The University of Tehran Press

Pollution

Print ISSN: 2383-451X
Online ISSN: 2383-4501

https://jpoll.ut.ac.ir/

The Distribution of Radioactive Elements in Peatlands of the Island Territories of the Russian Arctic (using the example of Kolguev Island)

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Article Info

Article type:
Research Article

Article history:
Received: 26 February 2025
Revised: 28 June 2025
Accepted: 4 September 2025

Keywords:
Russian Arctic
Kolguev Island
peatland
radioactive elements
accumulation rate

ABSTRACT

The distribution of radioactive elements in the peatlands of the island territories of the Russian Arctic has been studied for the first time (using the example of Kolguev Island).
The results showed that the total specific alpha activity of the peat is in the range of 16-87 Bq/kg; the total specific beta activity is 13-221 Bq/kg. The distribution of radioactive elements in the peatland is heterogeneous. The specific activities are concentrated in the upper layer of the peat (at a depth of 0-9 cm). Strontium-90 is concentrated at a depth of 0-15 cm. The lower layers of the peat have the lowest radioactivity. The peatland on the island has an extremely low accumulation rate of radioactive elements (about 0.10 cm/year). If the current warming trend continues, the thawing of permafrost may lead to the migration of radioactive elements from the upper layers of the peatland to the lower layers. The radioactivity of the peatland is attributed to its mineral composition. Increased alpha and beta specific activities of natural and technogenic radioactive elements have not been registered. The research results provide valuable information for predicting the migration of radioactive elements in peatlands under changing environmental conditions due to rapid climate warming in the Arctic.

Cite this article: Lukoshkova, A., Yakovlev, E., Puchkov, A., Lipkina, A., Orlov, A., Bykov, V., & Lapikov, P. (2025). The Distribution of Radioactive Elements in Peatlands of the Island Territories of the Russian Arctic (using the example of Kolguev Island). *Pollution*, 11(4), 1338-1349.
https://doi.org/10.22059/poll.2025.391182.2816

DOI: https://doi.org/10.22059/poll.2025.391182.2816

INTRODUCTION

The natural conditions of the Arctic favor the development of swamps and peat oligotrophic soils (Ananko et al., 2020; Sirin et al., 2020). The excess of precipitation over evaporation, the presence of poorly permeable soils, and permafrost contribute to the formation of excessive moisture. The short growing season is compensated by a long daylight period, which ensures sufficient productivity of vegetation, the remnants of which, under conditions of excessive moisture and incomplete decomposition, form peat. A wide range of diverse wetlands is represented in the Russian Arctic, with a predominance of permafrost wetlands (Sirin et al., 2020).

Due to its unique physical properties regarding water and heat, even a thin layer of peat serves as a protective barrier against the melting of permafrost. Climate change is most pronounced at high latitudes. Peatlands of permafrost wetlands, like other types of deposits subject to seasonal temperature variations, are sensitive to climate changes (Koroleva et al., 2021; Lim et al., 2024)

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and are among the least resilient to climate change and anthropogenic impacts (Minaeva & Sirin, 2011; Sirin et al., 2020).

Research was conducted on Kolguev Island, located in the eastern part of the Barents Sea and administratively part of the Nenets Autonomous Okrug. The largest area on Kolguev Island (169,000 hectares, or 35%) is occupied by flat-topped and polygonal mires in combination with shrub tundra on peaty soils (Lavrinenko & Lavrinenko, 2014; Lavrinenko et al., 2016).

According to a review of scientific publications during the development of modern global warming, Russian scientists are studying climate change in the Arctic. Based on the scientific publications of G. V. Alekseev (2014; 2015), manifestations and intensification of global warming are observed in the Russian Arctic. Research on the island's biota has been conducted on Kolguev Island (Bolotov, 2011; Pokrovsky et al., 2015; Kondratyev et al., 2019; Bespalaya et al., 2022; Potapov et al., 2022; Quillfeldt et al., 2022; Morozova & Tishkov, 2021; Glazov et al., 2024). A. G. Shmatova (2019; 2023) studied the spatial organization of the island's soil cover, finding that structural soils with hummocky microrelief are the most widespread. The mineral nitrogen in the cryogenic soils of Kolguev Island was researched by A. N. Lomakina and V. P. Yevdokimova (2019).

Despite the dominance of wetlands in the Russian Arctic, their role in shaping the environment and their particular vulnerability, the topic of the distribution of radioactive elements in peatlands of the island territories of the Russian Arctic remains unexplored. Currently, radioecological studies have been conducted on the peat of raised bogs in the European Subarctic of Russia (Lukoshkova et al., 2021; Lukoshkova et al., 2022). The relevance of research in the island territories of the Russian Arctic (including Kolguev Island) is determined by many factors, such as global climate warming, the transformation of island landscapes, and the threat to zonal ecosystems due to the exploitation of natural resources in these territories. In this study, we aimed to investigate for the first time the distribution of radioactive elements in the peatland of the island territory of the Russian Arctic (Kolguev Island).

