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The Geochemistry of Strontium-90 in Peatlands of the European Subarctic of Russia

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ABSTRACT

The subject of this research is the vertical migration of strontium-90 in peatlands of the European Subarctic region of Russia. The activity level of strontium-90 has been determined in peat samples, and the physicochemical parameters of peat deposits have been studied. The specific activity of the radionuclide has been determined using beta radiometric methods with radiochemical preparation according to the methodology. The physicochemical parameters of the peat have been determined using weight-based methods according to the specified procedures. The influence of physicochemical parameters on the vertical migration of the radionuclide in peatlands has been evaluated using correlation analysis. The results have shown that the specific activity of strontium-90 in peat deposits ranges from 0.25 to 7.7 Bq/kg. The results are consistent with typical values for all soils in Russia. The average value of the specific activity of strontium-90 in peat deposits is estimated to be 1.5±0.02 Bq/kg, which is below the established minimum values and average parameters for all soils in Russia. The pathways of vertical migration of strontium-90 in peat deposits demonstrate a downward direction with various trajectories. These pathways serve as a trace of past global atmospheric radioactive fallout. The vertical migration of strontium-90 in peat is associated with the organic matter content, ash content in peatlands, and recent local atmospheric fallout from nuclear fuel facilities. The research results provide valuable information for predicting the migration of strontium-90 into aquifers under changing environmental conditions due to the Arctic's rapid climate warming.

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INTRODUCTION

Peatland ecosystems are the main biocenoses of the European subarctic region of Russia. The dominant type of wetland is ombrotrophic bogs, which are nourished by atmospheric precipitation. Wetland complexes serve as natural landscape-geochemical barriers, hindering the migration of pollutants (Maximovich et al., 2011; Maximovich, 2010; Sysuev, 2021). According to modern concepts (Kasimov et al., 2002), a geochemical barrier is an open, non-equilibrium, dynamic, self-organizing system with multiple factors that contribute to the deposition of elements. Ombrotrophic bogs, due to their predominant atmospheric nourishment and pollutant sorption, are unique ecological archives. Studying them provides valuable information about past and present anthropogenic pollution loads associated with the accumulation of a wide range of atmospheric pollutants, including technogenic radionuclides such as strontium-90, cesium-137, americium-241, plutonium-239, lead-210, and others. These radionuclides are

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emitted into the atmosphere as a result of nuclear weapon tests, radiation accidents, and the activities of nuclear fuel cycle facilities (Omelyuk, 2020; Yakovlev et al., 2021). Technogenic radionuclides present in peatlands can migrate into groundwater (Karcher et al., 2010). With the changing environmental conditions resulting from intensified climate warming in the Arctic, the migration of technogenic radionuclides may increase and lead to their release into aquifers. To forecast such processes, it is necessary to investigate the presence of technogenic radionuclides and their behavior in the geological environment. It should be noted that despite the prevalence of peatland ecosystems in the European subarctic region of Russia, the specific activity and migration of technogenic radionuclides in these ecosystems are insufficiently studied.

Among the radionuclides of atmospheric fallout, we have considered the most common technogenic radionuclide, strontium-90 (^{90}Sr). The radioactive isotope ^{90}Sr, with a relatively long half-life (29 years), is one of the most dangerous products of uranium and plutonium fission in nuclear reactors, as this long-lived isotope is considered to be biologically significant. It is characterized by high toxicity (radiation hazard category "B") due to its ability to actively participate in the biological cycling of substances. Being an analogue of calcium, ^{90}Sr easily enters the metabolism of plants, animals, and humans (Bakhur, 2018; Bakhvalov et al., 2012; Chevychelov et al., 2017; Grechkina et al., 2020; Putilina et al., 2013; Rakhimova et al, 2020; Vasilenko et al., 2002).

In this study, using the example of two peat sections selected in the territories of the European Subarctic of Russia with different anthropogenic loads, we set ourselves the goal of studying the features of vertical migration of ^{90}Sr in the peatlands of the European Subarctic of Russia. To achieve this goal, two main tasks were performed: 1) to determine the activity level of ^{90}Sr in peat deposits, 2) to study the physico-chemical parameters of peat deposits to assess their influence on the vertical migration of the radionuclide in the conditions of the European Subarctic of Russia.

