COMPARATIVE DATA ON CHEMICAL COMPOSITION OF AEROSOLS ABOVE CONTINENTAL AND ARCTIC REGIONS OF EASTERN SIBERIA

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The results of chemical analysis of aerosol samples from station "Tiksi" (coast of the Laptev sea) during the fall and winter of 1995/96 are presented, in comparison with those for the continental regions (Irkutsk and "Mondy" Station in Eastern Sayan). The ion composition of samples has been studied using liquid chromatography (anions) and atomic absorption (cations) techniques. The element composition has been determined using the X-ray fluorescence technique. Possible mechanisms of aerosol formation above the Arctic coast of Siberia are discussed.

1. INTRODUCTION

Siberian region is of interest in respect to investigations of a wide scope of problems, concerning the global background aerosol and its role in climate formation on the global scale. There are regions in Siberia with big industrial centers while at the same time there are vast territories that are far from any anthropogenic sources that enables one to investigate the processes of global transfer of anthropogenic impurities.[1–6]

At the same time the vast territory makes the arrangement of large-scale experimental observations there to be very difficult. The work under the project INTAS "Atmospheric aerosol over the Asian Part of the former USSR," unites the efforts of several R&D institutes, thus being an attempt of resolving these difficulties. In this paper, some of these results, concerning the evaluation of variation in chemical composition of aerosols over the south region of Siberia, both background and anthropogenic, and over its Arctic coast are presented.

2. MATERIALS AND METHODS

To characterize the aerosol over continental regions of Siberia, the data of observations have been collected in the following three areas: "Mondy" (52°N, 103°E) at the astronomical observatory of the Institute of Solar-Terrestrial Physics, SB RAS, located on one of the gently sloping peaks of Hamar-Daban mountain ridge. The nearest dense populated area and industrial centers (Irkutsk and Ulan-Ude) are at a distance over 200 km. For this reason the observations at this station bear information on the regional aerosol background and long-distance transfer of atmospheric suspensions. Irkutsk is a large dense populated area and industrial center in the South of Eastern Siberia. The results obtained there characterize the aerosol in the atmosphere over industrial regions of Siberia.

Data on Arctic aerosol were obtained at the field-test sites of the Institute of Astrophysics and Aeronomy of Yakutsk Branch of SB RAS, located at a distance of several kilometers from the populated area of "Tiksi" (71°N, 129°E) on the seashore of Laptev sea. In all cases daily and two-days samples were collected with a low-capacity aspirator (35–40 litters/min) to the filters "Whatman–41."

The ion composition of aerosol was studied by the method of liquid chromatography (anions) using a "Milichrom" colorimeter with an error 4–7%, and an atomic absorption (cations) device AAS–30 with an error 4–6%. The element composition has been determined using the X-ray fluorescence technique at the Synchrotron center of the Institute for Nuclear Physics SB RAS.

3. DISCUSSION OF RESULTS

During the period of observations in "Irkutsk" and "Mondy" the data on chemical composition of aerosol were obtained for all seasons while on the seashore near "Tiksi" only for the cold period of the year (from October and until March), therefore the emphasis will be placed on this period of the year.

Analysis of directions of the atmospheric transfer over the observation period has shown, based on many-year mean data, that in "Tiksi" the transfer dominated either from central regions of the Middle Siberia, or from western regions of the Arctic coast due to invasions of cyclones (Fig. 1).

Irkutsk		Mondy		Tiksi	
86	9	64	0	26	12
0	5	36	0	62	0

FIG. 1. The recurrence, in %, of the directions of air mass transfer to the areas of observations. Winter 1995/96.

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TABLE I. Mean characteristics of the aerosol ion composition over different regions in Siberia, 1995/96, ($\mu g/m^3$).

