SOME RESULTS OF THE INVESTIGATION OF ICE NUCLEI IN THE ATMOSPHERE OVER LAKE BAYKAL

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In this paper we present some results of the investigation of ice nuclei in the atmospheric aerosol carried out on Lake Baykal in July, 1991. Experimental measurements were performed using filter technique at two stationary points and during a 7-day expedition on board a ship in the southern part of Lake Baykal. Measurement results showed that the concentration of the nuclei in the region under study was close to that measured in other geographical regions (Moldavia and Czechia) and varied from 0.1 to 5 nuclei per liter. Enchanced concentrations of the nuclei were observed only in the regions near centers of industrial activity. We also observed some influence of such meteorological factors as precipitations and wind on the concentration of ice nuclei in the atmosphere. The question on the effect of macroscopic transport of air mass on the concentration of ice nuclei in the region under study requires an additional and more long investigations.

Investigations of atmospheric ice producing aerosols were carried out during some years at the Central Aerological Observatory in different regions of Russia and abroad. As a result, the data on the number density of ice nuclei in the regions of active influence (station of hail protection in Moldavia[2] and Bulgaria[3], and Lake Sevan[1]) and near big cities (Gradets–Kralove, Czechia and Moscow region[6]) were obtained. Measurements over Lake Baykal were of interest because they could allow to obtain the data on the content of ice nuclei in the region that is different from those investigated earlier both in physical-geographical conditions and in the character of anthropogenic pollution. Chemical composition of air and characteristics of the anthropogenic sources of pollution of the Baykal region are studied quite well,[4] however, there are no data on the number density of active cloud nuclei in this region.

The peculiarity of physical-geographical conditions of the Baykal region is its relief that favors the penetrating of air masses from the surrounding continental areas to the Lake Baykal depression and causes the formation of a specific inner circulation in the lake area. The Irkutsk-Cheremkhovsk industrial complex, Ulan Ude industrial center, Gusinoozersk power station, and Baykal'sk pulp and paper mill mainly affect the lake and the surrounding atmosphere. Base metals, whose aerosols can have the ice producing properties, make a significant portion of the pollutants.

Measurements of the ice nuclei (IN) number density were carried out in July, 1991, within the framework of "Baykal-91" expedition to the South Baykal. Measurements were carried out near the village Listvyanka, in two sites situated at different heights above the sea level, namely, the meteorological station "Istok Angary" (470 m) and the plate "Telescope-Sibizmir" (800 m) as well as while cruising along east and west coasts of Lake Baykal during seven days with drops to the Angara and the Selenga. The cruise route and location of the measurement sites are shown in Fig. 1.

Measurements were performed by means of the nuclear membranes produced at the Joint Institute of Nuclear Studies (Dubna) with the pore diameter 0.36 μm and the filter diameter 35 mm that act as filters. Sampling on filters placed in sample collectors was done by blowing atmospheric air through them during 10–12 min. Total volume of the air passed through the filter was ~100 liters in each experiment. Sampling at the ground sites was done at 2.5–m height above the ground, on board the ship at 1.5–m height above the ship board. Filters with aerosol samples were kept, after exposing, in a special cassette providing the protection of a filter from external influence and pollution. Development of the filters was carried out under stationary conditions at Central Aerological Observatory in the isothermic diffusion chamber[5] at temperature – 20°C.

Measurements, carried out during the cruise, show that the ice nuclei number density varies in different sites of the South Baykal within one order of magnitude and covers the range 0.2–5 l^{-1}. The cruise route is shown in Fig. 1 by arrows. Significant temporal variations of the IN number density were recorded near the city of Baykal'sk where the measurements were carried out onboard the ship standing on the road at the distance of 0.5 km from the city. The ice nuclei number density was 0.5–0.6 l^{-1} when transfer of air mass occurred from the lake, and it increased up to 1.7 l^{-1} (sometimes up to 3–5 l^{-1}) when wind blew from the coast. The IN number density was practically constant on the route along east and west coasts and equal to 0.5–0.7 l^{-1}. It decreased to 0.2–0.3 l^{-1} with the distance from the coast increased to 10–15 km.