MATERIALS AND METHODS

The object of this study was the peat deposit (seasonally thawed layer) of the permafrost bog on Kolguev Island (near the village of Bugrino), peat core code TB-1, with a depth of 25 cm. Beneath the seasonally thawed layer lies the frozen peat. The geographic coordinates of the core sampling point are N68.7901°, E49.3201° (Fig. 1). The sampling date was July 14, 2024. The peat column was collected according to GOST 17.4.3.01-2017. The peat core is divided into 12 layers. The interval for dividing the peat core is 2 cm, with the exception of the very top horizon, which is 0-3 cm. Under laboratory conditions, the collected peat was dried on an air and in a SNOL 24/200 (SNOL, Lithuania) at a temperature of 105 °C until reaching an air-dry state. The dry peat was ground in a universal mill IKA-WERKE M20 (IKA, Germany). From the dried and ground peat samples, portions were taken for analysis. The peat portions were weighed on analytical balances DA-224C (BEL ENGINEERING SRL, Italy).

In the peat samples, six main physicochemical parameters were determined: actual acidity (pH_{water}) and exchange acidity (pH_{salt}), content of water-soluble salts (Soluble salts), ash content (A_{sh}), mass fraction of carbonates (CO_3^{2-}), and mass fraction of organic matter (X).

The actual and exchange acidity were determined using the potentiometric method (GOST 11623-89, 1990) and measured on the Expert 001-3 liquid analyzer using a combined glass electrode ESC-10603. The ash content, mass fraction of carbonates, and content of water-soluble salts were determined using the gravimetric method (GOST 26213-91, 1992; GOST 26423-85, 2011; GOST 27784-88, 1988). The mass fraction of organic matter was calculated based on the ash content (GOST 26213-91, 1992; GOST 27784-88, 1988). For the determination of physicochemical properties, the SNOL 24/200 drying oven (SNOL, Lithuania), the EKPS-10

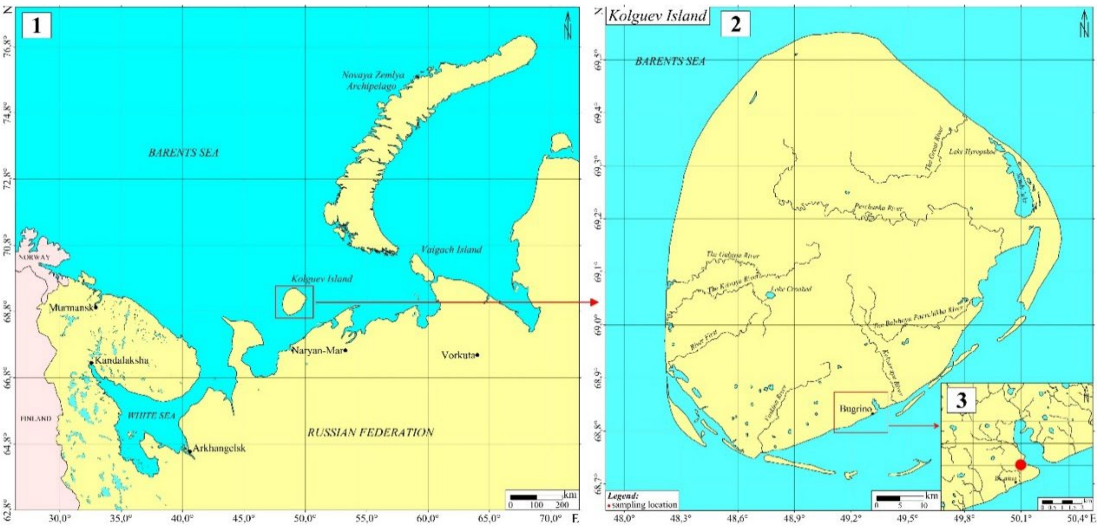

Fig. 1. Maps-schemes of the peat core sampling site TB-1
Map 1 scale 1:10 000 000, map 2 scale 1:500 000, map 3 scale 1:100 000.

muffle furnace (Russia), and the DA-224C analytical balances (BEL ENGINEERING SRL, Italy) were used.

In the peat samples, the total specific alpha and beta activity of the peat was determined using radiometric methods, as well as the specific activity of natural and technogenic radioactive elements: cesium-137 (^{137}Cs), radium-226 (^{226}Ra), thorium-232 (^{232}Th), potassium-40 (^{40}K), americium-241 (^{241}Am), lead-210 (^{210}Pb), beryllium-7 (^{7}Be), and strontium-90 (^{90}Sr). The parameters of total activity for alpha and beta radiation were measured using the alpha-beta radiometer RKS-01 'Abelia' (NTC Amplitude, Russia). The specific activity of radionuclides ^{137}Cs, ^{226}Ra, ^{232}Th, ^{40}K, ^{241}Am, ^{210}Pb, and ^{7}Be was determined using a low-background semiconductor gamma spectrometer ORTEC (USA) based on a co-axial detector GEM10 made of high-purity germanium (HPGe) with a digital analyzer and software (MAESTRO-32 and GAMMA-VISION-32). The specific activity of ^{90}Sr was determined on the alpha-beta radiometer RSK-01A 'Abelia' (NTC Amplitude, Russia) after preliminary radiochemical preparation of the counting samples according to the certified method (Methods for measuring the specific activity of strontium-90 (^{90}Sr)..., 2013).