MATERIALS AND METHODS

Study areas and sample collection

The research was conducted in the territories of the European Subarctic of Russia (Nenets Autonomous Okrug, Murmansk region) with different anthropogenic loads.

The Nenets Autonomous Okrug is located in the north of the East European Plain, with the majority of the okrug located beyond the Arctic Circle. The okrug is washed by the White Sea, Barents Sea, Pechora Sea, and Kara Sea of the Arctic Ocean. More than 19% of the Nenets Autonomous Okrug's area is occupied by peatlands. The predominant type is nutrient-poor upland bogs, whose main source of nutrition is aerosols, airborne dust, and atmospheric precipitation. The vegetation consists of shrubby-moss and herbaceous-moss tundra. There are no local sources of pollution of the natural environment with the technogenic radionuclide - ^{90}Sr in the territory of the okrug. Currently, the fuel and energy complex is developing in the okrug. The oil and gas industry is the leading sector of the okrug's economy. It has the greatest impact on the natural complexes of the Nenets Autonomous Okrug. The impact on the environment is observed at all stages of field development. Mechanical, chemical, radiation, biological, noise, and thermal pollution of the natural environment occur during the extraction and transportation of hydrocarbons. Radiation pollution during oil and gas extraction is associated with the release of natural radionuclides to the surface as part of mineralized associated waters and the exceedance of their natural level (background) (Eriksen et al., 2009; Report "On the State and Protection of the Environment of the Nenets Autonomous Okrug ..., 2021).

Murmansk region is located in the far northwest of Russia, almost entirely beyond the Arctic

Circle. The region is washed by the Barents Sea to the north and the White Sea to the east and southeast. About 40% of the area of Murmansk region is occupied by swamps. Swamps are particularly widespread in the eastern part of the region. Throughout the region, moss-heath upland bogs are common, and in the mountains and elevated areas, there are slope bogs with mesophilic meadow vegetation (Red Book …, 2003). The region is home to objects of the nuclear-fuel complex (Kizeev, 2015; Telelekova et al, 2014), the Atomic Icebreaker Fleet, and the Northern Fleet of Russia, which are local sources of fresh pollution of the natural environment with the technogenic radionuclide - ^{90}Sr.

The object of this study was peat deposits in the Nenets Autonomous Okrug (code for peat deposit TN 1-2, depth - 29 cm) and Murmansk region (code for peat deposit TM 1, depth - 36 cm). Peat columns were sampled using a PVC pipe according to GOST 17.4.3.01-2017.

The sampling of peat column TN 1-2 was conducted 18 km east of the city of Naryan-Mar (geographic coordinates of the sampling point N67.67854°, E53.40831°). The sampling date was 10.07.2019. After delivery to the laboratory, the peat column was divided into 14 layers (with a division interval of 2 cm, except for the topmost horizon of 0-3 cm). Peat column TM 1 was sampled 12 km southeast of the city of Murmansk (geographic coordinates of the sampling point N68.87057°, E33.19594°). The sampling date was 25.07.2019. After delivery to the laboratory, the peat column was divided into 17 layers (with a division interval of 2 cm, except for the two upper horizons of 0-3.5 cm and 3.5-6 cm). In laboratory conditions, the sampled peat was dried in a drying cabinet SNOL 24/200 (SNOL, Lithuania) at a temperature of 105°C until it reached an air-dry state. The dry peat was ground in a universal mill IKA-WERKE M20 (IKA, Germany). Samples of the dry and ground peat were taken for analysis. The peat samples were weighed on analytical balances DA-224C (BEL ENGINEERING SRL, Italy).

Determination of physico-chemical parameters of peat samples

To study the accumulation features of radionuclides in peat sections, the physico-chemical parameters of peat deposits were examined. The mass fraction of carbonates (CO_3^{2-}), ash content (Ash), and mass fraction of organic matter (X) were determined in each layer of peat.

