Heterogeneity of the caesium-137 distribution in the peat soil upper part

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Abstract. For the upper part of the peat soil profile of the Sodrinskoye upland swamp, which is the part of Mshinsky Swamp reserve, a high variability of the specific activity of caesium-137 in 28.6% was established. The specific activity of peat soil varies from 357±28 Bq/kg to 668±41 Bq/kg. To determine the accumulation coefficients of fungi and berries, it is recommended to select peat soil directly at the sample collection site, rather than using specific activity values averaged over large areas.

Keywords*:* caesium-137, upland bog, sphagnum, peat soil, distribution.

Introduction

According to the Ramsar Convention, the Mshinskoe Swamp Nature Reserve of federal significance, located on the territory of Leningrad Oblast, belongs to wetlands of international importance. On the map of radioactive contagination of the Leningrad Oblast, the areas of contamination with cesium-137 are marked in the reserve.

This isotope is absorbed by plants and fungi and enters the food chain. Its source in ecosystems is the fission products of nuclear fuel released into the environment as a result of the accident at the Chernobyl nuclear power plant, which occurred on 26.04.1986.

To protect of the population health, the activity of caesium-137 in wild raw materials of fungal and plants origin is monitored [1]. An important characteristic of the body's ability to accumulate caesium-137 is the accumulation coefficient, which shows the ratio of the radionuclide specific activity in the raw material to its activity in the soil.

The main type of soil in the upper bogs is peat soil, formed as a result of the sphagnum moss development. To determine the coefficient of caesium-137 accumulation by fungi and berries, we use the part of the soil profile in which the maximum number of woody plants and shrubs roots is detected. Usually, they are located at a depth of 5-10 cm in the upper part of the peat horizon. The reasons for this are that their distribution is limited lower down the profile by excessive moisture content, a reduction in the amount of available oxygen and an increase in the concentration of carbon dioxide.

To determine the coefficients of caesium-137 accumulation in fungi and plants, the specific activity of caesium-137 was measured in the upper part of peat soil and in the oches of sphagnum moss. As a result of the work carried out, it was found that the distribution of caesium-137 in the sphagnum moss and peat horizon is heterogeneous and varies in a wide range from permissible values of 356±37 Bq/kg, to values exceeding the valid value of 400 Bq/kg, such as 815±62 Bq/kg [2] and 853±41 Bq/kg [3].

Purpose of the study – to study the variation of the caesium-137 specific activity \ in the peat soil of the upper bog for samples collected on the territory of one hectare.

Materials and methods

The territory of the Sodrinsky swamp was chosen as a model object, where studies of cesium-137 accumulation in the producers and reducers of the upper swamp ecosystem are carried out [1].

The samples were taken in wet depressions located at the vertices of a square with a side of 100 m (Points 1-4), the fifth sample was taken at the intersection of the diagonals (Point 5). The coordinates of the sampling sites were determined by the etrex GPS navigator:

Point № 1. (N 59°08.350', E030°22.008', H 65 м).

Point № 2. (N 59°08.345', E030°21.900', H 62 м).

Point № 3. (N 59°08.293', E030°21.901', H 62 м).

Point № 4. (N 59°08.295', E030°22.014', H 62 м).

Point № 5. (N 59°08.321', E030°21.959', H 63 м).

The upper part of the sample is from 0 to 5 cm deep – alive shoots of sphagnum (oches). The second part of the soil sample from a depth of 5 to 10 cm is the upper part of the peat horizon. The selected samples were dried in an air stream with a temperature of 40 °C to an air-dry weight. The radionuclide composition of the sample was determined by gamma-ray spectrometry. The specific activity of caesium-137 (Bq/kg) was measured by beta radiation radiometry.

Results and discussion

The table shows the results of measuring the specific activity (Bq/kg) in the studied samples of peat soil.

Table – Specific activity* of caesium-137 in the upper part of peat soil

Point	1	2	3	4	5
Depth 0-5 см	439±19	357±28	553±29	353±25	668±41
Depth 5-10 см	256±25	301±24	322±16	245±22	547±35

* – the calculation of the confidence interval of the average activity was carried out at the significance level $p<0.05$

The variation coefficient of specific activity in the upper part of the soil profile (Table) is 28.6 %, which characterizes the detected variability as significant, and the distribution of caesium-137 as heterogeneous

At the same time, at each selection point, a decrease in specific activity is observed with increasing depth (table), which is characteristic of the regressive-accumulative type of distribution. At the same time, the variation in the values of specific activity becomes more significant and reaches a value of 36.8 %.

The sampling of peat soil was carried out in wet depressions in order to compare the results obtained with the data of the Ozernoye swamp study, also part of Mshinskoe Swamp Reserve. When determining the specific activity of samples taken in the Ozernoye swamp, sampling was also carried out in wet depressions, but along a route whose length was 2 km [3]. Six samples were selected, the specific activity of which varied in the range from 356±37 Bq/kg to 853±41 Bq/kg [4]. The coefficient of variation of gorge activity was 29.2%, which is comparable with the results obtained in this study.

Thus, the obtained results demonstrate the spatial mosaic of the caesium-137 distribution in the upper layer of the peat soil of the surveyed swamps, characterized by high variability. For the preliminary characterization of the studied swamps, this approach justifies itself. At the same time, it is not necessary to use the averaged data to determine the accumulation coefficient of caesium-137 by wild fungi and berries. If a high variation in specific activity is detected, it is recommended to select the soil directly at the place where fungi or berries are collected.

The sampling method used in this work is suitable for the analysis of those objects where the soil conditions are homogeneous, for example, in fields. In the case of swamp ecosystems, the method used is suitable for preliminary characterization of the caesium-137distribution. In further studies, the results obtained should be detailed taking into account the collection of those organisms, the accumulation of caesium-137 in which it is planned to study.

Special attention should be paid to the upper part of the soil profile when studying the distribution of caesium-137, since it is the place of the maximum concentration of the isotope. A regressive-accumulative type of distribution was established for peat soils of upland bogs in the study area, in which the specific activity of caesium-137 in the soil profile naturally decreases with depth.

One of the properties of peat soil and live sphagnum shoots is the acidification of the medium to pH values of 3.5-4.0. These are favorable conditions for the migration of the alkali metal caesium-137. The concentration of caesium-137 occurs as a result of assimilation processes occurring in growing sphagnum shoots. An additional resource for the migration of caesium-137 up the soil profile is the capillary properties of sphagnum stems. The evaporation of moisture by living

cells of the tops of moss shoots leads to the flow of moisture from deeper layers of peat to the surface.

Conclusion

It was found that the variability of the caesium-137 distribution in the upper part of the peat soil profile is 28.6 %. In this regard, to calculate the coefficients of caesium-137 accumulation in producers and reducers of swamp ecosystems, it is necessary to detail the activity of the radionuclide at the collection site of the studied sample, for example, the fungus fruit body or berries, and not to use averaged values, for example, per hectare or per square kilometer.

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