The influence of physicochemical parameters of peat on the vertical migration of radioactive elements in the peat bog was identified using mathematical correlation analysis. For each radioactive element, the coefficient of variation of specific activity values in the peat bog was calculated, along with the comparison coefficient of the specific activity of the radioactive element in the upper and lower layers of the peat bog.

RESULTS AND DISCUSSION

Physico-chemical parameters of peat samples

The liquid phase (pH_{wate}) and the solid phase (pH_{salt}) of the studied peat have an acidic reaction of the medium. The current acidity of the studied peat ranges from 3.7 to 3.9 pH, while the exchange acidity is between 2.6 and 3.0 pH (Table 1A, Fig. 2). The acidity indicators are stable throughout the depth of the peat bog. The studied peat from the island shows strong acidity compared to the acidity of the peat from the raised bogs of the European subarctic of Russia ($3.2 \leq pH \leq 5.2$). The values of the physicochemical parameters of the peat from the

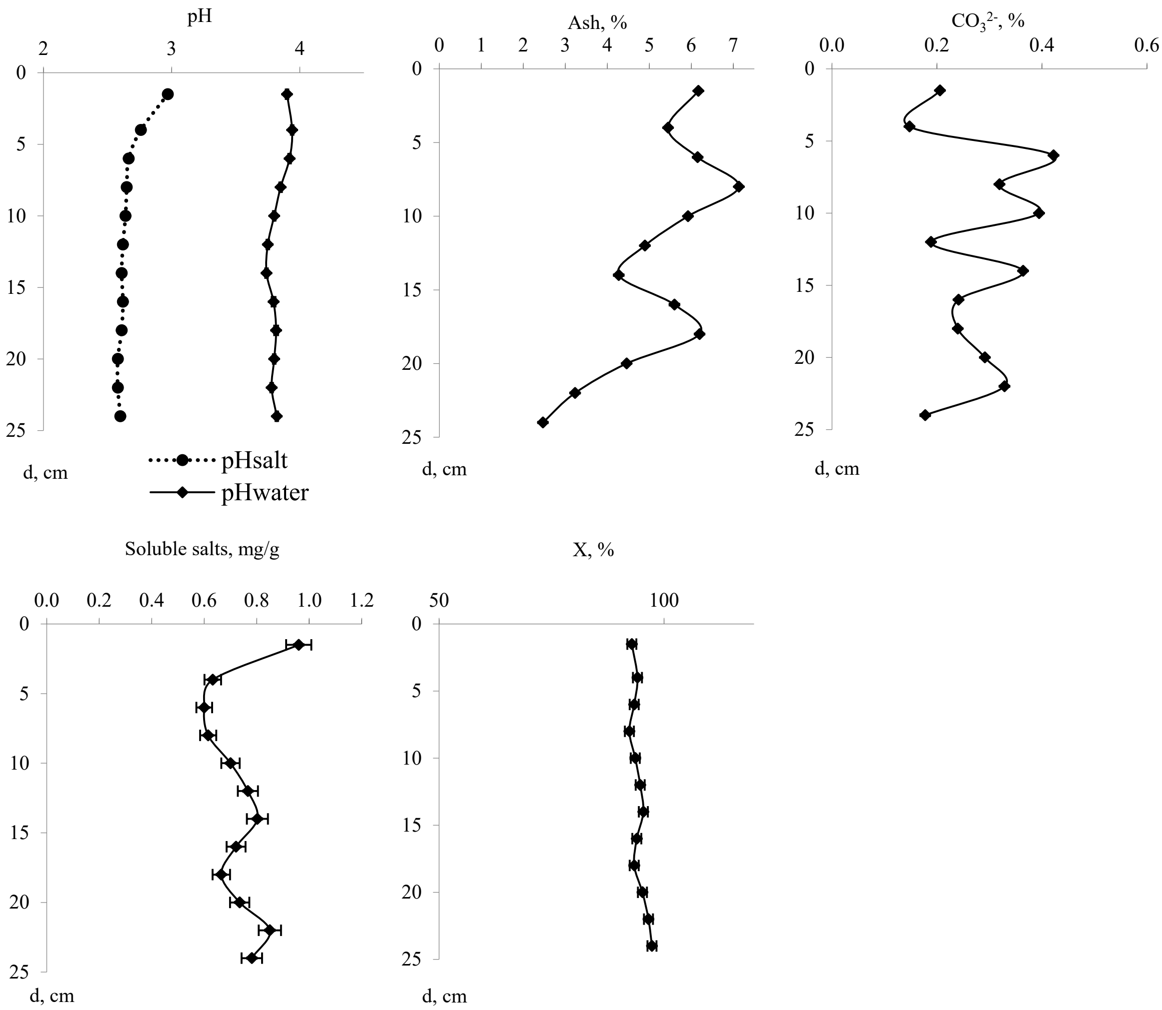

Fig. 2. The dependence of physicochemical properties of peat on the depth of the peat core TB-1

Table 1A. Physico-chemical parameters in the TB-1 peat core.