A sample of peat weighing 2-3 grams was placed in a quartz crucible, preheated to constant weight by calcination in a muffle furnace EKPS-10 (Smolensk SKTB SPU, Russia) at 900°C. Then the crucible with the peat sample was sequentially heated at 525°C and 900°C until a constant weight was achieved, which was determined by weighing on analytical scales. The losses on ignition (LOI), % and ω (CO_3^{2-}), % were calculated using the formulas:

$$LOI = \frac{m_{525} - m_{900}.100}{m_{a.d.m.}}, \qquad (1)$$

where m_{525} is the mass of the crucible with the sample after calcination at 525°C; m_{900} is the mass of the crucible with the sample after calcination at 900°C; $ma.d.m.$ is the mass of the absolutely dry sample, calculated using the formula:

$$m_{a.d.m.} = \frac{m_{sample}.(100 - W)}{100}, \qquad (2)$$

where m_{sample} is the weight of the peat sample, W is the moisture content of the sample determined according to GOST 28268-89.

$$\omega\ (CO_3^{-2}) = LOI - 1.36\ , \qquad (3)$$

where LOI is the loss on ignition; 1.36 is the conversion factor.

The coefficient was determined according to the expression:

$$Conversion\ factor = \frac{MW\left(CO_3^{2-}\right)}{MW\left(CO_2\right)} = \frac{60.01\ \text{g/mol}}{44.01\ \text{g/mol}} = 1.36 \qquad (4)$$

The determination of the mass fraction of organic matter in peat samples was performed using the gravimetric method according to GOST 26213-91. To do this, the ash content in the peat was preliminarily assessed according to GOST 27784-88. The mass fraction of organic matter (ω X) was calculated using the formula:

$$\omega X = (100 - \omega Ash) \qquad (5)$$

where ω Ash is the mass fraction of ash, %.

Determination specific activity of ^{90}Sr isotope

In each layer of peat, the specific activity of the radionuclide ^{90}Sr (A) was determined using the beta-radiometric method with radiochemical preparation according to the certified methodology (Methods for measuring …, 2013). The methodology is based on the measurement of beta radiation from a counting sample containing selectively isolated yttrium-90 (^{90}Y), which is the daughter product of the decay of ^{90}Sr and is in radioactive equilibrium with it in the sample, and the calculation of the specific activity of ^{90}Y (^{90}Sr) in the sample.

For the determination of ^{90}Sr, a 20-gram sample of peat was burned in a muffle (electric chamber) furnace EKPS-10 (Smolensk SCTB SPU, Russia) at a temperature of 500°C. After burning, solutions of strontium (25 mg calculated as metal) and yttrium carrier (100 mg calculated as metal) were added to the sample. Then the sample was decomposed with hydrochloric acid HCl (1:1) while heating. Subsequently, interfering radionuclides with beta particle energies similar to the beta radiation energy of ^{90}Y (protactinium-234m, bismuth-212, actinium-228, bismuth-214, thallium-208, ruthenium-106, rhodium-106, cerium-144, promethium-144) were removed using a radiochemical method involving double precipitation of oxalates and chromatographic separation of ^{90}Y. For the chromatographic separation of ^{90}Y, anion exchange resin AB-17-8 was used. The purified precipitate of oxalate ^{90}Y was transferred to the scintillation detector. A counting sample, as an example of one sample, is shown in Fig. 1. The measurement of counting samples was performed using an alpha-beta scintillation counter RSC-01A 'Abelia' (Amplituda, Russia) with software 'Abelia 1.0.7.0' immediately after its preparation. Five measurements were conducted for each counting sample. The duration of a single measurement of the counting sample was 1000 s. The stages of the radiochemical analysis are presented in the diagram (Fig. 2).

The specific activity of ^{90}Sr in the sample (A) was determined according to the formula:

$$\mathrm{A} = \frac{\mathrm{Aco}}{\eta \cdot M} \qquad (6)$$

where A_{co} is the activity of ^{90}Y in the counting sample (at the time of separation from ^{90}Sr), which is equal to the activity of ^{90}Sr when equilibrium between ^{90}Y and ^{90}Sr is maintained; η is the radiochemical yield of ^{90}Y, estimated by the gravimetric method; M is the mass of the sample taken for analysis.

$$\mathrm{Aco}\frac{I - If}{\varepsilon \cdot \kappa} \qquad (7)$$

Fig. 1. Counting sample (on the example of a sample TN 1-2, layer 0-3)

