Altitude profiles of biogenic components of atmospheric aerosol in Southwestern Siberia

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Unusual vertical profiles of concentrations of the total protein and culturable microorganisms in atmospheric aerosol of Southwestern Siberia at the altitudes from 500 to 7000 m were revealed previously. To understand the regularities of their formation, more detailed average annual profiles of these concentrations have been constructed, and their intra-year variation has been evaluated. It has been shown that no local bioaerosol sources contributing to the studied profiles are revealed during the warm period of the year against the background of the mean values of these concentrations of the total protein and culturable microorganisms for the studied atmospheric layer. The relation of the observed concentrations of the total protein and culturable microorganisms in atmospheric aerosol with concentrations of different elements in the same aerosol has been also analyzed. Chemical elements whose vertical profiles behave similarly to the observed vertical profiles of concentrations of the total protein and culturable microorganisms in atmospheric aerosol have been revealed.

1. Introduction

Previously we presented data on vertical concentrations of the total protein and culturable microorganisms in atmospheric aerosol of Southwestern Siberia at the altitudes from 500 to 7000 m (Borodulin et al., 2004; Safatov et al., 2006). It has been shown that, in contrast to the changes of the calculated aerosol concentration, which decreases by a factor higher than 10 as altitude increases for particles with the diameter of 0.4 μm (Panchenko and Pol'kin, 2001), the concentrations of the total protein and culturable microorganisms practically remain unchanged at the same altitudes. Variations of average annual altitude profiles of these values have been presented for 1999 – 2003 (Borodulin et al., 2004). However, the annual variation of these profiles remained "offscreen" on account a small number of repeats. The relation between the observed concentrations of the total protein and culturable microorganisms and concentrations of different elements in atmospheric aerosol has not been considered either. The present work is devoted to the analysis of the intra-year variation of altitude profiles of concentrations of the total protein and culturable microorganisms and the analysis of the relation between their observed concentrations and concentrations of different elements in atmospheric aerosol.

2. Materials And Methods

2.1 Sampling

Atmospheric air sampling was usually performed during the last ten days of each month since December 1998 with an *Optic-E* aircraft laboratory mounted on an Antonov-30 airplane (Belan, et al., 1995; Zuev, et al., 1992). It includes devices for determining environmental characteristics (temperature, relative humidity, overboard pressure, radiation characteristics of the atmosphere, the concentration and dispersion composition of atmospheric aerosol measured with a photoelectric counter), navigation parameters (altitude relative to the relief, the flight direction and speed relative to the ground surface, the wind direction and speed at the flight altitude), samplers for collecting samples for chemical, biochemical and biological analyses of atmospheric aerosol samples, gas analyzers for determining concentrations of basic gas pollutants of the atmosphere including hothouse ones (CO_2, CO, NH_3, SO_3, SO_4, O_3), besides, a LIDAR was mounted on the airplane for remote probing of the atmosphere (Zuev, et al., 1992). Sampling onto different samplers was performed with a specially constructed sampler inlets (Nazarov, 1985), which provided isokinetic sampling and increased pressure at the samplers' inlets as compared with the pressure outside the cabin. Cruising airspeed at the sampling was usually 360 km/hour.

2.2 The determination of the concentrations of the total protein and culturable microorganisms

The concentration of culturable microorganisms was determined with standard methods. Samples were seeded onto Petri dishes containing agarized media: LB (Miller, 1976) to detect saprophyte bacteria; depleted LB medium (diluted 1:10) - to detect microorganisms inhibited by the excess of organic substances, starch-ammoniac medium, (Saggie, 1983) – to detect actinomyces; soil agar – for soil microorganisms, Sabouraud medium (Saggie, 1983) – to detect low fungi and yeast. Serial sample dilutions were prepared when it was necessary. The seedings were incubated in an thermostat at the temperature of 28 - 30°C (25°C for fungi) for 3-14 days. Morphological peculiarities of detected bacteria and fungi were examined visually and with light microscopy. Fixed preparations of gram-stained cells and live preparations of cell suspensions observed with the phase contrast method were used for this purpose. Taxonomic groups the detected microorganisms referred to were determined according to (Starr, et al., 1981; Methods…, 1982), and for some bacterial strains the analysis of nucleotide sequences of PCR products corresponding to the fragments of 16S rRNA gene was performed (Peccia and Hernandez, 2006). The calculation of the number of culturable microorganisms in samples was carried out according to standard methods (Ashmarin and Vorobyov, 1962), and the number of microorganisms was averaged over 3-4 parallels of samples seeded onto 4-5 different media.

