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Accumulation and migration of ^{137}Cs in the tundra landscapes (North-West of Kola Peninsula)

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Abstract. The scope of the paper is the current radioecological situation on the Kola Peninsula. Activity of existing enterprises in the region increases the potential danger of radioactive contamination. One of such enterprises is the ship reparation yard Nerpa specializing in the disposal of decommissioned nuclear submarines of the Russian Federation Navy since 1992. The aim of the study is to determine the degree of Nerpa influence on the environment by investigation of spatial distribution of ^{137}Cs in the upper soil horizons and lichens as the most reliable indicator of radioactive contamination.

1. INTRODUCTION

The territory of the study is the tundra and forest-tundra zone at the west coast of the Kola Bay to north-west of the city of Murmansk. The vegetation is represented by forest-tundra woodlands, birch as well as by bushes, mosses and lichens. Soil cover is quite different but humic-illuvial podzols are dominated in forest-tundra, tundra humus podzolic soil and podbury are dominated mostly at the north and on the coastal area [2]. Relief of the district consists of uplifts and depressions formed under the influence of tectonic events, erosion activities, the actions of glaciers and the sea level fluctuations. It plays an important role in the redistribution of pollutants including radionuclides. The area to consider is located on the territory of development of the South-tundra acidic class landscapes. It is shown that these pollutants are transported mainly as suspended substance in the air and by surface water flows [6].

In accordance with the objective of the study the following tasks were reviewed: 1) determination ^{137}Cs contents in soil and lichen, 2) studying the vertical profile of radiocaesium distribution in different types of soils, 3) estimation effect of the shipyard Nerpa industrial zone on the basis of the distribution of radionuclides in ecosystem components.

2. MATERIALS AND METHODS

The present research is based on the teachings of the basic geochemical landscapes in the presentation of Prof. B. Polynov developed by Prof. A. Perelman and Prof. M. Glazovskaya [3, 6]. Landscape-geochemical mapping is executed at researched area, the results are represented as a 1 : 20 000 scale landscape map of Nerpa area and geochemical map of the north-west coast of the Kola Bay of 1 : 200 000 scale [4]. Autonomous and subordinate geochemical landscapes are estimated for the both maps on the base of analysis of geological and geomorphologic conditions, absolute and relative heights and hydro net features the hydro net features, features of hydro net. Prevailing situation in the autonomous landscapes which are not influenced by neighboring subordinate landscapes may be considered as an indicator of evaluation of the amount of radiation-chemical pollutants entering in atmosphere from natural landscapes.

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2.1 Sampling procedures

The main method to field research was landscape geochemical catenary grading with detailed sampling all elementary landscapes. Autonomous landscapes were sampling in order to determine the zone of influence shipyard "Nerpa" of the environmental. The samples were selected from all available vertices in different distance from the plant. To determine the characteristics of the ^{137}Cs vertical distribution in each sampling point several sections were made and samples of all genetic horizons were taken. Samples of lichen (*Cetraria, Cladonia*) were selected at each location. About 550 soil and lichen samples were taken at 203 points during 2004–2007.

Selected samples were analyzed for the content of ^{137}Cs and natural radionuclides (^{40}K, ^{226}Ra, ^{232}Th) (analyst A. Kerzin, IGEM RAS). The measurements were carried out at scintillation γ-ray spectrometer (detector - NaJ (Tl) 160 × 160 mm × 55 wells with 110 mm).

Concentrations of stable pollutants like S, As, V, Cu, Ni, Co, Zn, Pb, and some other elements in samples were determined. The measurements were carried out at XRF WD Spectrometer Philips PW2400 (analyst A. Yakushev, IGEM RAS).

3. RESULTS AND CONCLUSIONS

Study of distribution of ^{137}Cs in landscapes at researched area confirmed the high indicative ability of lichens and upper organic soil horizon. This horizon consists of more than half content of organic residues. These components accumulate and strongly hold ^{137}Cs receiving by precipitation, so they can serve as reliable indicators of radioactive contamination.

Radiocaesium concentrations at the territory of investigation studied in lichen (*Cetraria, Cladonia)* is widely represented in the tundra and forest tundra landscapes. They are fed through precipitation, and radionuclides from atmospheric fallouts are settled in the lichen consisting in the rain drops, snow, fog, dew, or in the form of dust and aerosols. The concentrations of absorbed substances may exceed lichens physiological needs. This feature allows indicate structure of precipitation and pollution. It also proves high absorptive capacity of lichens in relation to the radioisotopes [5].

