# Mineral composition of solid aerosol particles in towns of the Southern Baikal region

**V.P. Rogova,[1] V.Ya. Kiselev,[1] D.A. Chursin,[2] N.V. Fedorova,[2] and V.A. Skvortsov[2]**

[1] *State Federal Unitary Enterprise “Sosnovgeologiya,” Irkutsk*
[2] *Irkutsk Institute of Railway Transport Engineers*

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The results of studies of technogenic atmospheric pollution with disperse minerals in solid aerosol particles are presented. Mineral composition of solid aerosol particles in the air over Southern Baikal region is identified for the first time. Urban air is shown to be polluted with disperse emissions of quartz, calcite, feldspar, and amphibole. According to the data of snow-geochemical survey, mullite ($Al_9Si_3O_{19}F$) containing 28–32% of $Al_2O_3$ prevails in solid aerosol particles in winter. It is also the main component of power-production slag that allows its use as a secondary raw material for aluminum production.

Combined geo-ecological mapping carried out by Sosnovgeologiya over the territory of the Southern Baikal region revealed large areas of technogenic pollution. A considerable part of atmospheric pollution is due to solid aerosol particles. The mineral composition of such particles was not earlier studied in the Southern Baikal region.

To study the mineral composition of solid aerosol particles in industrial centers and in countryside, snow sampling was conducted in winter. In summer samples were collected with the use of dust collectors. In the winter period, snow was sampled into plastic bags from 0.5×0.5 m holes for the whole depth of the snow cover (0.4–0.6 m) except for the bottom layer 0.1 m thick, which may contain soil particles. In a chemical laboratory snow samples were let to stay in plastic reservoirs until complete melting, and then the water from melted snow was filtered. Solid residue was dried and then weighted with electronic scales. The filtered water was analyzed and evaporated to obtain the salt residue.

The amount of the solid residue was estimated in the process of carrying out the areal snow-geochemical survey in 1989–1999 on the territory of 12 towns and 5 industrial communities. In the Southwestern Baikal region (Irkutsk-Cheremkhovo industrial territory) the snow-geochemical survey was conducted over the total area of 12 000 km$^2$ including Irkutsk, Angarsk, Usol'e-Sibirskoe, Shelekhov, Slyudyanka, Baikalsk, farmlands, villages in six areas, and the southern bank of Lake Baikal. According to data of the Hydrology & Meteorology Committee, this territory refers to the category of most technogenically polluted territories in Russia. The survey was carried out late in February in accordance with the approved methodic recommendations. In towns and suburbs the sampling density was two to four samples per 1 km$^2$, in farmlands, forests, and on the bank of Lake Baikal it was one sample per 4 km$^2$. A total of 5000 samples were collected and analyzed.

In samples of snow water, the main cations Ca, Mg, K, Na and anions Cl, $SO^4$, $NO^3$, $HCO_3$, F, as well as pH, U, Hg were determined by quantitative methods. The filtered-out insoluble residue and evaporated soluble residue (salt phase) were weighted separately and then subjected to approximately quantitative emission spectral analysis for 50 elements.

The results of snow sample analysis were processed on a computer to plot multicomponent and combined maps by the technique developed in Sosnovgeologiya and Irkutsk Scientific Center. The maps show main topographic elements: drainage network, railways and highways, contours of the urban area, rural areas, and other territories. Points of snow sampling are shown by different signs in accordance with the technogenic load. Isolines of technogenic load in kilograms, grams, and milligrams per 1 m$^2$ a day are plotted as well. This mapping principle allows the pollution of particular territories and objects to be represented both in terms of content used by the Ministry of Public Health and in terms of technogenic loads used by the Hydrology & Meteorology Committee.

Multicomponent and combined 1:50 000 and 1:200 000 scale maps of the territory under study allowed, for the first time, the determination of the whole spectrum of inorganic compounds in atmospheric emissions, particular areas, intensity and sources of pollution to be presented. The mean level of technogenic load for towns is tabulated below.