Characteristics	Na^+	K^+	Ca^{2+}	Mg^{2+}	NH_4^+	HCO_3^-	Cl^-	NO_3^-	SO_4^{2-}
"Irkutsk" (winter)									
Average	0.12	0.18	0.44	0.13	2.17	0.00	0.20	1.29	3.98
Max	0.31	0.36	1.24	0.42	7.00	0.00	0.58	5.33	22.46
Min	0.00	0.07	0.05	0.04	0.41	0.00	0.00	0.23	0.31
Rms dev.	0.10	0.09	0.32	0.10	1.84	0.00	0.19	1.37	6.01
Median	0.12	0.20	0.36	0.10	1.90	0.00	0.11	0.87	1.90
"Irkutsk" (summer)									
Average	0.04	0.17	0.71	0.22	0.73	0.10	0.04	0.38	1.28
Max	0.30	0.39	1.31	0.44	1.44	0.34	0.29	0.86	2.57
Min	0.00	0.08	0.16	0.07	0.24	0.00	0.00	0.03	0.34
Rms dev.	0.06	0.06	0.32	0.09	0.30	0.12	0.07	0.23	0.68
Median	0.01	0.15	0.79	0.22	0.70	0.04	0.00	0.35	1.19
"Mondy" (winter)									
Average	0.00	0.02	0.02	0.02	0.09	0.05	0.00	0.02	0.28
Max	0.06	0.03	0.38	0.09	0.18	0.29	0.02	0.07	0.71
Min	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Rms dev.	0.01	0.01	0.09	0.02	0.04	0.08	0.01	0.02	0.19
Median	0.00	0.02	0.00	0.01	0.08	0.01	0.00	0.02	0.26
"Mondy" (summer)									
Average	0.04	0.12	0.04	0.04	0.22	0.03	0.02	0.10	0.51
Max	0.28	0.31	0.13	0.12	0.59	0.16	0.21	0.30	2.07
Min	0.00	0.03	0.00	0.01	0.06	0.00	0.00	0.00	0.02
Rms dev.	0.08	0.07	0.04	0.03	0.13	0.04	0.05	0.09	0.45
Median	0.00	0.11	0.03	0.04	0.18	0.02	0.00	0.08	0.47
"Tiksi" (winter)									
Average	0.07	0.04	0.02	0.03	0.20	0.00	0.10	0.02	0.27
Max	0.55	0.14	0.11	0.09	0.42	0.01	0.86	0.09	0.62
Min	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.02
Rms dev.	0.11	0.03	0.03	0.02	0.08	0.00	0.16	0.02	0.16
Median	0.03	0.04	0.01	0.03	0.19	0.00	0.05	0.01	0.26

Average ion composition of aerosols and several characteristics of its variability in the regions under study are given in the Table I.

From the average data it is seen, that concentrations at the "Mondy" and "Tiksi" stations differ insignificantly. Somewhat less total content of ions in "Mondy" can be caused by a higher location of this locality. An order of magnitude higher concentrations of ions in Irkutsk, of course, are connected with the influence of anthropogenic sources. Differences between the arithmetic mean and median values of ion concentrations (see Table I) may point to the presence (if the differences are great) or absence (if the differences are insignificant) of the near source of the given ion. For example, it is seen, that there are near sources of sulfates and chlorine (anthropogenic waste) in winter in Irkutsk, in Mondy there are hydrocarbons (soil, rocks), in Tiksi – sodium, chlorine (sea salts, and also Br, Fig. 2).

The ion composition, expressed in a percent-equivalent form (Table II), also point out to a significant contribution of Na and Cl ions to soluble part of winter aerosols of Arctic regions (>10%-equiv, compared with 2%-equiv. in Irkutsk and nearly zero values in Mondy). Therefore in a cold period of the year, sea salts continue to comprise an essential part of Arctic aerosols, in spite of the dominance of the atmospheric transfer from the continental regions of Siberia and snow cover during this time. The latter two factors (transfer from continental regions and ice cover of the sea explain the fact that the main contribution of soluble fraction of aerosol here are sulfates and ammonium (more 40%), as in continental regions. Quite an essential discrepancy in the balance of cations and anions for Irkutsk and Tiksi can be connected with the greater variety of the ion composition near anthropogenic sources and the seashore, than for nine anions chosen. For the background continental aerosol (Mondy) these nine basic ions are practically sufficient for completion of the ion balance.

Conservation of the marine component in Arctic aerosol when changing the air mass (transition from NW to SW) in cold period is an evidence of the fact, that continental areas of Eastern Siberia (in the medium reaches of the Lena river) due to the snow cover and freezing at that time, have no powerful

natural sources of atmospheric aerosol, besides some local industrial-type sources, (for example, Noril'sk, situated to the west), emitting some specific aerosols into the atmosphere. Apparently, in summer, the dependence of the aerosol composition on the origin of the air mass will be different.