Experiments proved that the representative of different species and different morphological groups doesn't accumulate radionuclides equally. Analysis of the available data showed that the lichen *Cetraria*

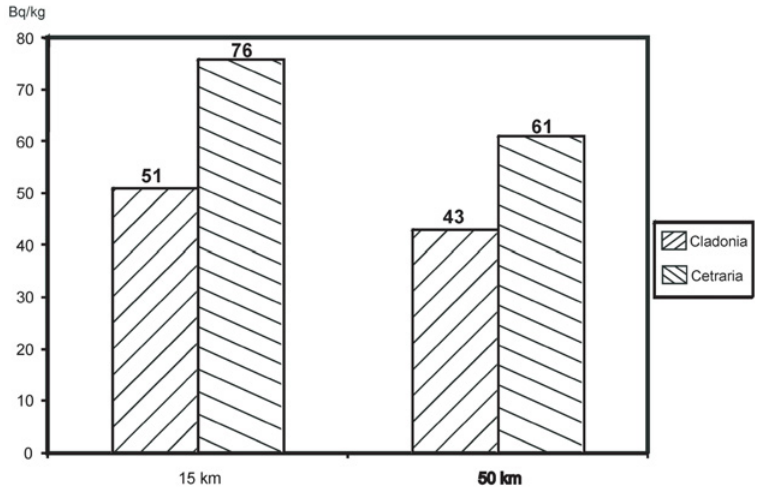

Figure 1. Values ^{137}Cs specific activity (Bq/kg) in the different kind of lichens.

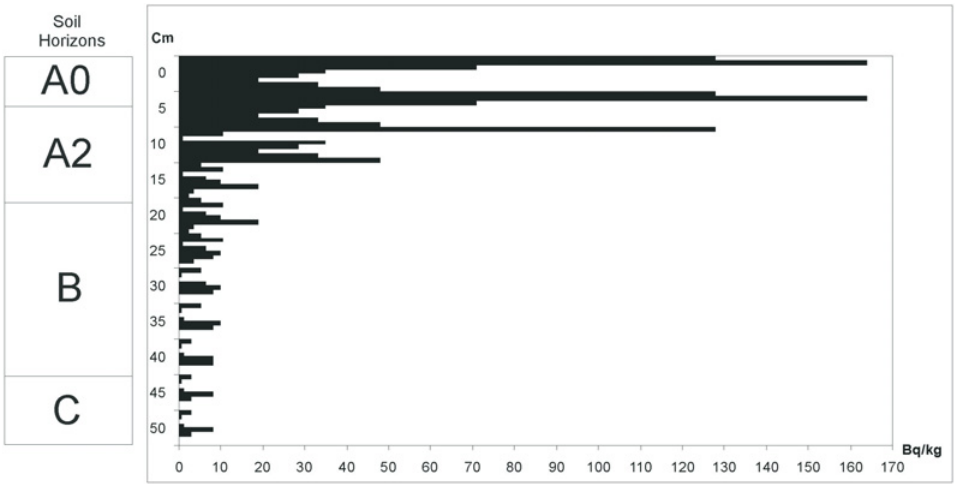

Figure 2. Distribution of ^{137}Cs on the typical podzol profile.

consumes more of ^{137}Cs than *Cladonia* in 1.4 times (Fig. 1). Radioactivity of all samples of lichens significantly lower (at 80–85%) than limit values specified in 480 Bq/kg [1].

To determine the vertical distribution of radiocaesium the major soil types commonly occurring in the territory of the north-west coast of the Kola Bay were examined. The most common soil types in the territory are podzols, podbury and tundra-ranker. They are formed at different parent rocks with different granulometric composition. Studies have shown that the most amount of ^{137}Cs (80 to 92%) is concentrated in the top organic layer and not to exceed deeper 20 centimeters. At the same time soil distribution of ^{137}Cs depends on the type of the profiles and has some differences.

Major amount of radiocaesium in a typical podzol profile is located in the horizons A0-A2 with deepness of 10–12 cm (average 64 Bq/kg). Reducing the content of the radionuclide in the lower horizons to 8 Bq/kg is gradual but rather abruptly (Fig. 2).