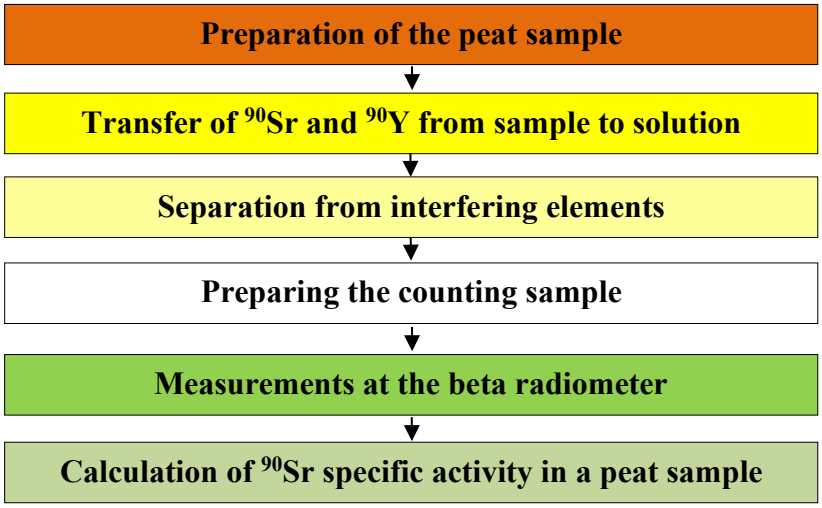

Fig. 2. Scheme of the radiochemical analysis of ^{90}Sr radionuclide in peat samples

I, If - the average counting rates of beta particles from the counting sample and background, respectively; ε - the sensitivity of the radiometer to beta radiation from ^{90}Y in the geometry of the counting sample; κ - a coefficient that takes into account the decay of ^{90}Y over the time t elapsed from the moment of separation of yttrium to the measurement of the counting sample.

The counting rates I, If were determined as the average values over multiple observations of the counting sample and background.

The coefficient κ was determined from the expression:

$$\kappa = exp\left(-\lambda y \cdot t\right), \qquad (8)$$

where λy is the decay constant of ^{90}Y, t is the time from the separation of yttrium to the measurement of the counting sample.

The radiochemical yield of ^{90}Y was determined according to the expression:

$$\eta = \frac{m}{0.340}, \qquad (9)$$

where m is the mass of the precipitate of yttrium oxalate transferred to the measurement cuvette; 0.340 is the calculated mass of yttrium oxalate at 100% yield, corresponding to the amount of stable yttrium introduced.

The determination of the radionuclide was carried out in the laboratory of environmental radiology of the Federal Research Center for Comprehensive Study of the Arctic named after Academician N.P. Laverov, which complies with the accreditation criteria for testing laboratories established in ISO/IEC 17025. The laboratory has a wide range of sources standard for equipment calibration and quality control procedures for measurements. Calibration, registration efficiency control, quality control of beta-radiometric measurements are carried out using sources standard.

RESULTS AND DISCUSSION

Physico-chemical parameters of peat profiles

The obtained data on physico-chemical parameters are presented in Table 1 and Figure 3.

The mass fraction of carbonates, caused by potassium (mesoelement) and magnesium (microelement) salts of carbonic acid, is insignificant in peat deposits and ranges from 0.31% to 0.83%. The total mineral content, which includes non-combustible mineral particles originating from plants and brought in by wind, atmospheric precipitation, groundwaters, and surface

Table 1. Physico-chemical parameters, specific activity of ^{90}Sr isotope in two peat profiles.