2.3 The determination of the total protein concentration

Total protein content was analyzed in a laboratory according to the fluorescent method using a dye described in (You, et al., 1997); the method sensitivity was 0.1 μg/ml of the sample, and the error of the measured concentration value did not exceed 20%.

2.4 The element composition of aerosol

The determination of the element composition of atmospheric aerosol samples was performed with the method of the secondary ionic mass-spectrometry with the depth distribution of elements (Kutsenogii, 2006).

3. Results And Discussion

3.1 Intra-year variation of vertical profiles of concentrations of the total protein and culturable microorganisms

It's natural to expect that local bioaerosol sources contributing to the studied profiles will appear during the warm period of the year against the background of the mean value of these concentrations for the studied atmospheric layer. However, the results of the construction of normalized altitude profiles of concentrations of the total protein and culturable microorganisms averaged for each of the months of 1999-2007 show that it's impossible to reveal intra-year variations of altitude profiles of concentrations of the total protein and culturable microorganisms in Southwestern Siberia, Fig. 1. This indicates that the contribution of local sources to the measured concentration values at the altitudes of 500 – 7000 m is small. Normalization was performed by dividing the value determined for a concrete altitude of atmospheric air sampling by the mean of all values determined for 8 altitudes at which samples were collected. Then all normalized profiles constructed for a concrete month of the year were averaged. The confidence interval generally did not exceed 50% for the total protein and 100% for culturable microorganisms.

Fig. 2 presents average annual altitude profiles of these concentrations calculated for 1999 – 2007 normalized over average annual value of concentrations of the total protein and culturable microorganisms. As follows from the presented figures, expressed tendencies of change of the observed altitude profiles for these years are not revealed: all of them are characterized by practical consistency at the altitudes of 500 – 7000 m with small deviations from mean values, which are probably caused by the differences in atmospheric processes in the region.

The obtained data indicate that the observed vertical profiles of concentrations of the total protein and culturable microorganisms in Southwestern Siberia are formed mainly by powerful remote bioaerosol sources, and the contribution of bioaerosols from local sources is small.