Most intense pollution (Fig. 1) was observed in the main industrial centers of the region under study and in their suburbs. This fact agrees completely with the data on the amount of emissions published by the Hydrology and Meteorology Committee and other institutions. Because such towns as Irkutsk, Shelekhov, Angarsk, and Usol'e-Sibirskoe are located not far (16–40 km) from each other, a continuous area of technogenic pollution with the length of 125 km and the width of 15–25 km is formed along the bank of River Angara.

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**Mean technogenic load on the territory of Baikal towns as calculated per 1 km² a year**

| Town | Total dust load, t | Total load by soluble forms of chemical elements in the salt phase, t | Total load by acid components ($NO_3$, $HSO_3$, Cl, F, $SO_4$), t | Total load by soluble forms of heavy metals (lead, zinc, copper, cobalt, nickel, manganese), kg |
|---|---|---|---|---|
| Irkutsk | 72.8 | 9.1 | 6.9 | 8.9 |
| Angarsk | 62.2 | 6.8 | 9.1 | 8.6 |
| Usol'e-Sibirskoe | 56.9 | 13.8 | 13.5 | 8.7 |
| Shelekhov | 44.3 | 7.6 | 6.2 | 4.2 |
| Slyudyanka | 99.3 | 9.2 | 8.0 | 7.7 |
| Baikalsk | 20.0 | 9.3 | 10.9 | 15.7 |
| Nizhneudinsk | 40.2 | 2.3 | 1.9 | 5.5 |
| Taishet | 36.2 | 5.5 | 5.3 | 10.1 |
| Ust'-Ilimsk | 20.1 | 4.1 | 5.7 | 6.7 |
| Bratsk | 72.0 | 16.5 | 15.9 | 17.5 |
| Zheleznogorsk-Ilimskii | 73.0 | 11.7 | 9.0 | 11.5 |
| Kirensk | 16.5 | 9 | 3.5 | 3.7 |
| | *Background for the Southern Baikal region* | | | |
| | 7.3 | 0.73 | 1.1 | – |

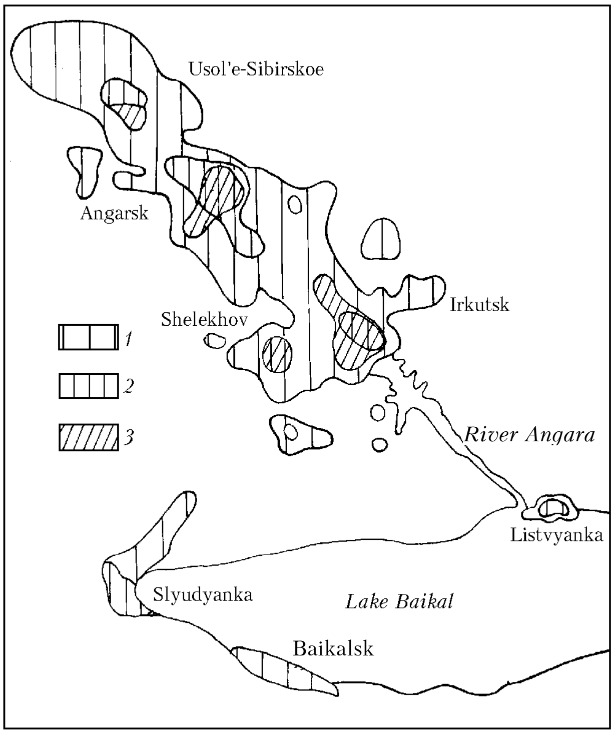


**Fig. 1.** Map of snow cover pollution with solid aerosol particles in towns of the Southern Baikal region. Drawn using the data of Sosnovgeologiya for 1992. Technogenic load (kg/km² a day): 5–150 (*1*), 150–300 and higher (*2*); urban territories (*3*).

The population of this territory makes up about 50% of population of the whole region. The polluted area includes vast farmlands and a lot of gardening cooperatives. Agricultural products from this territory used for food are dangerously polluted. This is indicated by our experience of studying the quality of agricultural products near Shelekhov.

In the composition of pollutants, a significant role belongs to acid components: sulfurous anhydride, fluorine, chlorine, nitrogen and carbon oxides, and heavy metals of the first class of danger: lead, arsenic, mercury, zinc, beryllium, etc.