Profile ID	Depth (cm)	ω (CO_3^{2-}) (%)	ω (Ash) (%)	ω (X) (%)	^{90}Sr (Bq/kg)
TN 1-2	0-3	0.54±0.06	45.54±0.001	54.46±0.002	1.55±0.02
	3-5	0.43±0.02	32.87±0.007	67.13±0.003	2.44±0.03
	5-7	0.42±0.01	23.63±0.002	76.37±0.002	1.62±0.02
	7-9	0.41±0.02	16.90±0.004	83.10±0.005	2.58±0.03
	9-11	0.31±0.04	11.38±0.003	88.62±0.004	2.05±0.02
	11-13	0.40±0.01	13.82±0.007	86.18±0.012	1.29±0.02
	13-15	0.38±0.01	16.92±0.003	83.08±0.010	1.18±0.02
	15-17	0.45±0.01	39.78±0.001	60.22±0.008	0.91±0.02
	17-19	0.43±0.04	64.55±0.006	35.45±0.007	0.91±0.02
	19-21	0.47±0.02	76.66±0.002	23.34±0.001	0.56±0.02
	21-23	0.50±0.02	77.48±0.001	22.52±0.001	0.47±0.02
	23-25	0.47±0.01	80.77±0.016	19.23±0.002	0.46±0.02
	25-27	0.41±0.02	89.46±0.028	10.54±0.006	0.39±0.02
	27-29	0.38±0.01	94.13±0.032	5.87±0.08	0.25±0.02
TM 1	0-3.5	0.53±0.05	13.75±0.040	86.25±0.029	7.69±0.02
	3.5-6	0.42±0.02	8.69±0.024	91.31±0.031	3.61±0.02
	6-8	0.49±0.02	9.49±0.016	90.51±0.036	1.84±0.02
	8-10	0.74±0.06	12.48±0.002	87.52±0.032	1.71±0.02
	10-12	0.83±0.06	23.75±0.003	76.25±0.004	1.02±0.02
	12-14	0.74±0.06	27.88±0.015	72.12±0.006	1.21±0.02
	14-16	0.80±0.06	24.40±0.002	75.60±0.001	1.43±0.02
	16-18	0.59±0.04	8.44±0.05	91.56±0.003	1.75±0.02
	18-20	0.58±0.04	5.98±0.02	94.02±0.003	1.18±0.02
	20-22	0.51±0.03	5.21±0.04	94.79±0.031	1.56±0.02
	22-24	0.54±0.02	5.47±0.01	94.53±0.024	1.01±0.02
	24-26	0.52±0.01	5.52±0.02	94.48±0.047	0.89±0.02
	26-28	0.47±0.01	5.34±0.01	94.66±0.061	0.55±0.02
	28-30	0.55±0.01	7.72±0.04	92.28±0.057	1.38±0.02
	30-32	0.49±0.02	10.04±0.001	89.96±0.043	1.97±0.02
	32-34	0.49±0.02	9.56±0.06	90.44±0.074	0.99±0.02
	34-36	0.53±0.02	18.57±0.002	81.63±0.051	0.78±0.02

runoff, ranges from 5.2% to 94% in peat deposits. The opposite indicator of mineral content is the mass fraction of organic matter, which varies in peat deposits from 5.9% to 95%.

The carbonate content in the peat deposits of the TN 1-2 profile ranges from 0.31% to 0.54%. The carbonate content of the peat deposits in the TM 1 profile is higher, ranging from 0.42% to 0.83%. In geological terms, the Murmansk region represents the northeastern part of the Baltic crystalline shield. Here, strongly metamorphosed rocks of the Archean and Proterozoic are most widely developed, with intrusive rocks and weakly altered Paleozoic sedimentary-volcanic formations subordinate in presence. Almost everywhere, these complexes are covered by a thin layer of loose Quaternary deposits. During the weathering process of the bedrock, the primary feldspars, pyroxenes, and biotites are primarily broken down, resulting in the formation of carbonates, hydroslates, clay minerals, and amorphous silica (Antropov, 1958). The soil solution of the investigated peat in the TM 1 profile has a weakly acidic or neutral reaction. The acidity

