samples of atmospheric air.

We studied the dinamics of the numbers of cocci, bacilli, nonsporiferous bacteria and mold fungi in samples of atmospheric air. Therein, the group referred to as "nonsporiferous bacteria" included various microorganisms that did not form endospores: Gram-variable and Gram-positive coccobacilli, various nonsporiferous bacilli stained Gram-negatively (pseudomonas, coli bacteria *etc.*), as well as mycobacteria and nocardiae. As an example, in Fig. 4 the dependence of diversity of microorganisms on the altitude is presented for one of two summer months.

It was found that as the sampling altitude changed, the representation of culturable mi-

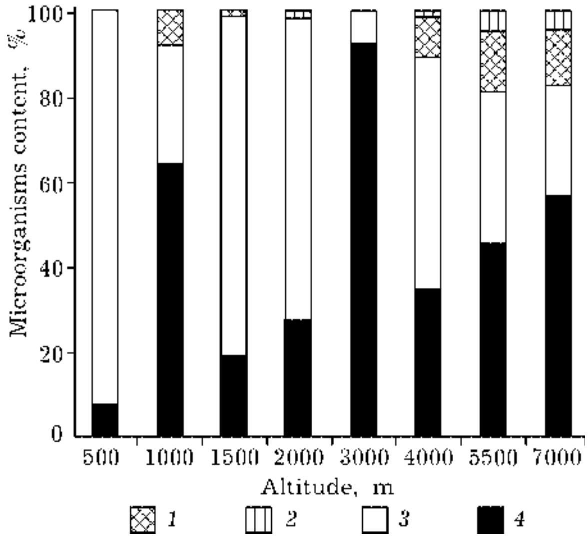


Fig. 4. Representation of culturable microorganisms in air samples taken at various altitudes in July, 1999: *1* – Actinomycetes, *2* – nonsporiferous bacteria, *3* – cocci, *4* – bacilli.

croorganisms in a sample may change radically: cocci, bacilli or other microorganisms may be dominant. Therefore, most probably, air masses that get into the sampling site at various altitudes have different history and are enriched with microorganisms from different sources. More at length, possible remote bioaerosol sources will be considered below.

On-ground measurements

As it was already noted above, on-ground measurements were carried out in several sites. In the site of the State Research Center "Vector", in 2001 samples of atmospheric air were taken during 24 h consecutively, and after estimating the total protein concentration and the number of culturable microorganisms in them, average daily values were calculated and homogeneity of the data obtained was estimated by Smirnov test [37] (Table 2). The time course of changes in the total protein concentration and in the numbers of microorganisms obtained in on-ground measurements on the whole replicates the seasonal time course of these values in 2001 in the atmosphere at the altitude of 500–7000 m (see Fig. 3). However, the amplitude of the changes in summer turned out to be smaller in on-ground measurements than in ones at higher altitude. This, in particular, may be accounted for by the fact that in summer 2001 intense precipitations which fell out repeatedly were observed rather often in the sampling region, which can have led to "washing out" from the air masses aerosol particles containing the total protein and microorganisms. It is natural that the "washout" of aerosol particles from higher layers is less significant, which is the case according to the data of aircraft probing of the atmosphere (cf. the data of Table 2 and Fig. 3). At the same time, this is still another argument in favor of the hypothesis of remoteness of the sources which mainly determine the biogenic component of the atmospheric aerosol in the south of West Siberia.

TABLE 2

Concentration of the total protein and culturable microorganisms in the atmosphere in the site of the research center "Vector" in 2001

Month of measurement	Total protein concentration, $\mu g/m^3$	Logarithm of the number of microorganisms in 1 m^3
January	0.9	2.4
February	0.4	3.2
March	0.4	2.9
April	**0.7**	3.6
May	0.6	**4.2**
June	**3.3**	**3.5**
July	1.0	3.5
August	0.8	**4.2**
September	0.9	**3.3**
October	0.9	3.2
November	0.5	**3.2**