The mineral composition of solid-phase particles and solid insoluble particles in Irkutsk was studied for the first time in 1999–2001. For this purpose, snow-geochemical samples in Irkutsk and Baikalsk were collected in February, and dust samples were collected in Angarsk, Usol'e-Sibirskoe, and Angasolka village in August.[1,2]

Minerals were diagnosed by X-ray quantitative phase analysis on a DRON-2 setup (copper radiation, voltage of 30 kV, current of 20 mA).

In Irkutsk for the winter period of 1999–2000, 1.2 g of insoluble residue was accumulated in 1 m² of 0.22 m-thick snow cover. In Baikalsk, 0.8 g of disperse particles were accumulated on 1m² of 0.62 m-thick snow cover. In the solid residue of water from melted snow, one of the main minerals in both Irkutsk and Baikalsk was technogenic mineral mullite $Al_9Si_3O_{19}F$. Other minerals in samples collected in Irkutsk are (in the order of decreasing content) quartz, albite-oligoclase, haematite, orthoclase. Amphibole and muscovite are present in the amounts less than 1%. The samples collected in Baikalsk contain much smaller amount of quartz, the double amount of orthoclase, and haematite and albite-oligoclase in equal amounts. In summer solid particles were studied in most of the industrial cities: Angarsk and Usol'e-Sibirskoe (near the chemical plant), as well as in Angasolka village (southern end of Lake Baikal).

The dust in Angarsk is enriched with quartz and in Usol'e-Sibirskoe with calcite. In both cases the concentration of minerals exceeds that in surrounding rock, that is, a significant part of minerals is of the technogenic origin. The solid-phase part of aerosols in Usol'e-Sibirskoe consists of (in %): quartz – 24, orthoclase – 28, albite – 25, amphibole – 7, calcite – 16, kaolin and hydromica – less than 1. The samples of solid particles in Angarsk include (in %): quartz – 30, orthoclase – 18, albite – 28, amphibole – 13, calcite – 2, kaolin and hydromica – less than 1%. The content of quartz and amphibole in solid aerosol particles in Angarsk is almost twice as high as in particles sampled near the chemical plant in Usol'e. Disperse quartz causes a lung disease – silicosis. The content of calcite in solid aerosol particles in Angarsk is twice as high as the background level, and that near the chemical plant in Usol'e-Sibirskoe is 16 times higher than the background one.

In Angasolka village at the territory of macadam plant, samples were collected from power-production slag and ash dump dust, as well as from rocks in open mine and from mine dust. In power-production slag and ash dump dust, the main mineral is mullite, while quartz, feldspars, and micas are present in small amounts. The composition of the mine dust is almost the same as that of rocks: the main minerals are quartz, feldspars, and micas.

The main source of atmospheric pollution in all the towns and villages is the heat and power industry (mostly, boilers operating without the exhaust gas cleaning, and individual heating) and cars. In some towns (Usol'e-Sibirskoe, Angarsk), industrial plants are the main sources of pollution.

According to the results of investigation into the effect of atmospheric dust on the human health, which were reported in the State Report "On the State of the Environment" in Moscow in 1992, quartz and calcite cause some serious diseases. Calcite favors bronchitis and chronic maxillary sinusitis, while quartz stimulates development of pulmonary tuberculosis and cancer of lungs. The effect of mullite on the human body was not studied. Physical properties and chemical composition of this mineral suggest that its effect is similar to that of asbestos.

Thus, the technique of snow-chemical survey should be complemented with analysis of the mineral composition of solid particles from melted snow, and eco-geochemical survey of the surface should include analysis of the mineral composition of dust.

To decrease the content of mullite in air, utilization of power-production slag is needed. The increased content (28–32%) of $Al_2O_3$ in mullite allows the slag to be used as a secondary raw material for aluminum production.

## References

1. D.A. Chursin, N.V. Fedorova, V.P. Rogova, and V.A. Skvortsov, in: *Siberian Aerosols* (IAO SB RAS, Tomsk, 2000), p. 35.
2. D.A. Chursin, N.V. Fedorova, V.P. Rogova, and V.A. Skvortsov, in: *Siberian Aerosols* (IAO SB RAS, Tomsk, 2000), p. 34.