Depth of the profile (cm)	pH_{water}	pH_{salt}	Soluble salts, (mg/g)	ω (CO_3^{2-}), (%)	ω (Ash), (%)	ω (X), (%)
0-3	3.9±0.1	3.0±0.1	0.96±0.05	0.21±0.01	6.2±0.01	93±0.02
3-5	3.9±0.1	2.8±0.1	0.63±0.03	0.15±0.02	5.4±0.01	94±0.05
5-7	3.9±0.1	2.7±0.1	0.60±0.03	0.42±0.01	6.1±0.03	93±0.10
7-9	3.8±0.1	2.6±0.1	0.62±0.03	0.32±0.02	7.1±0.01	92±0.01
9-11	3.8±0.1	2.6±0.1	0.70±0.04	0.39±0.01	5.9±0.01	94±0.08
11-13	3.7±0.1	2.6±0.1	0.77±0.04	0.19±0.01	4.9±0.02	95±0.03
13-15	3.7±0.1	2.6±0.1	0.80±0.04	0.36±0.02	4.3±0.05	95±0.01
15-17	3.8±0.1	2.6±0.1	0.72±0.04	0.24±0.02	5.6±0.06	94±0.02
17-19	3.8±0.1	2.6±0.1	0.67±0.03	0.24±0.02	6.2±0.03	93±0.06
19-21	3.8±0.1	2.6±0.1	0.74±0.04	0.29±0.02	4.5±0.01	95±0.02
21-23	3.8±0.1	2.6±0.1	0.85±0.04	0.33±0.04	3.2±0.03	96±0.04
23-25	3.8±0.1	2.6±0.1	0.78±0.04	0.18±0.06	2.5±0.04	97±0.02

raised bogs of the European subarctic of Russia are presented in Table 3A.

The peat contains few mineral components and is characterized by low ash content. The ash content of the peat ranges from 2.5% to 7.1% (Table 1A, Fig. 2). The peat is primarily classified as medium-ash. Low-ash layers of peat (A_{sh} < 5.0%) are located in the middle and lower parts of the peat bog. The maximum ash content is observed at a depth of 7 to 9 cm. The ash content of the island's peat is 2 to 13 times lower than that of peat from the raised bogs of the European subarctic of Russia (5.0% ≤ A_{sh} ≤ 94%).

The mineral portion of the peat includes carbonates, attributed to carbonic acid salts, potassium (a mesoelement), and magnesium (a microelement); water-soluble salts. Up to 10% of the mineral portion of the peat consists of carbonates. The overall content of water-soluble salts in the peat is negligible. The mass fraction of carbonates in the peat ranges from 0.15% to 0.42% (Table 1A, Fig. 2). The carbonate content of the peat on the island is twice as low as that of the peat in the raised bogs of the European subarctic of Russia ($0.26 \le CO_3^{2-} \le 0.83$). The high carbonate content in the peat of the raised bogs of the European subarctic of Russia (in some areas) can be explained by atmospheric deposition of carbonates in the form of dust, precipitation, and the presence of carbonates among the weathering products of bedrock (feldspars, pyroxenes, and biotites).

The overall content of water-soluble salts in the peat varies within the range of 0.60-0.96 mg/g (Table 1A, Fig. 2). In the peat bog, salinity is absent (the amount of water-soluble salts is less than 0.3%). The peat of the island does not contain toxic salts, which is atypical for the peat of raised bogs in the European subarctic of Russia.

The main component of peat is organic matter. The mass fraction of organic matter in peat ranges from 92% to 97% (Table 1A, Fig. 2). Organic matter is concentrated in all layers of the deposit. The share of organic matter in the peat profile increases with depth, with the maximum value observed at a depth of 23-25 cm. Peat has a high proportion of organic matter compared to the peat of raised bogs in the European subarctic.

There are significant correlation relationships observed between the physicochemical parameters: a direct relationship between pH_{water} and pH_{salt} (r=0.65) and an inverse relationship between A_{sh} and X (r=-0.84). No significant correlation relationships have been established between other physicochemical indicators of peat.

The peat bog of the island territory of the Russian Arctic has distinctive physicochemical characteristics compared to the raised bogs of the European subarctic of Russia: strong acidity, low ash content, absence of salinity, and a high proportion of organic matter.

Specific activity of radionuclide elements in peat samples

The total specific alpha activity of the peat core TB-1 ranges from 16 to 87 Bq/kg, the total specific beta activity ranges from 13 to 221 Bq/kg. The specific activity of radioactive elements (^{137}Cs, ^{226}Ra, ^{232}Th, ^{40}K, ^{210}Pb, ^{90}Sr) has been recorded in all peat samples, except for ^{241}Am and ^{7}Be. The specific activity of ^{241}Am was detected in the layers of 3-25 cm, while the specific activity of ^{7}Be was found only in the upper layer of 0-3 cm. The specific activity of ^{137}Cs in the peat bog ranges from 1.3 to 21 Bq/kg, ^{226}Ra from 0.60 to 2.2 Bq/kg, ^{232}Th from 0.70 to 1.6 Bq/kg, ^{40}K from 17 to 30 Bq/kg, ^{210}Pb from 5.7 to 250 Bq/kg, ^{241}Am from 0.00 to 0.80 Bq/kg, ^{7}Be at 11 Bq/kg (only in the layer of 0-3 cm), and ^{90}Sr from 0.08 to 3.6 Bq/kg. The obtained data on the total specific alpha and beta activities, as well as the specific activity of radioactive elements in the peat samples, are presented in Table 2A. Figure 3 show the relationships of total specific alpha and beta activity, and the specific activity of radioactive elements in peat with depth in the peat core.