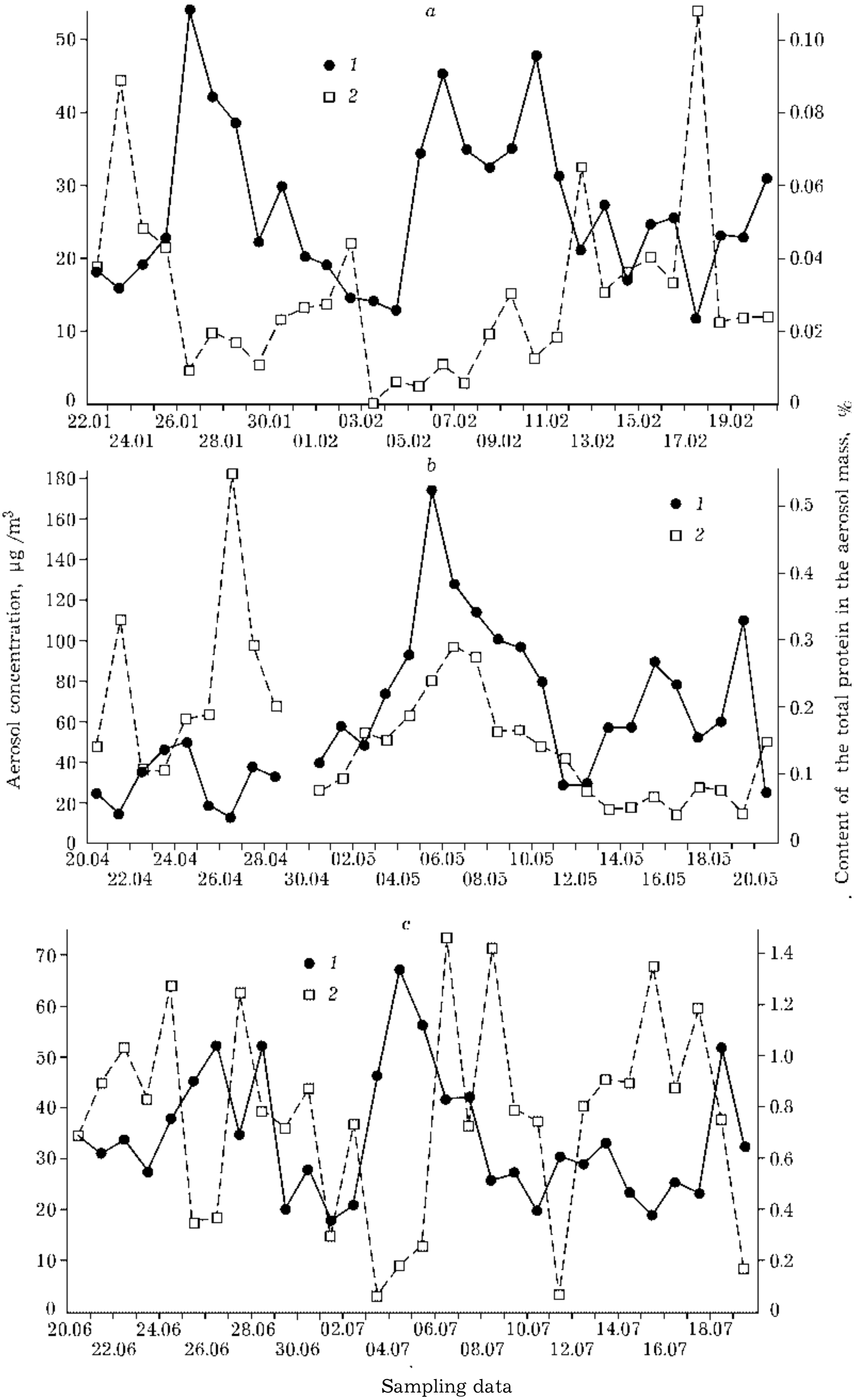
Note. For explanations, see the text.

The days on which, according to Smirnov test [37], at the 95 % confidence level, the observed data may not be considered as homogeneous are listed in Table 2. Judging by these data, so far one may not speak of the diurnal cycle of the atmosphere characteristics measured, and the dispersion of culturable microorganism concentration in the air is on the whole much greater (especially at the spring–autumn period) than that of the total protein.

The latter fact witnesses to the fact that most probably the process of formation of aerosols containing culturable microorganisms is different from the process of formation of protein-containing particles.

