Radioactive elements in atmospheric precipitations of the Western Siberia

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Abstract. The radionuclide composition of the atmospheric precipitations (rain and snow) fell out on the territory of the South of the Western Siberia in 2016-2017 was studied. It is shown that, the maximum of deposition of ⁷Be and ²¹⁰Pb were observed in a foothill zone (618 and 171 Bq/m²), the minimum - in the Alpine zone (104 and 27 Bq/m²), for the forest-steppe zone these values are 237-340 Bq/m² and 73-93 Bq/m². Deposition density of ¹³⁷Cs in comparison with ²¹⁰Pb and ⁷Be is small and does not exceed 1 Bq/m². Average values of total specific activities of ²¹⁰Pb and ⁷Be in rain waters are 242 and 2434 mBq/l, in the snowmelt - 506 and 1611 mBq/l. ⁷Be/²¹⁰Pb activity ratio in rain waters more than three times higher, than in snowmelt: 10,1 to 3,2. The highest values of ⁷Be/²¹⁰Pb activity ratios are observed in the finest fraction (<0.45 μm) of the suspended matter: 19 - in rain and 10 - in snowmelt waters.

1 Introduction

Radioactive isotopes of natural origin ⁷Be and ²¹⁰Pb in significant amounts deposit on the Earth's surface from the atmosphere. They have different sources of origin. ⁷Be, with a half-life of 53.2 days, is a cosmogenic radionuclide naturally produced in the stratosphere and troposphere through cosmic-ray spallation of nitrogen and oxygen [1, 2]. ²¹⁰Pb_{atm} is a decay product of atmospheric gaseous ²²²Rn derived from soil ²³⁸U decay chain and emanated to the atmosphere from the Earth's surface. Just after production ⁷Be, ²²²Rn atoms and its decay products are electrically charged. They attach to aerosols and dust particles and deposit on the Earth's surface with "dry" (dust, aerosols) fallouts and "wet" (rain, snow) atmospheric precipitations [3-11]. ⁷Be and ²¹⁰Pb_{atm} are often used as indicators of various natural processes, including, geochronological modeling of modern sedimentation processes, study of aerosol transfer in the atmosphere, atmospheric circulation models and meteorological dynamics, etc. [12-29] According to some estimates [30] more than 90% of ⁷Be and ²¹⁰Pb_{atm} are delivered to the Earth's surface through "wet" atmosphere precipitations. There are no reliable data about deposition of ²¹⁰Pb and ⁷Be with atmospheric precipitations in such extensive region as the Western Siberia now. The

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purpose of this research is to estimate concentration levels and to reveal the main features of ^7Be and ^{210}Pb deposition with the atmospheric precipitations (rain, snow) falling out on the territory of some regions of the Western Siberia (South-East of Novosibirsk region, South-East of Altai Territory, North-West of Altai Republic).

2 Materials and methods

In this research samples of the wet atmospheric precipitations (rain, snow) fell out in 2016 and 2017 on the territory of the South of the Western Siberia in different landscape-geographical zones (Fig. 1, forest-steppe (I, II, III), foothill (IV), mountain-taiga (V) and Alpine (VI)) were studied. The volume of samples of snowmelt or rainwaters was 10-20 liters. During the sample preparation procedure of the studied water samples the separation of the suspended matter was performed by sequential filtering of all sample volume via the 3,0 μm filter and the 0,45 μm membrane. It allowed to allocate two components of the suspended matter with dimensions more than 3 μm and 3-0,45 μm corresponding to dust particles of various sizes. The water solution received after filtering was evaporated to solid residual. This fraction (<0,45 μm) include fine aerosol and dust particles, colloids and dissolved component. In filters and solid residual determination of activities of ^7Be , ^{210}Pb and ^{137}Cs was carried out on ORTEC gamma-spectrometer with HPGe well-type detector. All analytical procedures were performed at the Shared-Use Center for Multielemental and Isotope Studies, Siberian Branch of the Russian Academy of Sciences.