The specific activity of natural radioactive elements (^{226}Ra, ^{232}Th, ^{40}K) in peat does not exceed the global average values in soil (33 Bq/kg, 45 Bq/kg, and 420 Bq/kg, respectively). The specific activities of anthropogenic radioactive elements in the peat of the island do not exceed

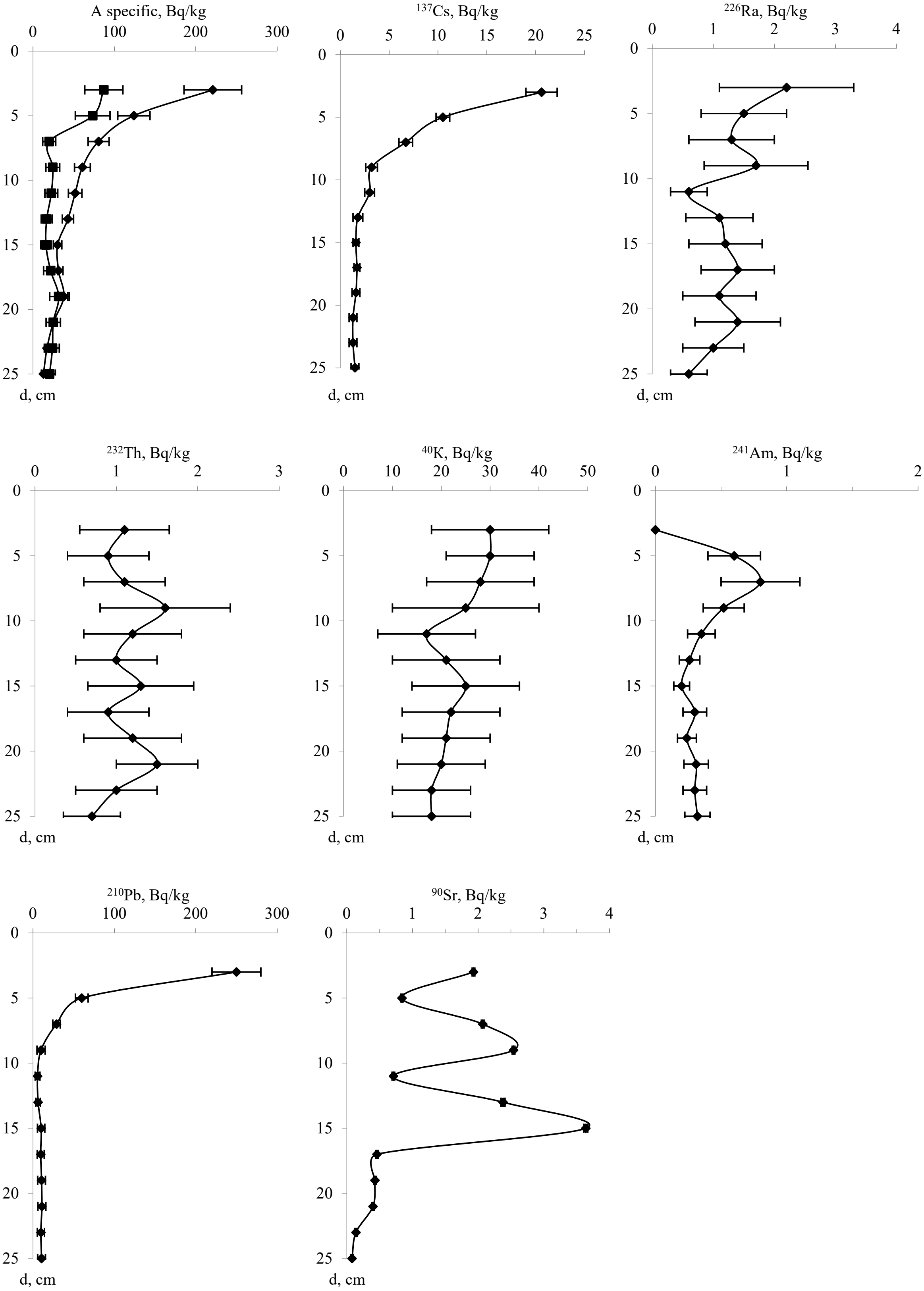

Fig. 3. Dependence of the total specific alpha and beta activity, specific activity of radioactive elements on the depth of the peat core TB-1

Table 2A. Specific activity of radionuclide elements in the TB-1 peat core.