A very important question that enjoyed a considerable attention in the present work is the estimation of the share of the biogenic component in the whole atmospheric aerosol. Let us compare the observed mass concentrations of the total protein in the atmosphere with those of bioaerosols measured by other authors. Our measurements carried out in the settlement Klyuchi in various seasons of 2001 demonstrate that the portion of the total protein makes up 0.01–1.5 % of the mass of all the atmospheric aerosols measured by the gravimetric method at respective time period, and the estimated total mass of microorganisms in the atmospheric aerosol is much smaller (Fig. 5).

At the same time, in the literature there are data where the mass portion of biogenic


a
1
2
b
1
2
c
1
2
Aerosol concentration, μg/m3
Content of the total protein in the aerosol mass, %
Sampling data
22.01
24.01
26.01
28.01
30.01
01.02
03.02
05.02
07.02
09.02
11.02
13.02
15.02
17.02
19.02
20.04
22.04
24.04
26.04
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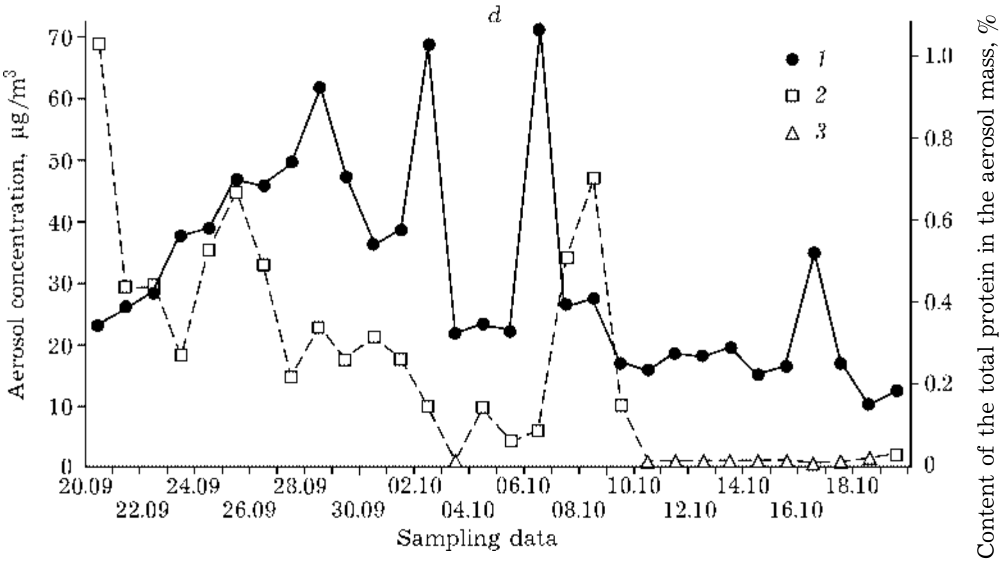

Fig. 5. Dynamics of the mass concentration of atmospheric aerosol in the vicinities of settlement Klyuchi and its protein component in 2001: *a* – winter, *b* – spring, *c* – summer, *d* – autumn; *1* – aerosol, *2* – protein, *3* – upper estimate of the proportion of protein in the total mass.

aerosols in the region of Lake Baikal makes up during the year about 10 to 80 % [38]. Moreover, according to [1, 2, 39–41], this portion of biogenic particles may be as large as 95 %. It is natural that biogenic particles consist not only of protein; however, since protein is the foundation of any living matter, it usually makes up a considerable part of the total mass of biological material. That is why the difference of two orders of magnitude can hardly be accounted for by only this cause. Most probably, it is also that those biogenic particles that have been studied in the above mention works consisted not wholly of biological material (like, *e. g.*, particles of plant pollen). In this way, the question of composition of biogenic particles in the atmosphere is still open and requires additional studies. A detailed information about the composition of bioaerosols could make it possible to establish more reliably their possible remote sources.