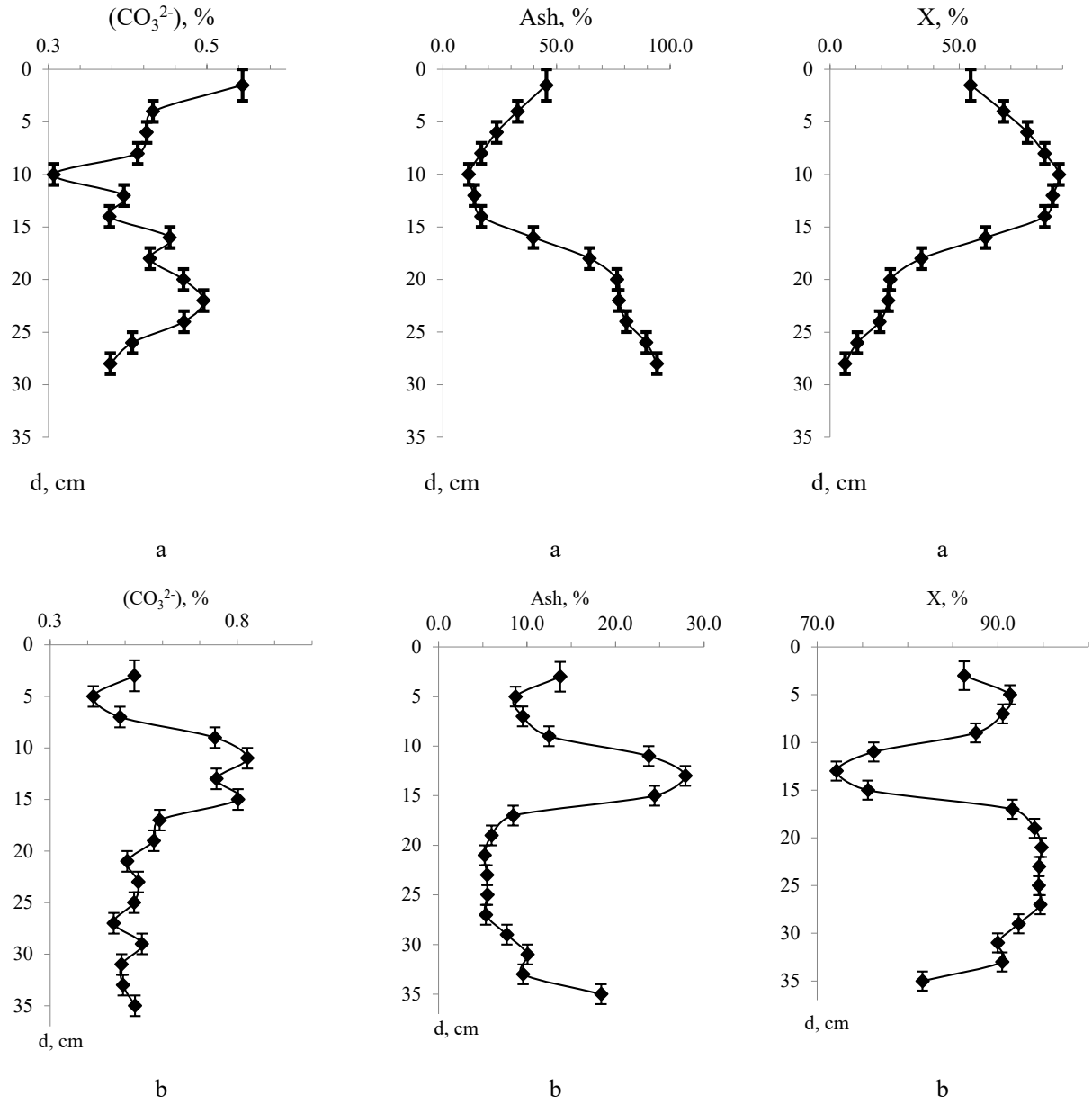

Fig. 3. Dependence of physicochemical properties on depth in a peat profile
«a» – a peat profile TN 1-2, «b» – a peat profile TM 1