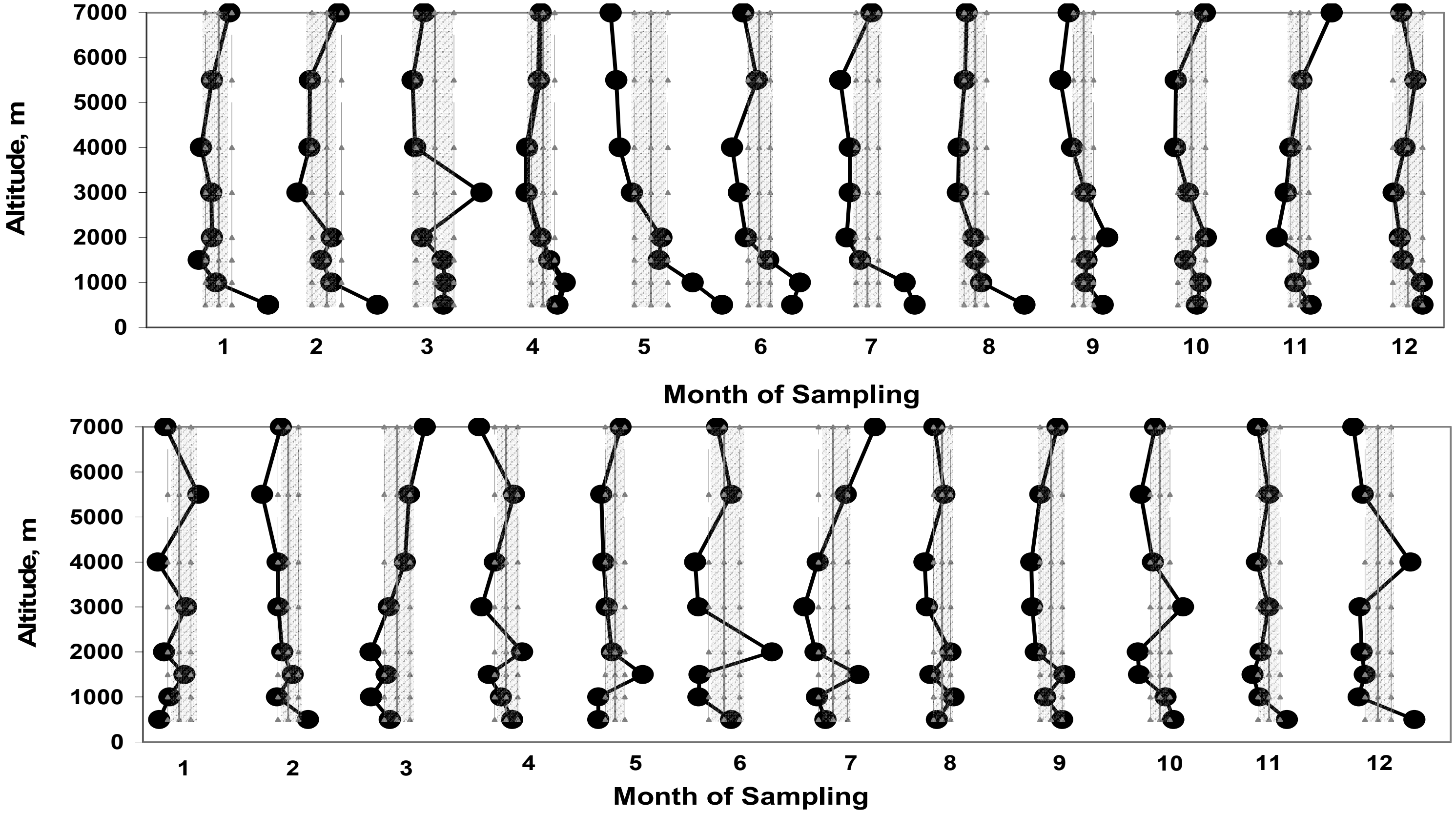

Fig. 1. Intra-year variation of normalized vertical profiles of concentrations of the total protein (above) and culturable microorganisms (below). Each profile was constructed against the background of the mean concentration value for a given month ± the confidence interval (shaded area) at the significance level of 95%.