Estimation of location of possible remote bioaerosol sources

As it was noted above, for a reliable estimation of doses of various factors which act on the population of the region in the process of life activity, it is necessary to know the characteristics of the sources of these factors, in our case characteristics of bioaerosol sources. As for local sources, such a problem has been solved (see, *e. g.*, the solutions of the problem of estimation of characteristics of the known local sources presented below). Moreover, at the State Research Center "Vector" works are being carried on which make it possible to estimate the coordinates, type and characteristics of local sources by a few measurements [42–44]. Solution of analogous problem for remote sources is very difficult. At the same time, at present approaches have been developed which make it possible on the basis of the above mentioned methods (see also [29, 45, 46]) to calculate the probability of an aerosol particle that started from a certain point on the surface of the Earth reaching the sampling point.

This problem can be solved by Eulerian methods. On the other hand, one may apply the Lagrangian approach, averaging those reverse trajectories of movement of air masses which touch the Earth surface during a definite period. A peculiarity of the calculated trajectories is that the air masses gathered in the sampling site have different previous histories. During their movement they have been at different altitudes, over different sites of the surface, and often even over different continents and oceans. As the trajectories get nearer to

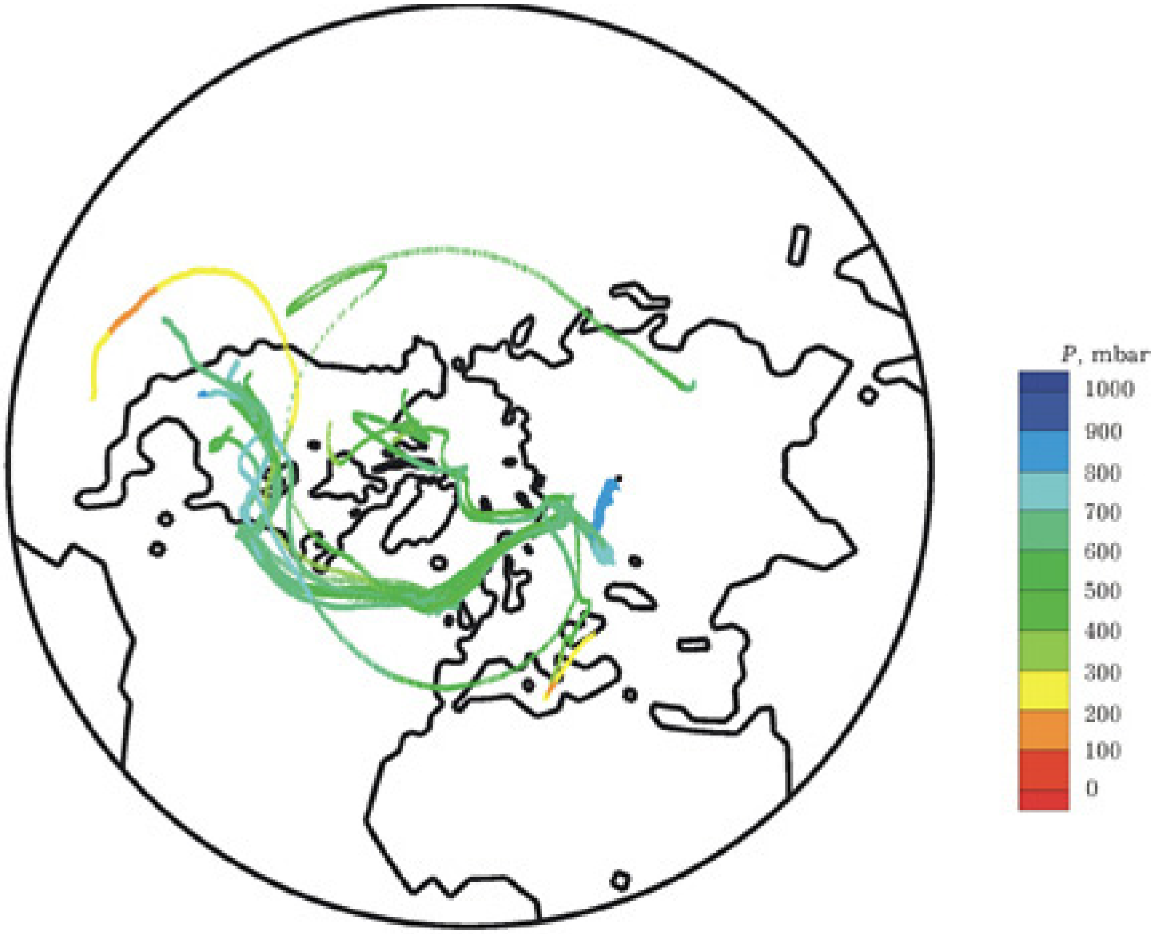

Fig. 6. Reverse trajectories of air masses from the sampling point in the Novosibirsk Region at the altitude of 1.5 km on July 20, 1999.

the sampling site, they mix and converge to one point. Therefore, in the sampling site there really can be aerosol particles coming to the atmosphere from different sources. The described situation is illustrated by Fig. 6.