Depth of the profile (cm)	^{137}Cs, (Bq/kg)	^{226}Ra, (Bq/kg)	^{232}Th, (Bq/kg)	^{40}K, (Bq/kg)	^{210}Pb, (Bq/kg)	^{241}Am, (Bq/kg)	^{90}Sr, (Bq/kg)
0-3	21±1.6	2.2±1.1	1.1±0.55	30±12	250±30	0.0	1.9±0.02
3-5	10±0.70	1.5±0.70	0.90±0.50	30±9	60±7.8	0.60±0.20	0.84±0.02
5-7	6.7±0.70	1.3±0.70	1.1±0.50	28±11	29±4.6	0.80±0.30	2.1±0.02
7-9	3.2±0.60	1.7±0.80	1.6±0.80	25±15	10±5.0	0.52±0.16	2.5±0.02
9-11	3.0±0.50	0.60±0.30	1.2±0.60	17±10	5.7±2.9	0.35±0.10	0.71±0.02
11-13	1.8±0.50	1.1±0.50	1.0±0.50	21±11	6.4±2.9	0.26±0.08	2.4±0.03
13-15	1.6±0.30	1.2±0.60	1.3±0.65	25±11	10±4.5	0.20±0.06	3.6±0.03
15-17	1.7±0.30	1.4±0.60	0.90±0.50	22±10	9.6±4.3	0.30±0.09	0.46±0.02
17-19	1.6±0.40	1.1±0.60	1.2±0.60	21±9	11±4.8	0.24±0.07	0.43±0.02
19-21	1.3±0.40	1.4±0.70	1.5±0.50	20±9	11±4.9	0.31±0.09	0.40±0.02
21-23	1.3±0.40	1.0±0.50	1.0±0.50	18±8	9.8±4.4	0.30±0.09	0.14±0.02
23-25	1.5±0.40	0.60±0.30	0.70±0.35	18±8	11±4.8	0.32±0.10	0.08±0.02
Average specific activity, Bq/kg	4.6±0.57	1.3±0.62	1.1±0.55	23±10	35±6.7	0.38±0.12	1.3±0.02
Standard deviation	5.5	0.42	0.24	4.4	66	0.05	0.32
Coefficient of variation, %	121	34	22	19	188	46	25
Comparison coefficient of specific activity in the upper and lower layers of the peat bog	14	3.7	1.6	1.7	23	1.9	24

Table 3A. Range of values of physicochemical indicators of peat in the raised bogs of the European subarctic region of Russia.

Territory	pH_{water}	pH_{salt}	ω (A_{sh}), (%)	ω (CO_3^{2-}), (%)	Soluble salts, (mg/g)	ω (X), (%)
Nenets Autonomous Okrug, the city of Naryan-Mar	3.9-5.2	3.2-4.3	5.0-94	0.26-0.60	0.30-5.5	5.9-95
Murmansk Oblast, the city of Murmansk	4.2-4.9	3.6-4.1	5.2-28	0.42-0.83	1.0-9.8	0.42-0.83

the established minimum significant standards (NRB-99/2009) and their activity values in the peat of raised bogs in the European subarctic of Russia (Table 4A).

The total specific alpha activity of the peat is represented by the emissions of natural radioactive elements: ^{226}Ra, ^{232}Th, and a negligible emission from the anthropogenic radioactive element – ^{241}Am. It is possible that the natural element ^{210}Po contributes to the total specific alpha activity, as it is a decay product in the uranium-238 radioactive decay chain. The total specific beta activity of the peat is primarily attributed to the emissions of natural radioactive elements: ^{40}K, ^{210}Pb, and ^{7}Be, with a minor contribution from anthropogenic radioactive elements: ^{137}Cs and ^{90}Sr. Significant correlation relationships have been identified between the total specific activity and physicochemical parameters: α-$A_{specific}$ – pH_{water} (r=0.68), β-$A_{specific}$ – pH_{water} (r=0.70); α-$A_{specific}$ – pH_{salt} (r=0.90), β-$A_{specific}$ – pH_{salt} (r=0.99); β-$A_{specific}$ – A_{sh} (r=0.49), α-$A_{specific}$ – CO_3^{2-} (r=-0.49).

The specific activities of natural radioactive elements (^{226}Ra, ^{232}Th, ^{40}K) are distributed more uniformly in the peat core. The coefficients of variation for the specific activity values of the radioactive elements are as follows: ^{226}Ra 34%, ^{232}Th 22%, and ^{40}K 19% (Table 2A). The specific activities of natural elements decrease with depth in the core (Fig. 3). A decline in the activity of natural radioactive elements is observed at a depth of 9-11 cm. The vertical migration pathway of natural radioactive elements in the peat core is determined by physicochemical parameters of the peat. Mathematical correlation analysis has revealed strong positive correlations between the specific activity of ^{226}Ra, ^{40}K, and pH_{water} (r=0.71, r=0.72, respectively); between ^{226}Ra, ^{40}K, and pH_{salt} (r=0.72, r=0.73, respectively); between ^{226}Ra, ^{40}K, and A_{sh} (r=0.54, r=0.51, respectively), as well as strong negative correlations between ^{226}Ra, ^{232}Th, and X (r=-0.61, r=-0.69, respectively), (Fig. 4).