When cruising along the Angara near the city of Irkutsk, the sampling of nuclei was done under conditions of north-west transfer of air mass. The ice nuclei number density reached 3.8 l^{-1} (2.2 l^{-1} in average). The higher number densities can be connected with the neighbor industrial pollution sources. Measurements on the Selenga were carried out in the mouth of the river (at entrance and exit) and at the distance of ~ 20 km from the mouth near the Shugaevo village. The IN number density near Shugaevo was significantly greater (from 1.3 to 2.8 l^{-1}; 1.9 l^{-1} on average) than near the mouth, where it was 0.8–1 l^{-1}.

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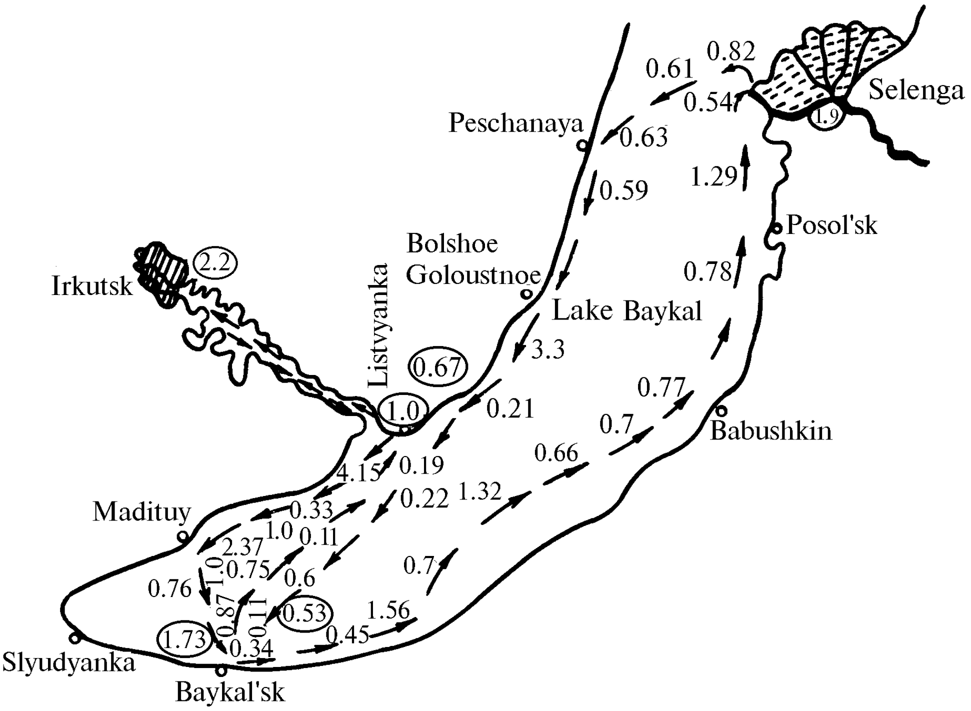

FIG. 1. Measurements of atmospheric aerosol in the South Baykal region in July, 1991. Average number densities of ice nuclei (IN). Circled values show average number densities of IN measured at observational sites, uncircled values present number densities obtained at the points of route.

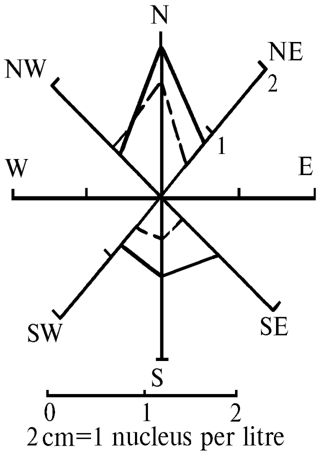

FIG. 2. Dependence of the IN number density on the wind direction at observation sites: "Meteostation" (solid line) and "Telescope" (dashed line).

Measurements of the ice nuclei carried out during six days at two ground–based sites show that the ice nuclei number density at the elevated site "Telescope" are on average 30% lower than at "Meteostation". The measured number density is shown in Fig. 2 as a function of wind direction. The north direction is distinguished by both sites, when the IN number density increased and was 1.2–1.3 l^{-1}. At the south transfer, the IN number density decreased down to 0.3–0.5 l^{-1} at "Telescope" and to 0.9–1 l^{-1} at "Meteostation". Coincidence of the direction of the higher number density at both sites allows us to suppose the presence of a common remote source of ice nuclei for this region.