Since the particles of micrometer size range can be present in the atmosphere for a rather long time, they can reach the observation point together with the air masses. In the process of movement, the air masses shift from one altitude to another, may touch the surface (where the air masses are probably enriched with bioaerosols), at certain sites their intense mixing takes place (for each reverse trajectory these sites are different), whereupon such masses reach the measurement point.

As an example of realization of the Eulerian approach, let us present total sensitivity functions for the functional describing the measurements carried out in July 1999 in the point with coordinates of 54.23° N. L. and 82.09° E. L. at the height of about 1.5 km (Fig. 7).

It turned out that at this moment it was the most probable to detect particles from North-West Kazakhstan. Calculations for a different time of measurement show that in the majority of cases in the south of West Siberia it is the most probable to detect particles from Middle Asia and North-West Kazakhstan. At the same time, even for particles that started from northern regions of Africa, West Europe and even the north of Canada, there is a noticeable probability (more than 10^{-3} %) to be detected at the moment of the sampling carried out in our region.

Biogenic component of atmospheric aerosol in the snow cover

Snow is a good accumulator of pollution coming in winter from the atmosphere. This

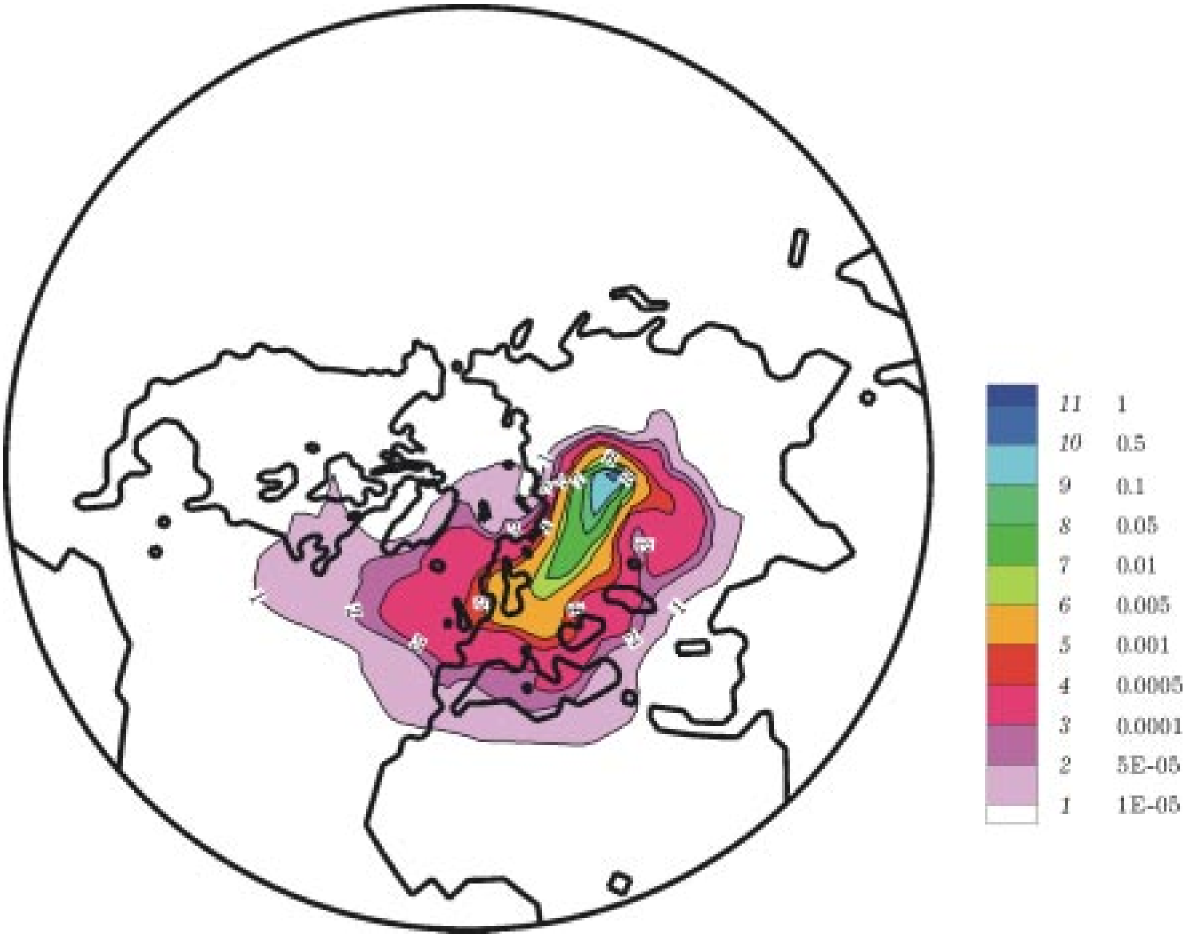

Fig. 7. Distribution of probability of reaching the sampling point in the Novosibirsk Region at the height of 1.5 km on July 29, 1999 for aerosol particles that started from different points on the Earth surface.

has been confirmed by the earlier performed studies of the content of polyaromatic compounds, radionuclides and heavy metals for estimation of ecological situation in the region [47–51]. The uniqueness of the data obtained consists in the fact that by other methods it is difficult to estimate correctly the concentration of aerosols and to reconstruct by it the