The specific activity of the natural radioactive element ^{210}Pb has a completely different vertical migration pathway within the peat core (Fig. 3). ^{210}Pb is characterized by the highest coefficient of variation for specific activity values (188%), (Table 2A). The maximum activity of this radioactive element (250 Bq/kg) is recorded in the upper layer (0-3 cm) of the peat core. Starting from the 3-5 cm layer, the activity of ^{210}Pb significantly decreases and levels off, reaching equilibrium with ^{40}K in the lower layers. ^{210}Pb is characterized by the highest comparison coefficient of specific activity between the upper and lower layers (Table 2A). The peak activity of ^{210}Pb in the upper part of the core is due to the continuous migration and dispersion of ^{210}Pb resulting from natural processes of leaching and weathering of rocks, as well as human activities. The mathematical correlation analysis revealed strong positive correlations between the specific activity of ^{210}Pb and pH_{water} (r=0.52); between ^{210}Pb and pH_{salt} (r=0.96); and between ^{210}Pb and soluble salts (r=0.57). The accumulation rate of ^{210}Pb in the peat of Kolguev Island is 0.13 cm/year. To determine the rate of peat accumulation using ^{210}Pb, the authors applied the Monte Carlo method, as presented in the work of J. A. Sanchez-Cabeza et al. (2014). For the calculation of the peat accumulation rate, data on specific activities of ^{210}Pb and ^{226}Ra in the horizons (0.0-17 cm) were used. Horizons below the depth of 17 cm were not considered in estimating the peat accumulation rate, as there is no change in the activity of ^{210}Pb. The dating obtained using this method establishes the year 1956 at a depth of 5-7 cm, which corresponds

Table 4A. Range of values of specific activity of radioactive elements in peat of the raised bogs of the European subarctic region of Russia.

Territory	**^{210}Pb, (Bq/kg)**	**^{137}Cs, (Bq/kg)**	**^{90}Sr, (Bq/kg)**	**^{241}Am, (Bq/kg)**
Nenets Autonomous Okrug, the city of Naryan-Mar	1.1-382	1.4-199	0.25-2.6	0.01-3.5

	pH_{water}	pH_{salt}	ω (A_{sh})	ω (CO_3^{2-})	Soluble salts	ω (X)
^{137}Cs	0.71	0.99	0.37	0.26	0.35	-0.33
^{226}Ra	0.49	0.72	0.54	-0.19	0.18	-0.61
^{232}Th	-0.12	-0.10	0.49	0.51	0.21	-0.69
^{40}K	0.72	0.73	0.51	0.13	0.09	-0.40
^{241}Am	0.89	0.71	0.44	0.24	-0.76	-0.34
^{210}Pb	0.52	0.96	0.26	0.29	0.57	-0.27
^{90}Sr	-0.07	0.22	0.33	0.29	0.02	-0.34

Fig. 4. Correlation dependencies of the activity of radioactive elements on the physicochemical parameters of the peat from Kolguev Island Notations: red, green color – significant correlation relationships, yellow color – insignificant correlation relationships.

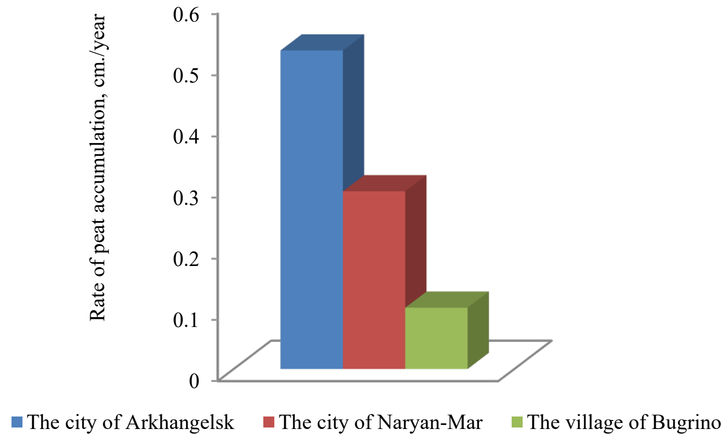

Fig. 5. Changes in peat accumulation rates depending on the changes in natural and climatic conditions in the Western Sector of the Russian Arctic (data for the city of Arkhangelsk and Naryan-Mar from Yakovlev, 2024)

to the maximum depth of ^{241}Am identified, potentially providing an additional verification due to the low migration capability of ^{241}Am and its appearance in atmospheric deposition in this region not earlier than the specified year.

The activity of natural ^{210}Pb, whose main input channel is atmospheric deposition, gradually decreases with depth. The exponential decline of ^{210}Pb activity with depth indicates that there is no influence of cryogenic mixing processes (cryoturbation) in the sampling area, which are generally characteristic of the soil cover of Kolguev Island. This allows the use of ^{210}Pb activity data for dating the peatlands of Kolguev Island.