The basic chemical compounds, which accumulate the ions in the aerosol substance in the atmosphere over the regions under study can be evaluated by the degree of correlation of their daily variation. Thus, the correlation coefficients between the contents of basic cations and anions are as follows:

Station	NH_4^+ and SO_4^{2-}	NH_4^+ and NO_3^-	Na^+ and Cl^-
"Irkutsk"	0.78	0.74	0.25
"Mondy"	0.85	0.39	−0.09
"Tiksi"	0.69	0.72	0.95

It is seen, that in the region of "Mondy" station the aged continental aerosol of $(NH_4)_2SO_4$ dominates that confirms the opinion about this station as a "background" continental one.

Ions of Na and Cl in Tiksi region are almost entirely are in the form of the sea salt. The element composition of Arctic aerosol (observations in the region of Tiksi) is either essentially more deficient in typically soil elements than the continental one (Ca), or contain them at the same level (Fe, Ti), but differs by higher concentrations of the marine-origin elements like Br, Se, Mo (see Fig. 2), what allows one to characterize winter arctic aerosol as the marine one.

It is of a particular interest to estimate the content of anthropogenic components in the chemical composition of aerosols.

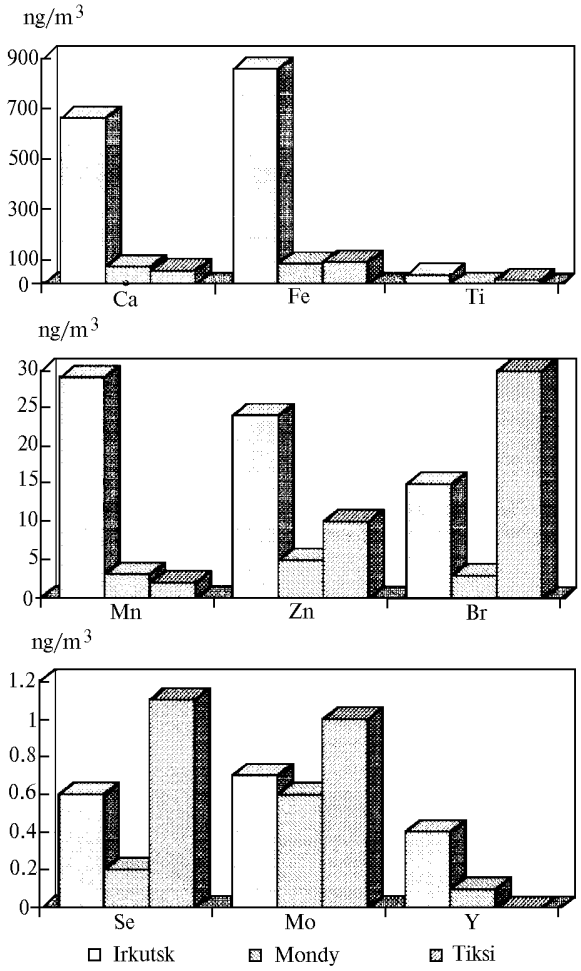

FIG. 2. Average concentration of some elements in the observation points.

TABLE II. Ion composition (%-equiv.) of winter atmospheric aerosols.

Station	NH_4^+	Ca^{2+} +Mg^{2+}	Na^+	K^+	Σ%	HCO_3^-	Cl^-	NO_3^-	SO_4^{2-}	Σ%
"Irkutsk"	44.2	12.0	1.9	1.7	59.8	0.0	2.1	7.6	30.5	40.2
"Mondy"	33.3	17.4	0.0	3.3	54.0	5.3	0.0	2.0	38.7	46.0
"Tiksi"	40.7	12.6	11.0	3.7	68.0	0.0	10.3	1.1	20.6	32.0

For the "Tiksi" station Ni can be considered as an indicator of anthropogenic origin of aerosols. The presence of it in aerosols of continental stations (even in Irkutsk) is practically equal to zero, while in Tiksi its content in particles is constant being within the interval of 1–1.5 ng/m^3. The source of this element here, most likely is Noril'sk metallurgical plant, located on the way of the main air mass transfer to Tiksi.

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