characteristics of the source because of irregular work of the latter, stochastic nature of diffusion of aerosol contamination in the atmosphere and difficulty of carrying out simultaneous sampling in many points of discharge circuits. Besides, snow does not contain the inherent soil biogenic components and therefore it is fit for studying the biogenic component of the atmosphere. It is known that biological particles and even living microorganisms are well preserved at low temperatures in snow and ice [15, 52, 53].

Snow samples collected in late February in the vicinities of the Berdsk Chemical Plant (BCP, 2000 and 2001), the Novosibirsk Condenser Plant (NCP, 2000) and the Novosibirsk Electrode Plant (NEP, 2001) were analyzed by the methods described above. It was found that the concentration of total protein in the snow varied according to a definite law as it became farther from the aerosol source. At the same time, in these samples no dependence of the number of culturable microorganisms on the distance was found (Fig. 8).

It is noteworthy that the concentration of total protein at the distance of 500 m from the source (see Fig. 8) may be determined by getting into the snow of an alien object not noticed in the process of sampling. By the above described method regression models were found that described the observed dependencies. In Fig. 9, such dependence for BCP (2001) is pre-

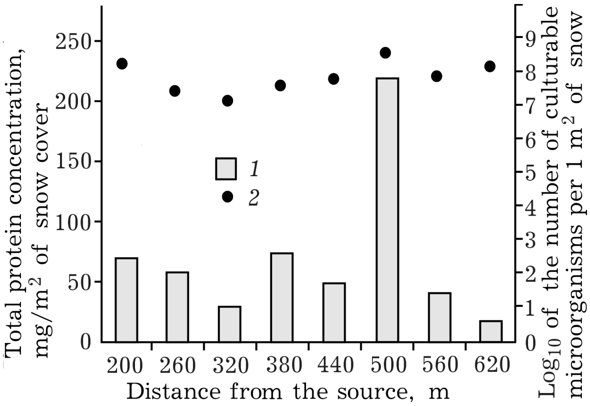

Fig. 8. Dependence of total protein concentration (*1*) and of the number of culturable microorganisms (*2*) on the distance from the chimney of BCP in the snow cover in 2001.

sented. Analogous dependences have been found also for BCP and NCP in 2000. We failed to find an adequate model for NEP.

Let us compare the results of estimation of discharges of the total protein by BCP in the winter of 2000–2001 with the data obtained for the BCP and NCP in 2000. According to the data presented in Table 3, the power of discharges and the disperse composition of aerosol in the region of BCP measured at different time are close to each other.