Indirectly, dating can be performed based on the activity of the least migratory anthropogenic radionuclide, ^{241}Am, the peak activity of which indicates the fixation of radiological events. Thus, the maximum activity of ^{241}Am at 0.80±0.30 Bq/kg is observed at a depth of 6 cm, which, considering the possibility of this peak forming due to the maximum global fallout of 1963, allows us to conclude that the accumulation rate of the studied peatland on Kolguev Island is about 0.10 cm/year. This is an extremely low rate of peat accumulation, which is associated with the harsh climatic conditions that hinder active peatland growth. In comparison, the accumulation rates of peat in the northern part of the Arkhangelsk region are around 0.52 cm/year, while in the area of the city of Naryan-Mar in the Nenets Autonomous Okrug, the rate is 0.29 cm/year (Fig. 5).

The vertical migration pathway, similar to that of ^{210}Pb, is characteristic of the anthropogenic radioactive element ^{137}Cs (Fig. 3). The coefficient of variation for the specific activity values of ^{137}Cs is 121% (Table 2A). The maximum activity of the anthropogenic radioactive element (21 Bq/kg) is recorded in the upper layer (0-3 cm) of the peat core. From the 3-5 cm layer, the activity of ^{137}Cs significantly decreases and levels off, reaching equilibrium with ^{226}Ra in the deeper layers. The comparison coefficient of the specific activity of ^{137}Cs between the upper and lower layers is 14 (Table 2A). The maximum activity of ^{137}Cs in the upper part of the core is due to the dispersion of anthropogenic radioactive elements from nuclear tests and the Chernobyl disaster. Mathematical correlation analysis has revealed strong positive relationships between the specific activity of ^{137}Cs and acidity ($r > 0.50$).

The values of the specific activity of the anthropogenic radioactive element ^{90}Sr, which is associated with ^{137}Cs, are variable. The coefficient of variation for the specific activity values of ^{90}Sr is 25% (Table 2A). The maximum specific activity of the anthropogenic radioactive element (3.6 Bq/kg) was recorded in the layer (13-15 cm) of the peat core; below this layer, the specific activity of ^{90}Sr decreases significantly. The deep migration of the long-lived radioactive element ^{90}Sr is attributed to its high chemical activity, similar to that of calcium. The comparison coefficient of the specific activity of ^{90}Sr between the upper and lower layers is 24 (Table 2A).

CONCLUSIONS

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

In the peat deposit of the island, elevated alpha and beta specific activities of natural and technogenic radioactive elements have not been registered. The total specific alpha and beta activity is concentrated in the upper layers of peat (at a depth of 0-9 cm). The specific activity of natural radioactive elements is within the average global values for soil and does not exceed the established minimum significant standards. Technogenic radioactive elements with a long half-life (^{137}Cs, ^{90}Sr, ^{241}Am) have been recorded in the peat deposit of the island, indicating a significant impact from past technogenic radioactivity resulting from global nuclear tests. The specific activities of technogenic radioactive elements in the peat deposit of the island fall within the ranges typical for peat from raised bogs in the European subarctic of Russia, and are below the established minimum significant standards.

The coefficients of variation for the specific activity values of radioactive elements decrease in the following order: $^{210}Pb \rightarrow {}^{137}Cs \rightarrow {}^{241}Am \rightarrow {}^{226}Ra \rightarrow {}^{90}Sr \rightarrow {}^{232}Th \rightarrow {}^{40}K$. The specific activities of radioactive elements are concentrated in the upper layers of the peat bog (at a depth of 0-9 cm), with the exception of the long-lived anthropogenic radioactive element ^{90}Sr, which exhibits high chemical activity. The maximum specific activity of ^{90}Sr was recorded at a depth of 13-15 cm in the peat core. Natural radioactive elements are concentrated in the mineral part of the peat, which is confirmed by mathematical correlation analysis. Strong positive correlations have been established between the specific activity of ^{226}Ra, ^{40}K, and ash content, as well as strong negative correlations between ^{226}Ra, ^{232}Th, and the fraction of organic matter. Radioactive elements migrate downward through the core. On Kolguev Island, the accumulation rate of peat with radioactive elements is extremely low (about 0.10 cm/year). The lower layers of the peat bog have the lowest radioactivity. The comparison coefficient of specific activity between the upper and lower layers of the peat bog decreases along the series of radioactive elements: $^{90}Sr \rightarrow {}^{210}Pb \rightarrow {}^{137}Cs \rightarrow {}^{226}Ra \rightarrow {}^{241}Am \rightarrow {}^{40}K \rightarrow {}^{232}Th$. If the current warming trend continues, the melting of frozen peat may lead to further migration of radioactive elements from the upper layers of the peat bog to the lower layers.

ACKNOWLEDGEMENT

Referees provided very helpful comments for improving the manuscript.

GRANT SUPPORT DETAILS

The studies were conducted with financial support for the research topic of the FNIIR Federal State Budgetary Institution of Science Federal Research Center for Comprehensive Study of the Arctic named after Academician N.P. Lavrov of the Ural Branch of the Russian Academy of Sciences: “Features of the migration of elements and their isotopes in the components of the environment of the Western sector of the Russian Arctic under conditions of climatic and technogenic changes” No. 125022002727-2. Expeditionary research was conducted with financial support from the “Arctic Floating University-2024”.

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.

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