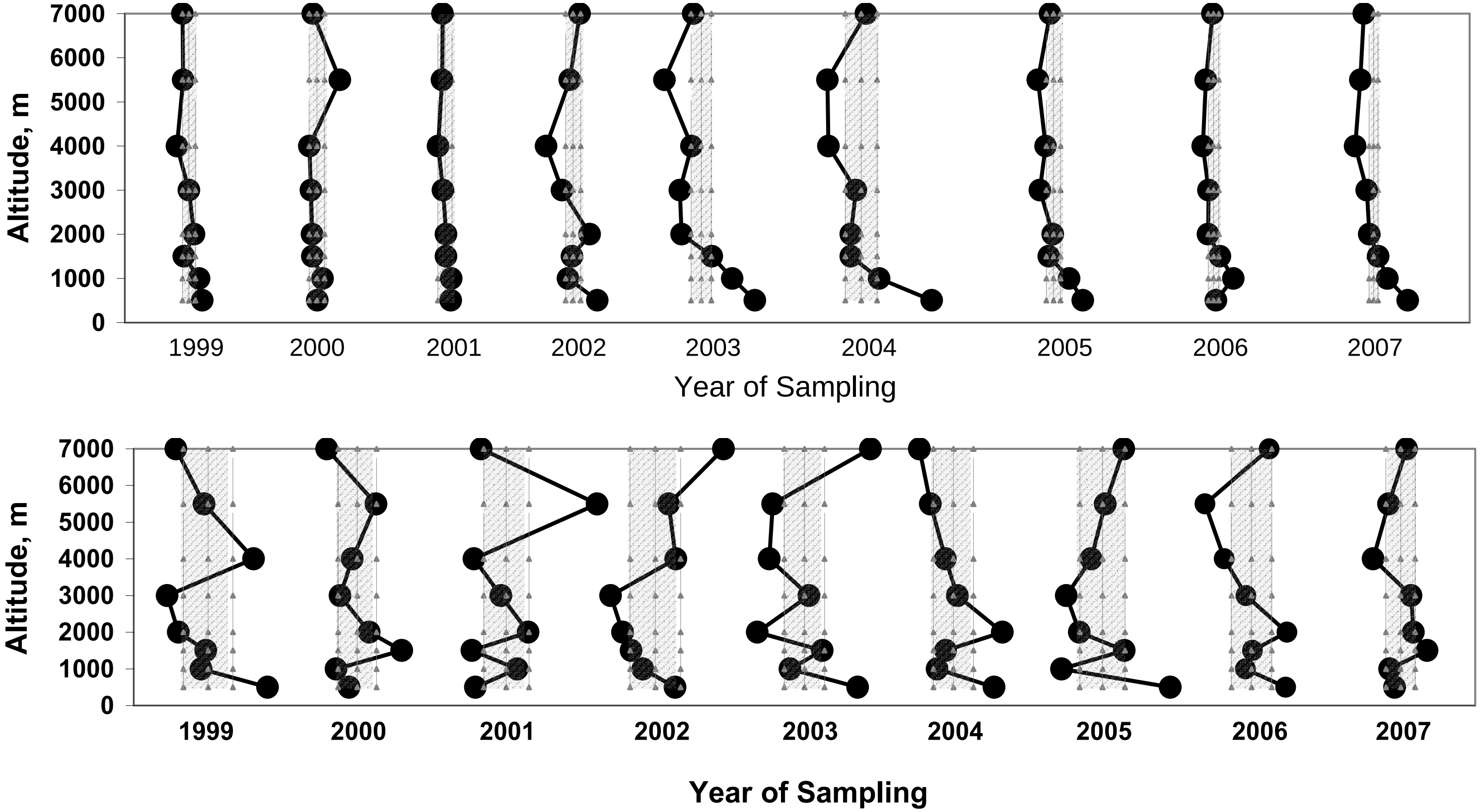

Fig. 2. Average annual variation of normalized vertical profiles of concentrations of the total protein (above) and culturable microorganisms (below). Each profile was constructed against the background of the mean concentration value for a given year ± the confidence interval (shaded area) at the significance level of 95%.

3.2 The relation of concentrations of chemical elements and concentrations of the total protein and culturable microorganisms in atmospheric aerosol

Pair correlation coefficients of biogenic components and the element composition of atmospheric aerosols were calculated for the whole pool of monitoring data to understand how and from which bioaerosol sources the observed profiles are formed. It turned out that the sought correlations were practically absent. For instance, the maximal correlation coefficient for the total protein concentration (+0.27) is observed for Co concentration, and for the concentration of culturable microorganisms, the correlation coefficient is maximal for Mg (+0.22), Mn and Cu.

The Spearman rank correlations give somewhat higher correlation coefficients for the relation of concentrations of the total protein and chemical elements (for example, the maximal determined value was about +0.30) and practically the same coefficient values for the relation of concentrations of the culturable microorganisms and chemical elements (the maximal-module coefficients for Co and for Ca make up approximately 0.16).

Thus, it’s necessary to conclude that the performed analysis did not allow us to reveal correlation relations between concentrations of chemical elements and concentrations of the total protein or culturable microorganisms in atmospheric aerosol.

3.3 The comparison of altitude profiles of concentrations of chemical elements and concentrations of the total protein and culturable microorganisms in atmospheric aerosol

The comparison of the observed altitude profiles of these values has been performed. It revealed the existence of such profiles, which behave similarly to altitude profiles of the total protein and culturable microorganisms. Fig. 3 and 4 give examples of altitude profiles, for which the correspondence of concentrations of the total protein or culturable microorganisms with one of the chemical elements is observed as well as profiles for which such correspondence is not observed. Altitude profiles of the total protein and Ca, Mg as well as those of culturable microorganisms and Ag, Sn, Cr, Mg, Mn correspond to each other most closely. This suggests a relation between the concentrations of these chemical elements and biogenic components of atmospheric aerosol; however, it does not seem possible to refer these metals to any concrete bioaerosol sources, as they belong to the vast variety of biogenic material.

4. Conclusion

The performed analysis of altitude profiles of biogenic components of atmospheric aerosol of Southwestern Siberia revealed their unique altitude dependence – practical consistency at the altitudes of 500 – 7000 m. This consistency is preserved both from year to year and in different seasons. Such profiles can be formed from remote powerful aerosol sources as a result of long-term mixing in turbulent atmosphere in the process of their spread in higher atmospheric layers.

The attempt to find relations of the observed concentrations of chemical elements as a part of aerosol particles with biogenic components of atmospheric aerosol did not reveal any significant relations either, though similar altitude profiles of concentrations of the total protein and culturable microorganisms and some chemical elements have been revealed.