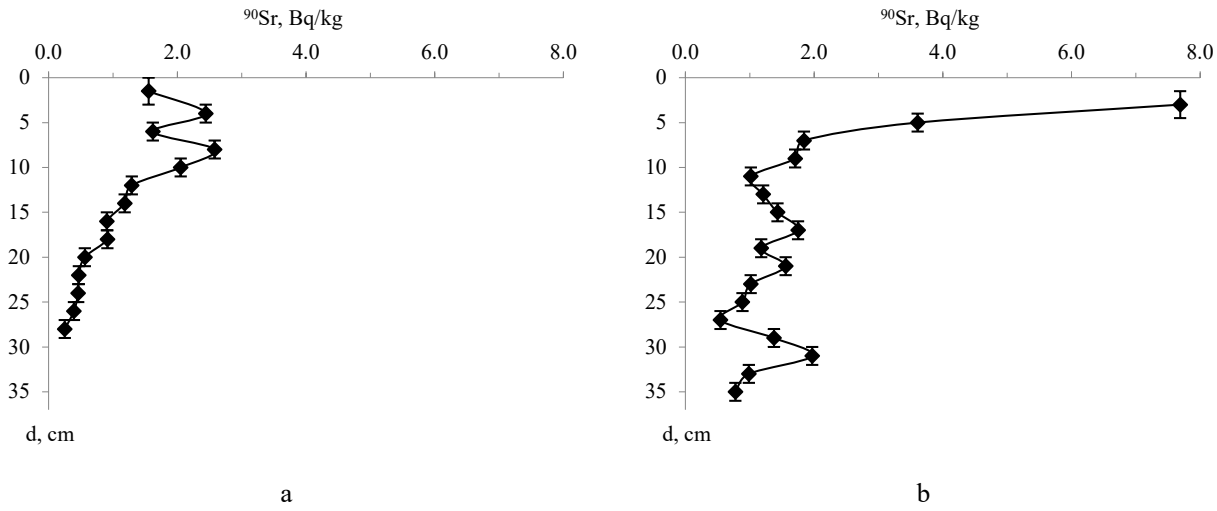

Fig. 4. Dependence of specific activity of ^{90}Sr on the depth of peat profile
«a» – a peat profile TN 1-2, «b» – a peat profile TM 1

(pH), associated with the content of free H^+ and OH^- in the soil solution, ranges from 4.2 to 4.9. The acidity was determined by the potentiometric method in the water extract of the peat. The presence of carbonates among the weathering products and the reaction of the peat environment account for a high content of carbonates in the peat deposits sampled in the Murmansk region.

Carbonates are primarily deposited in peat deposits from the atmosphere in the form of dust and precipitation. Due to atmospheric deposition, the upper layers of the deposits (0-3 cm layer in the TN 1-2 profile, 10-12 cm layer in the TM 1 profile) exhibit the highest carbonate values. From the upper layers of the deposits, carbonates leach into the lower layers and are distributed along the profile in a decreasing order.

In general, the mineral content (ash content) for the TN 1-2 peat profile ranges from 11% to 94%. According to the obtained data, the TN 1-2 peat profile represents a two-level system, where the upper part (depth 17 cm) consists of high-ash peat (11% ≤ Ash ≤ 45%). The lower part (depth 18-29 cm) is represented by peaty soil (Ash ≥ 64%). As we move down the TN 1-2 profile, there is a tendency for an increase in ash content. The high ash content in the TN 1-2 peat profile is caused by the presence of aeolian sand, clay, and mineral elements and substances that are unavailable to plants for nutrition.

The ash content for the TM 1 peat profile ranges from 5.2% to 28%. The TM 1 peat profile represents a multilayered system. Increased ash content (Ash > 10%) is characteristic of the upper layers (4-7) and the bottom layer, while average ash content (5.0% < Ash < 10%) is found in layers 2-3 and 8-16.

The opposite parameter to ash content is the mass fraction of organic matter, which varies within the horizons of the TN 1-2 peat profile from 5.9% to 89%. Organic matter is concentrated in the upper layers of the deposit. The maximum value of this parameter is observed in the 11-13 cm layer. The fraction of organic matter decreases with depth in the profile.

The mass fraction of organic matter in the TM 1 peat profile ranges from 72% to 95%. The maximum value of this parameter is observed in the 20-22 cm layer.

Specific activity of ^{90}Sr isotope in peat profiles

According to the results of the radiochemical analysis, the technogenic radionuclide ^{90}Sr was detected in all samples from the investigated peat bogs. The specific activity of ^{90}Sr in peat

bogs ranges from 0.25 to 7.7 Bq/kg and falls within the typical range established for all soils in Russia (0.80-8.6 Bq/kg). The average value of the specific activity of ^{90}Sr in the samples from the investigated peat bogs is 1.5±0.02 Bq/kg, which does not exceed the established minimally significant norm (100.000 Bq/kg) and is lower than the average parameter for all soils in Russia (4.7 Bq/kg). The obtained data on the specific activity of ^{90}Sr in peat samples are presented in Table 1 and Figure 4.