Organic horizon in tundra-ranker soil containing the majority of ^{137}Cs has deepness up to 20 centimeters. The average content of radiocaesium is lower (54 Bq/kg) than in podzole. Radioisotope penetration to lower horizons does not exceed 10% (1–5 Bq/kg). Major activity of ^{137}Cs in podbury is located in a layer of depth less than 18–22 centimeters, at the same time average content in this layer (62 Bq/kg) is the same as in podzole. Concentrations of radiocaesium are reducing to 1–3 Bq/kg in the lower horizons.

To determine the border of the shipyard influence the content of ^{137}Cs from autonomous landscapes depending on the distance from industrial zone were estimated. The study allows offering a hypothesis that the impact of the plant does not exceed 50 km distance. The calculations include data of radiocaesium content in the A0 soil horizon sampled in 5, 10, 15, 20 and 50 km from the industrial zone of the plant. The averages inside each area were calculated (Fig. 3). Generalized average of ^{137}Cs concentrations calculated for the territory is 50.3 Bq/kg with an error of 2.07. Analysis of distribution of ^{137}Cs depending of distance from the plant showed that the local average contents in 20 and 50 km zones not exceeding the generalized average. The boundary between 15 and 20 kilometer zones looks as a steep threshold. We suppose this reflects a natural border of the plant impact to environment.

Average content of radiocaesium outside the zone of Nerpa influence is 34 Bq/kg and corresponds to background concentration values provided by regional atmospheric fallout. Inside the zone concentrations of radiocaesium is reaching 75 Bq/kg. This concentration consists of base concentration amounts of ^{137}Cs and shipyard industrial impact. According to the existing federal law the earth's surface

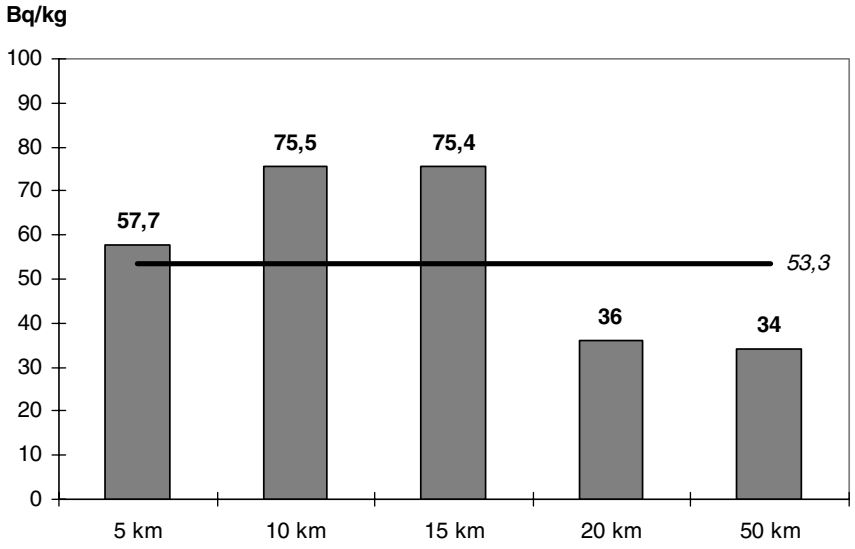

Figure 3. Distribution of ^{137}Cs (Bq/kg) in autonomous landscape soils in respect of distance from the plant.

area is to be considered as radioactively-contaminated if activity of ^{137}Cs increases 1–2 Ku/km^2. In the territory of investigations average amount of ^{137}Cs corresponds to 0.07–2 Ku/km^2.

4. SUMMARY

The average content of radiocaesium in samples of soil and lichen selected near the shipyard "Nerpa" is significantly below the limits. Most of ^{137}Cs (80 to 92%) is concentrated in the top organic soil layer with deepness not more than 20 centimeters and it doesn't depend on their genetic type. The average contents in lichens are 48 Bq/kg (*Cladonia*) and 70 Bq/kg (*Cetraria*), the type of lichen *Cetraria* accumulates an average of 1.5 times more ^{137}Cs than *Cladonia*.

Analysis of the contents of radiocaesium in the top soil horizon landscape allows indicate shipyard "Nerpa" influence zone. The boundary of the zone could be located at a distance of 14–16 kilometers from the industry. The results of the research can be used to monitor the territory of the north-west coast of the Kola Bay.

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