The results of simultaneous hourly measurements of ice nuclei at "Meteostation" and "Telescope" on July 12–13 are shown in Fig. 3*a* (measurement at "Telescope" were delayed for 10 hours for the technical reasons). The variations of the ice nuclei content in the atmosphere during these days were connected with both the natural diurnal behavior of the atmospheric aerosol number density and the change of meteorological conditions. Sunny weather with a weak wind from the south was observed on July 12. The IN number density increased slowly at "Meteostation" from 8 a.m. to 12 a.m. and then decreased to approximately 1 nucleus per liter at 5 p.m. Meteorological conditions sharply changed after 10 p.m. It rained, clouds increased, and the wind direction changed to the north one. Number density of IN increased up to 1.8–1.9 l^{-1} and only at 8 a.m. on July 13 it decreased to 1 l^{-1}. Variations of the IN number density had the same behavior at the "Telescope" site during the cycle of simultaneous measurements.

Diurnal behavior of the IN number density near Baykal'sk is shown in Fig. 3*b*. As is seen, it is completely governed by wind direction variations for this region. The elevated number densities of ice nuclei were observed for the air mass transfer from the coast.

The behavior of the ice nuclei number density at "Meteostation" on July 15 is shown in Fig. 3*c*. Precipitations were observed during all this day. The ice nuclei number density was constantly low ~0.5 l^{-1} during the day.

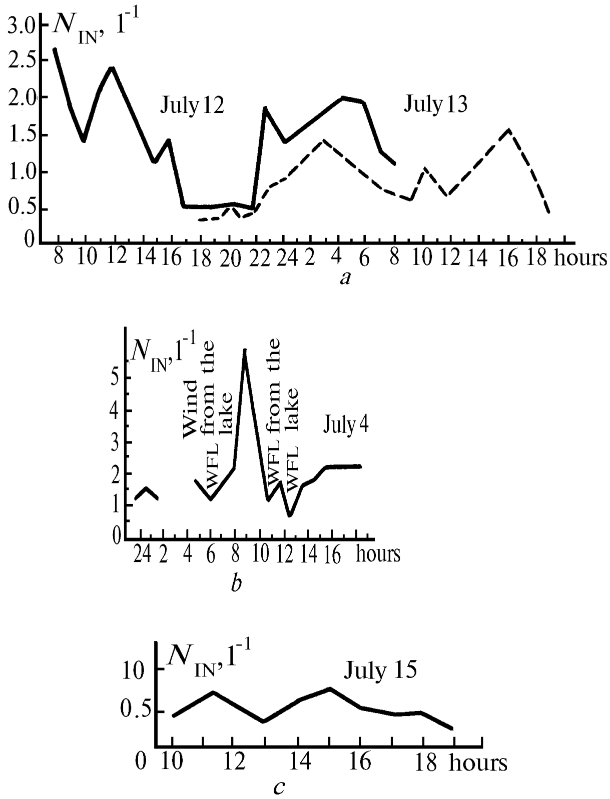

FIG. 3. Diurnal behavior of IN content at measurement sites: a) July 12–13; solid line corresponds to "Meteostation" and dashed line corresponds to "Telescope"; b) July 4, city of Baykal'sk; and, c) July 15, at "Meteostation". WFL denotes the situations of wind from the lake.

In general, the data obtained allow us to conclude that the average values of ice nuclei number density are approximately 1 nucleus per liter. It coincides with the results of measuring the ice nuclei number density performed earlier by scientists from Central Aerological Observatory in Moldavia and Czechia[1] and it evidences the fact that Baykal region is close to the rural areas of European regions in its ice producing characteristics (Table I).

TABLE I. Average number density of IN in different regions.

Region	Year of measurement	Number density, l^{-1}
Baykal	1991	1.04
Moldavia	1985–89	1.6
Czechia	1989	1.1

The local industrial centers affect on the ice nuclei content in the atmosphere by increasing the IN number density up to one order of magnitude.

The problem on effects of the air mass macroprocess on the formation of ice nuclei number density in the region requires a more long-term measurements.

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