At the same time, according to our data, NCP is not the source of the protein however, in its vicinities, too, the change of protein concentration in the snow cover is described

TABLE 3

Estimation of regression parameters and the total protein emission

Source, year of measurement	Θ_1	Θ_2	Total discharge, kg
BCP, 2001	2.22	−2.62	16.2
BCP, 2000*	1.06	−3.68	24.7
NCP, 2000*	0.73	−5.84	15.4

*Data borrowed from [47].

by an analogous dependence given in [54]. It seems that a considerable part of protein getting into the snow is simply washed out from the atmosphere by coarse particles of the discharges, but does not come directly from anthropogenic sources. This hypothesis is favored also by the fact that the total protein concentration in the atmosphere observed in winter is rather high.

As it was noted above, whereas there is a pronounced dependence of the total protein concentration on the distance from possible contamination source, the concentration ofculturable microorganisms does not display such a dependence. This witnesses to the fact that in our case probably the sources of the total protein and of microorganisms are not connected with each other and have different nature. Moreover, if one proceeds from the hypothe-

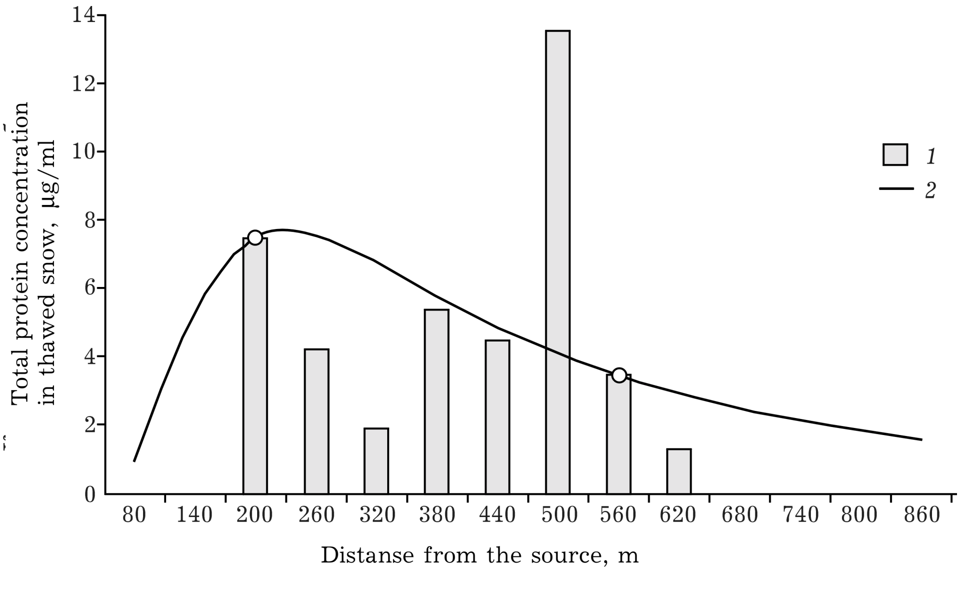

Fig. 9. Experimental (*1*) and calculated (*2*) concentrations of total protein in the snow cover in 2001 depending on the distance from the chimney of BCP. Two reference points used for estimation of regression dependence parameters are indicated.

sis of "washout" of aerosol containing the total protein, one has to make the following conclusion: the detected viable microorganisms and the major part of the protein are contained in particles of different size. It is natural that rather large particles containing atmospheric microorganisms [9] practically do not interact with coarse particles of anthropogenic discharges, whereas fine particles containing the total protein are "washed out" from the atmosphere by coarse particles of the discharges, creating deposits in the snow which are described by models of discharges from the sources with mode sizes of particles localized in micrometer range.

Let us attend to results of studies of diversity of the composition of microorganisms found in the snow cover. As it follows from the obtained data presented in Fig. 10, even in the points neighboring with respect to distance a change of representation of various microorganisms is observed, although it is not as clear-cut as in atmosphere points of close altitudes.

Such a situation is quite expected, since the snow, collecting the particles that have got into it and storing them throughout the winter, carries out the natural integration of the existing time-dependent change of diversity of the microorganisms found in the atmosphere. Let us also note that the obtained data on the concentration and representation of microorganisms in snow cover samples are consistent with those for other regions [55–58].