Fig. 1. Study area and sampling locations.

3 Results and discussions

The study of the samples of the snow precipitations accumulated over the entire winter season and collected at the end of the period of an active snow accumulation (the end of March) in various landscape-geographical zones of the South of the Western Siberia showed that (Fig. 2.):

a) Deposition density of ^{137}Cs in comparison with ^{210}Pb and ^7Be is small and does not exceed 1 Bq/m^2 in all studied points. This fact indicates the insignificant modern content of this radionuclide in the atmosphere.

Fig. 2. Average values of the deposition densities of Be-7 and Pb-210 within various landscape-geographical zones of the South of the Western Siberia.

b) The maximum of deposition densities of ^7Be and ^{210}Pb were observed in a foothill zone - 618 ± 62 and $171\pm17\text{ Bq/m}^2$, respectively. The minimum values corresponded to the Alpine zone - 104 ± 11 and $27\pm4\text{ Bq/m}^2$. For the forest-steppe zone deposition densities of ^7Be and ^{210}Pb varied within $237\text{--}340\text{ Bq/m}^2$ and $73\text{--}93\text{ Bq/m}^2$, respectively.

The comparative analysis of radionuclide composition of "wet" atmospheric precipitations (10 rain and 8 snow samples) on the territory of the South of the Western Siberia shows:

Fig. 3. Average integrated specific activities of Pb-210 and Be-7 in rain and snowmelt waters.

a) Taking into account a contribution of all granulometric fractions of the suspended matter, average values of total specific activities of ^{210}Pb and ^7Be in rain waters, sampled in the spring and autumn period of 2017, are 242 ± 23 and $2434\pm200\text{ mBq/l}$, respectively (see Fig. 3). In the snowmelt waters characterizing single snowfalls of the winter period of 2017, these values are 506 ± 45 and $1611\pm130\text{ mBq/l}$. It is obvious that concentration of ^{210}Pb in winter "wet" precipitations is almost twice higher, than in summer one. The specific activity of ^7Be is much higher during the summer period. This fact can be explained by more active ingress of this isotope from an upper atmosphere during the spring and summer period. It should be noted that $^7\text{Be}/^{210}\text{Pb}$ activity ratio in rain waters more than three times higher, than in snowmelt: 10,1 to 3,2.

b) The study of ^{210}Pb and ^7Be distribution in granulometric fractions of the suspended matter of rain and snowmelt waters showed that (Fig. 4) in fraction with dimension more than 3 microns activities of ^{210}Pb and ^7Be in rain waters are $191\pm19\text{ mBq/l}$ and 1859 ± 150

mBq/l, in snowmelt waters - 403 ± 35 and 1206 ± 110 mBq/l, respectively; 2) in fraction 0,45-3 microns these values are equal 26 ± 3 , 119 ± 12 mBq/l and 85 ± 9 , 226 ± 22 mBq/l, and in fraction <0,45 microns - 24 ± 3 , 456 ± 37 and 18 ± 2 , 180 ± 18 mBq/l. These results show that the highest values of $^7\text{Be}/^{210}\text{Pb}$ activity ratios are observed in the finest fraction of the suspended matter: 19 - in rain and 10 - in snowmelt waters. This fraction consists of fine aerosol and dust particles, colloids and dissolved components. Moreover, it is the concentrator of ^7Be . In spite of the fact that in more coarse-grained fractions the total amount of ^{210}Pb , and ^7Be is much higher, $^7\text{Be}/^{210}\text{Pb}$ activity ratios here are significantly less: 4,5-10 in rain and about 3 in snowmelt waters. As these fractions are generally presented by the dust particles of various dimension, it is possible to assume that the concentrator of ^{210}Pb are these particles.

Fig. 4. Average specific activities of Pb-210 and Be-7 in granulometric fractions of the suspended matter of rain and snowmelt waters.

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