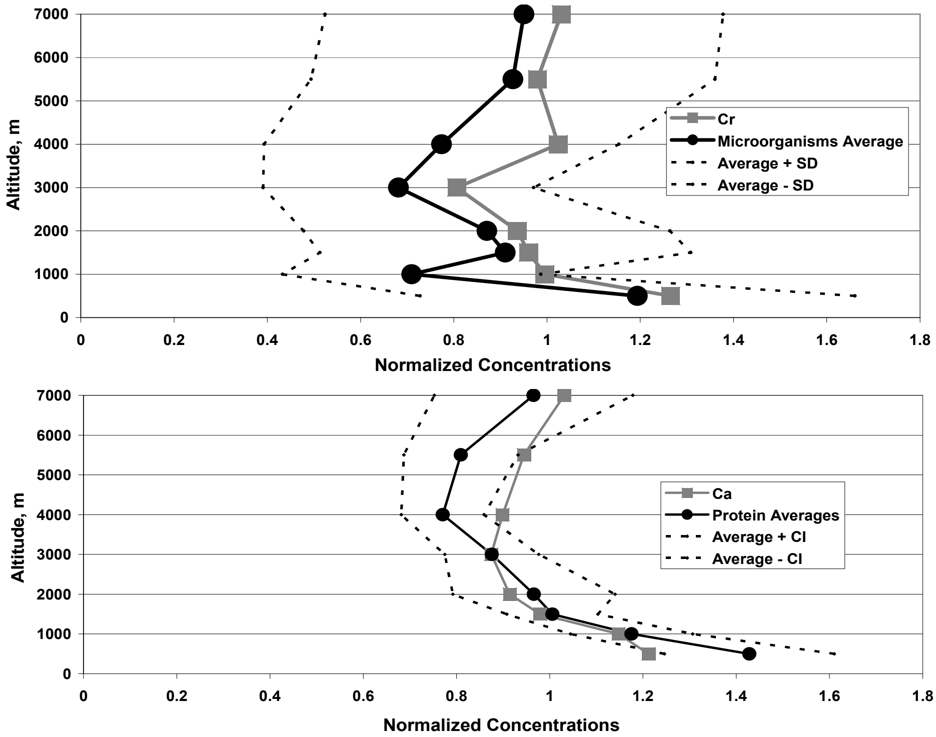

Fig. 3. “Similar” altitude profiles of culturable microorganisms and Cr (above) and the total protein and Ca (below) normalized by the mean value. CI = the standard interval for mean values of the total protein and culturable microorganisms at the significance level of 95%.

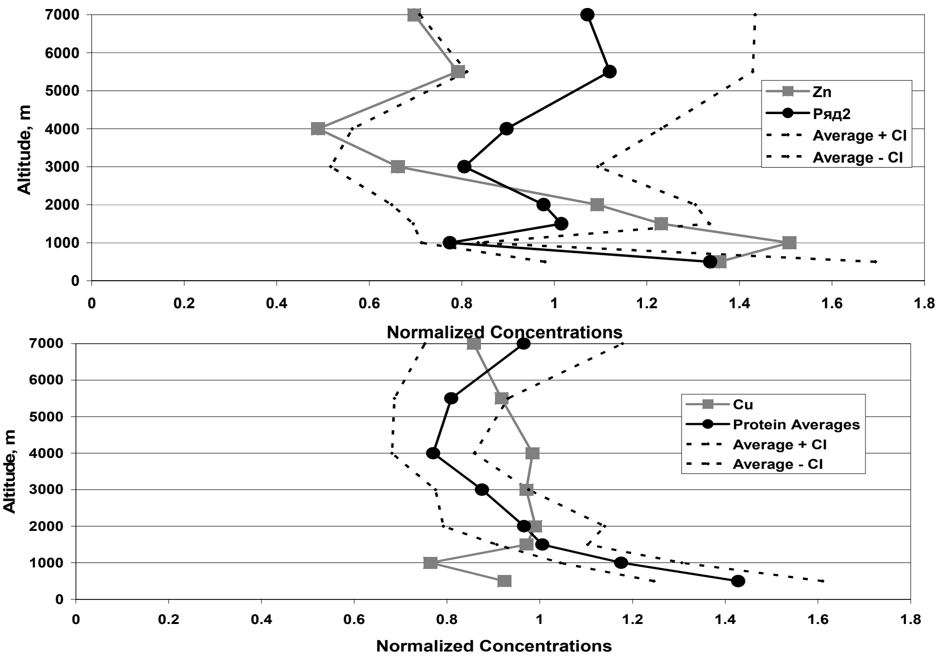

Fig. 4. "Dissimilar" altitude profiles of culturable microorganisms and Zn (above) and the total protein and Cu (below) normalized by the mean value. CI = the standard interval for mean values of the total protein and culturable microorganisms at the significance level of 95%.

At the next work stages, it will be necessary to determine which types of sources contribute to the observed altitude profiles of concentrations of the total protein and culturable microorganisms in atmospheric aerosol of Southwestern Siberia, where these sources are located and which mechanisms provide the bioaerosols' rise to higher altitudes and transfer for long distances.

5. Acknowledgments

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