Sources and accumulation of ^7Be , ^{210}Pb and ^{137}Cs isotopes in the annual needles of larch and cedar in Novy Urengoy region (Arctic part of Western Siberia)

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Abstract. Annual needles of larch and cedar were sampled in the tundra zone of the Arctic part of Western Siberia in order to determine ^7Be , ^{210}Pb and ^{137}Cs specific activities. Higher concentrations of ^{137}Cs in the needles of cedar relative to the needles of larch can be associated with a clear difference in the properties of accumulation and translocation of caesium among these species. Higher concentrations of ^7Be and ^{210}Pb in the needles of larch relative to cedar needles and close isotopic ratios ($^7\text{Be}/^{210}\text{Pb}$) are probably due to more efficient aerosol deposition on vegetative canopies of larch.

1 Introduction

Landscape-geochemical processes that determine the migration flows of elements and their forms in the environment cause their regional background levels and the formation of natural and anthropogenic anomalies. The Arctic zone is significantly under a dense snow cover during each year, thus the atmospheric transport makes a significant contribution to the formation of a modern geochemical background (chemical elements and radionuclides) of the surface landscapes of the Arctic region of Siberia. So atmospheric transport. In order to estimate the factors influencing the change in the geochemical background, we will consider radioisotope indicators (^7Be , ^{210}Pb) and ^{137}Cs .

Natural radioactive isotopes ^7Be and ^{210}Pb in significant quantities enter the earth's surface from the atmosphere, depending on the season and weather conditions. The ^7Be ($T_{1/2} = 53$ days) is a cosmogenic isotope that forms in the upper atmosphere when protons and neutrons of cosmic radiation interact with the nuclei of ^{14}N and ^{16}O isotopes [1]. Mostly, it falls on the earth's surface in the adsorbed on aerosol particles form, together with rain and snow. And ^{210}Pb ($T_{1/2} = 22$ years) is a daughter product of ^{222}Rn , resulting from the radioactive decay of ^{238}U -series and entering the atmosphere from the earth surface [1]. It is also mainly fall out as the adsorbed on aerosols form. At the same time,

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when particles fall out, there are such important parameters as particle size distribution, surface morphology and meteorology [2]. The capture of aerosol particles, and as a result of the natural radionuclides, by the needles of larch and cedar may be different. This may be due to the canopy geometry and aerodynamics [3].

The ^{137}Cs ($T_{1/2} = 30.2$ years) – man-made isotope, which appeared in the environment as a result of nuclear weapon testing, as well as after various accidents at the nuclear facilities [4, 5]. This isotope as well as ^7Be and ^{210}Pb for a long time fell out on the earth's surface with the atmospheric precipitation. The increased content of ^{137}Cs in the Arctic ecosystems of Western Siberia is inherited from the time of nuclear tests on Novaya Zemlya. In 1998, the specific activities of ^{137}Cs in forest litter, lichen, soil and other components of biogeocenosis sampled in the Arctic zone were compared with the specific activities of ^{137}Cs in the same components sampled in the Altai Krai. Studies have shown a significant excess of ^{137}Cs activities in samples taken in the Arctic zone [6]. The data for 2018 also shows higher activities of ^{137}Cs in the ecosystems of the Novy Urengoy region compared with the Altay [7]. However, a comparison of current data with twenty years ago data suggests a significant decrease in average specific activities of ^{137}Cs in all components of ecosystems.

After the moratorium adoption on the nuclear weapons tests the fall out of ^{137}Cs from the atmosphere is sharply reduced and the question of its secondary redistribution between ecosystem components becomes more and more urgent. A large number of works are devoted to the accumulation and redistribution of radio caesium among plants. For trees, the accumulation and internal transfer of caesium and potassium are similar - both of these elements are highly mobile, making internal translocation to newly emerging tissues/sinks particularly important [8, 9]. Co-transport Cs with K could be tree species [10]. On the example of Chernobyl and Fukushima, it is known that at later stages after the accidents, the radionuclide activities in the biomass compartments increased due to their root uptake from the soil profile and reached certain quasi-stable levels depending on the ratio between the two major processes, radionuclide root uptake and its return to soil [11, 12].

In our study we consider the features of the ^7Be , ^{210}Pb and ^{137}Cs contents in the annual needles of larch and cedar sampled in October 2018 on the Novy Urengoy city area, the Arctic part of Western Siberia.

2 Samples and method

The sampling points were located along the route Novy Urengoy – Korotchaev – Tarko-Sale. Sampling was carried out at a distance about 100 meters from the road, to eliminate its possible impact. The sampling radius of one sample was 10–20 meters from the GPS fixation point (Fig. 1).

Most often in this area are found larch woods, less cedar and even less birch. The needles of larch and cedar trees only were examined to further compare the results between points and relative to the results for the southern part of Western Siberia. Samples of larch and cedar needles were selected. Cedar needles were taken with meristem endings (with an age no more than 1 year). Samples were taken in plastic bags and dried under laboratory conditions at room temperature, then made ash for 6 hours at $T = 450$ °C.