The specific activity of ^{90}Sr in the TN 1-2 peat profile ranges from 0.25 to 2.6 Bq/kg. The average value is 1.2 ± 0.02 Bq/kg. The activity of ^{90}Sr decreases with depth along the profile. The maximum radioisotope activity is observed in two layers: the 7-9 cm layer (2.6 Bq/kg) and the 3-5 cm layer (2.4 Bq/kg). The low activity of ^{90}Sr in the first layer of the profile (0-3 cm) may be due to soil-plant transfer of the radioisotope and the absence of recent radioactive fallout in the investigated area. The vertical migration pathway of ^{90}Sr in the TN 1-2 peat profile is influenced by physico-chemical parameters. A strong positive correlation (r=0.82 ± 0.09) was found between the specific activity of 90Sr and the fraction of organic matter during mathematical correlation analysis. Conversely, a strong negative correlation (r=-0.82 ± 0.09) was observed between the specific activity of ^{90}Sr and ash content.

The upper part of the two-tier profile system of the TN 1-2 profile, with a thickness of 17 cm (layers 1 to 8), consists of high-ash-content peat (with a high organic matter content) and acts as a sorption barrier for ^{90}Sr. The gradient of the sorption barrier (G), which characterizes the change in specific activity of ^{90}Sr in the direction of isotope migration, is equal to 0.05. The contrast of the sorption barrier (S), which is determined by the ratio of the specific activity of the radionuclide before and after the barrier, is 2.8. The sorption capacity of the barrier is a measure of the maximum specific activity of the radionuclide that can accumulate in one kilogram of substrate, and it is 2.6. The specific activity of ^{90}Sr after the sorption barrier is higher than the zero value, indicating that the barrier is permeable.

The technogenic radionuclide ^{90}Sr has a completely different vertical migration path in the peat profile TM 1. The specific activity of ^{90}Sr in the TM 1 peat profile ranges from 0.55 to 7.7 Bq/kg. The average value is 1.8±0.02 Bq/kg. The highest specific activity of ^{90}Sr is found in the upper part of the profile up to a depth of 8-10 cm, with a maximum activity (7.7 Bq/kg) observed in the uppermost layer of 0-3.5 cm. This is possibly due to the input of the radionuclide from the current local fallout from nuclear fuel cycle facilities and its biogenic accumulation. According to literary sources, the specific activity of ^{90}Sr in the snowfall in the Murmansk region in 2018-2019 was estimated at 0.30-0.40 Bq/l (Report "On the state and protection of the environment of the Murmansk region…", 2021). The radionuclide is unevenly distributed throughout the entire TM 1 peat profile. Below a depth of 10 cm, three peaks of radionuclide activity are observed. The peak at a depth of 16-18 cm is likely associated with the Chernobyl accident (1986), while the deeper peaks (20-22 cm and 30-32 cm) may indicate past global fallout from nuclear tests prior to 1963. Correlation dependencies between the specific activity of ^{90}Sr and the physico-chemical parameters in the TM 1 peat profile have not been established.

CONCLUSIONS

Based on the conducted research, the following conclusions have been drawn.

The ^{90}Sr is detected in the peat deposits of the European Subarctic region of Russia, indicating a significant impact of past technogenic radioactivity from global nuclear tests as well as recent technogenic radioactivity from local sources. The specific activity of ^{90}Sr in the peat deposits of the European Subarctic region of Russia falls within the range typical for all soils in Russia; it is below the established minimally significant regulatory norm and the average parameter for all soils in Russia.

The vertical migration pathways of ^{90}Sr in the peat deposits of the European Subarctic region of Russia vary. In the Nenets Autonomous Okrug peat bog, the concentration and decrease in the migration intensity of ^{90}Sr occur at the sorption barrier - a layer of high-ash peat (17 cm thick) formed at the top of the deposit. The sorption barrier is permeable, and the radionuclide migrates downward along the profile. A strong positive correlation was found between the specific activity of ^{90}Sr and the organic matter content, and a strong negative correlation was found between the specific activity of ^{90}Sr and the ash content, based on the mathematical correlation analysis. The migration path of ^{90}Sr in the peat profile serves as an informational trace of past global atmospheric fallout and is determined by physico-chemical parameters.

The highest specific activity of ^{90}Sr was found in the peat bog of the Murmansk region, which contains radiation hazardous facilities. The radionuclide is primarily localized in the uppermost layer and migrates unevenly downward along the profile. The migration path in the peat profile serves as an informational trace of both past global atmospheric fallout from nuclear tests and recent local atmospheric fallout from nuclear fuel complex facilities.

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CONFLICT OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research. Acknowledgements of people, grants, funds, etc. should be placed in a separate section before the References.

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