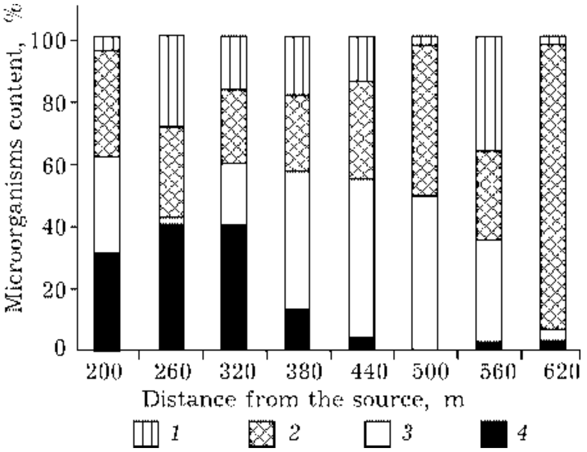

Fig. 10. Microorganisms content of specimens of snow cover taken in the vicinities of BCP in 2001: *1* – Actinomycetes, *2* – nonsporiferous bacteria, *3* – cocci, *4* – bacilli.

In this way, the study of the snow cover gives an information about the biogenic component of the atmospheric aerosol, its possible local and remote sources, which is extremely important for our region.

Connection of population morbidity with the atmospheric biogenic load

Within the framework of the complex of works being carried out, collection of medical information about the population morbidity in our region has begun. In the settlement Kol'tsovo, *e. g.*, about 15 cases were detected for 4 years which may be considered as belonging to the sought dependence. It is obvious that so far there are no sufficient data to make reliable conclusions, so that works in this direction should be extended onto a large part of the territory of the south of West Siberia. At the same time, one must note that activity in plasma coagulation tests is displayed by more than 40 % of the microorganism strains detected in atmospheric air samples. This witnesses to a high potential pathogenicity of the detected microorganisms and to their possible influence on the observed population morbidity structure in the region.

CONCLUSIONS

Summarizing the data of the 3 year long study of the biogenic component of atmospheric aerosol, one can make the following conclusions.

1. There is a summer-autumn increase in the concentration of total protein and culturable microorganisms in the atmosphere as compared to the winter-spring period. The difference between the maximal and minimal concentrations of the total protein in the atmosphere is about an order of magnitude, and that between respective concentrations of microorganisms is about two orders. From literature data it is known that seasonal dependencies for plant pollen [11] have also been found in our region.

2. Information about the mass composition of atmospheric aerosol in the south of West Siberia and about the portion of the biogenic

component in it has been obtained. It has turned out that in the full mass of atmospheric aerosol the portion of total protein does not exceed 1.5 % even in summer. The great diversity of culturable microorganisms in the atmospheric air is also noteworthy.

3. In atmospheric aerosols tens of various species of bacteria, Actinomycetes, mold fungus and yeast have been detected. Such a diversity witnesses to the fact that in the process of formation of the air microflora in our region a certain role is played by different sources of microorganisms. Besides, such a wide representation of microorganisms has been found also at high altitudes; therefore these sources are situated rather far from the study site. The presented numerical estimates demonstrate that the most probable location of these sources is in north Kazakhstan.

4. Unique information has also been obtained from analysis of snow samples collected near anthropogenic sources, including those which are not the sources of biogenic component of the atmospheric aerosol. Probably, the total protein gets into the snow cover from the atmosphere by means of "washing out" of the submicron particles containing it. At the same time, getting of microorganisms into the snow cover takes place most probably by means of a different mechanism.

5. A work has been started on collecting medical information about the structure of population morbidity in the region in order to estimate the influence of the detected biogenic component of the atmospheric aerosol on the population health.

In this way, the results of the carried out studies demonstrate that despite the importance of the results obtained, the work is still far from being completed. At present, there are more questions than answers to them. Only a long-term monitoring of the biogenic component of the atmospheric aerosol, together with estimation of its physicochemical characteristics and characteristics of the atmosphere, and the accumulated information about the population morbidity in the region during these years will permit to establish the connection between the observed population morbidity in the region and the influence of the biogenic compounds and microorganisms detected in the process of monitoring. That is why studies of the biogenic component of atmospheric aerosol in the south of West Siberia must be continued.

Acknowledgements

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