Determination contents of ^7Be , ^{210}Pb and ^{137}Cs in the studied samples of needles was carried out by semiconductor gamma-spectrometry using HPGe well detector (GWL-220-15). Samples were measured in the well detector. When the activities were calculated, it took into account influence of the measurement geometry and density of the analyzed sample. The spectral lines were used to determine radionuclides: 477 keV (^7Be); 46.5 keV (^{210}Pb); 662 keV (^{137}Cs). The registration efficiency of spectral lines was 60% for 46.5 keV and 5–4% for 477 and 662 keV. The detection limit of the radionuclides was 0.02 Bq. The

duration of a single sample measurement is from 3 to 24 hours. The duration of measurement time was chosen so that the statistical error in determining the areas of analytical photopeaks is 46.5; 477 and 662 keV did not exceed 5%.

Fig. 1. Larch and cedar needles sampling locations.

3 Results and discussions

After determining the activities of ⁷Be, ¹³⁷Cs and ²¹⁰Pb, the specific activities of these isotopes in the samples of needles studied were calculated. The results, shown in Table 1, evidenced a noticeable accumulation of ²¹⁰Pb and ⁷Be in the needles of larch compared to cedar needles. ¹³⁷Cs mainly accumulates in the needles of cedar; there is an increase in its content by almost an order of magnitude compared with the needles of larch.

Table 1. Specific activities (Bq/kg)* of ⁷Be, ²¹⁰Pb and ¹³⁷Cs in annual larch and cedar needles.

Samples number	Larch needles, Bq/kg			Cedar needles, Bq/kg		
	²¹⁰ Pb	⁷ Be	¹³⁷ Cs	²¹⁰ Pb	⁷ Be	¹³⁷ Cs
11	88±4	145±7	4.1±0.4	12±1	33±2	73±7
12	110±5	180±9	6.1±0.6	22±1	46±2	19±2
13	83±4	167±8	6.0±0.6	20±1	30±2	52±5
14	164±8	184±9	19.1±2	14±1	33±2	12±1
15	122±6	223±11	7.6±0.8	24±1	86±4	62±6

* Specific activities are given in terms of dry weight

The main evidence of the ⁷Be and ²¹⁰Pb atmospheric origin in the needles of both tree species, and not the accumulation through the root system from the soil can be the isotopic ratio (⁷Be/²¹⁰Pb).

In the needles of cedar at four points out of five, the ⁷Be/²¹⁰Pb values are slightly higher than in the needles of larch, however, they can are comparable to each other. All these values range from 1 to 3, while in lichens collected at these field points it falls below 0.5 (Fig. 2).

Fig. 2. ${}^7\text{Be}/{}^{210}\text{Pb}$ ratio in larch needles, cedar needles and lichen.

Lichens are several years old, and because of the difference in half-lives ${}^{210}\text{Pb}$ accumulates relative to ${}^7\text{Be}$. ${}^7\text{Be}$, however, accumulates in the needles of larch and lichen in approximately the same volume (Fig.3). The similarities of the ${}^7\text{Be}/{}^{210}\text{Pb}$ isotope ratios of the needles of both species indicate that, regardless of the species of the annual needles, these isotopes exclusively originate from fall out of aerosol particles from the atmosphere during the preceding 6 months. In turn, the accumulation in the larch needles of ${}^7\text{Be}$ and ${}^{210}\text{Pb}$ relative to cedar needles is very noticeable. The similarity of isotopic ratios and the difference in specific activities of ${}^7\text{Be}$ and ${}^{210}\text{Pb}$ between the two types of needles may indicate that the volume of accumulated aerosol particles by these species is different over the last 6 months. The reasons may be related to the difference in the morphology of the crown (the area of vegetative canopies) and the shape of the needles themselves in these trees, the degree of roughness of their surface [3]. All of these parameters can play a significant role in the capture of atmospheric aerosols and as the result atmospheric radionuclides.

Fig. 3. ${}^{137}\text{Cs}$ and ${}^7\text{Be}$ specific activities in larch needles, cedar needles and lichen.

${}^{137}\text{Cs}$ in difference from ${}^7\text{Be}$ and ${}^{210}\text{Pb}$ accumulates mainly in the needles of cedar (Fig.3). Since larch accumulates more aerosol particles than cedar, the low ${}^{137}\text{Cs}$ content in the larch needles confirms the well-known tendency for a significant decrease in ${}^{137}\text{Cs}$ the aerosol deposition from the atmosphere. The established tendency for a higher content of ${}^{137}\text{Cs}$ in cedar needles compared with larch needles in four of the five observation points may be associated with species-specific factors for caesium accumulation through the root system. Earlier pollution of this territory [6] suggests that there are processes of redistribution of radio caesium between the components of the ecosystem. Probably, decomposition of dying moss and lichen fragments led to a partial release of ${}^{137}\text{Cs}$ and its migration with surface waters [11, 12].

In the general trend of accumulation of ${}^{137}\text{Cs}$ with cedar needles, one exception is observed. At point 14, the ${}^{137}\text{Cs}$ distribution between ecosystem components (larch needles, pine needles, lichen) looks like the ${}^7\text{Be}$ (atmospheric tracer) distribution. In cedar needles, the content of ${}^{137}\text{Cs}$ is less than in the needles of larch and lichen (Fig.3). This makes it possible to assume a local fallout of this radionuclide together with aerosol particles from the atmosphere during the last 6 months. The exceptional observation point is located in the

area of Korotchaevo village, where the route changes its direction from sub latitudinal to sub longitudinal. For example, this is possible if, in the area of active anthropogenic impact, the turf cover is disturbed, and together with dust particles, caesium rises into the near-surface layer of the atmosphere and then falls out. However, this statement requires further verification. A more conclusive explanation of this exclusion can be given with a further increase in the sample size as a result of planned monitoring studies in the area.

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