Dynamics of distribution of ^{137}Cs in soils of transitional bogs

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Summary

Specific features of ^{137}Cs accumulation, transformation, and migration in humus-peaty and peaty-gley soils of transitional bogs are discussed with reference to the southwestern part of Russian Federation, which was most heavily contaminated after the Chernobyl accident. It is concluded that bog soils accumulate ^{137}Cs in the form of hardly movable compounds and, as a consequence, transitional bogs are transformed into critical ecosystems.

Key index words: transitional bogs, ^{137}Cs, radioactive contamination.

Introduction

The soils of bog ecosystems are known to accumulate and transform radionuclides (Polyakov et al., 1962; Evans and Dekker, 1967; Tyuryukanov et al., 1973; Molchanova and Karavaeva, 1981). However, there is little information about the forms of radioactive cesium, and its migration in peaty soils. In this relation, the purpose of this study was to analyze these processes in the southwestern part of the Russian Federation, which was most heavily contaminated after the Chernobyl accident.

Materials and Methods

Field studies were performed in Bryansk oblast, using the method of soil keys, from 1990 to 2005. A permanent monitoring station with three key soil plots (KSP) – Topilovskii, Veprinskii, and Krasnogorskii – was established in natural ecosystems of transitional bogs. Each key plot included one to three permanent test plots 25–30 m^2 in size, which were located closely to each other in the same type of the bog site (facies).

Topilovskii KSP

(The village of Staryi Vyshkov, Novozybkovskii raion): Golnoe Topilo site, a transitional bog in a deep depression amid old arable fields. Vegetation: *Betula pubescens* (strongly suppressed), *Eriophorum vaginatum*, and *Sphagnum spp*. Raisedbog humus-peaty transitional soil (*Klassifikatsiya…*,1977) with 20–50% peat decomposition and the groundwater table at a depth of 40 cm.

Veprinskii KSP

(The village of Veprino, Klintsovskii raion): a transitional bog in the forest. Vegetation: *Betula pubescens* (suppressed), *Pinus sylvestris* (suppressed), *Eriophorum vaginatum, Ledum palustre*, and *Sphagnum spp*. Raised-bog humus-peaty transitional soil with 20–50% peat decomposition and the groundwater table at a depth of 25 cm.

Krasnogorskii KSP

(Krasnogorskaya forest site, Krasnogorskii raion): a transitional bog in the forest. Vegetation: *Betula pubescens, Pinus sylvestris, Eriophorum vaginatum, Ledum palustre, Oxycoccus palustris, Vaccinium vitis-idaea, V. myrtillis, V. uliginosum*, and *Sphagnum spp*. Raised-bog peaty-gley ferruginous humic soil with 10–30% peat decomposition and the groundwater table at a depth of 30 cm.

Soil pits were established in these plots in August–September 1990, 1992, 1999 and 2005. Soil samples were taken from every 2-cm layer to a depth of 30 cm and from every 5-cm layer at greater depths. Different forms of ^{137}Cs were consecutively extracted with distilled water, 1 N ammonium acetate, and 6 N hydrochloric acid, with the soil : solution ratio being 1 : 50.

Specific activity of ^{137}Cs was determined by the method of semiconductor γ-spectrometry in an IN-1200 instrument with a germanium detector (Ortek) and by a scintillation method in an GAMMA +. The specific radioactivity of ^{137}Cs in the soil before extraction was taken as its total content in calculations of ^{137}Cs distribution by fractions ^{137}Cs concentrations were expressed in kBq/dm^3. These units of measure were chosen because of considerable changes on the density of peaty soils down the profile.

Results and discussion. The distribution of the total cesium content in the raised-bog humus soils had a peak in peat dust (Figs. 1a, 1b). Two peaks, in the T1 and T2 horizons, were found in the profile of raised-bog peaty-gley ferruginous humic soil (Fig. 1c). Peaty horizons in this soil had a small depth (about 30 cm) and were underlain with

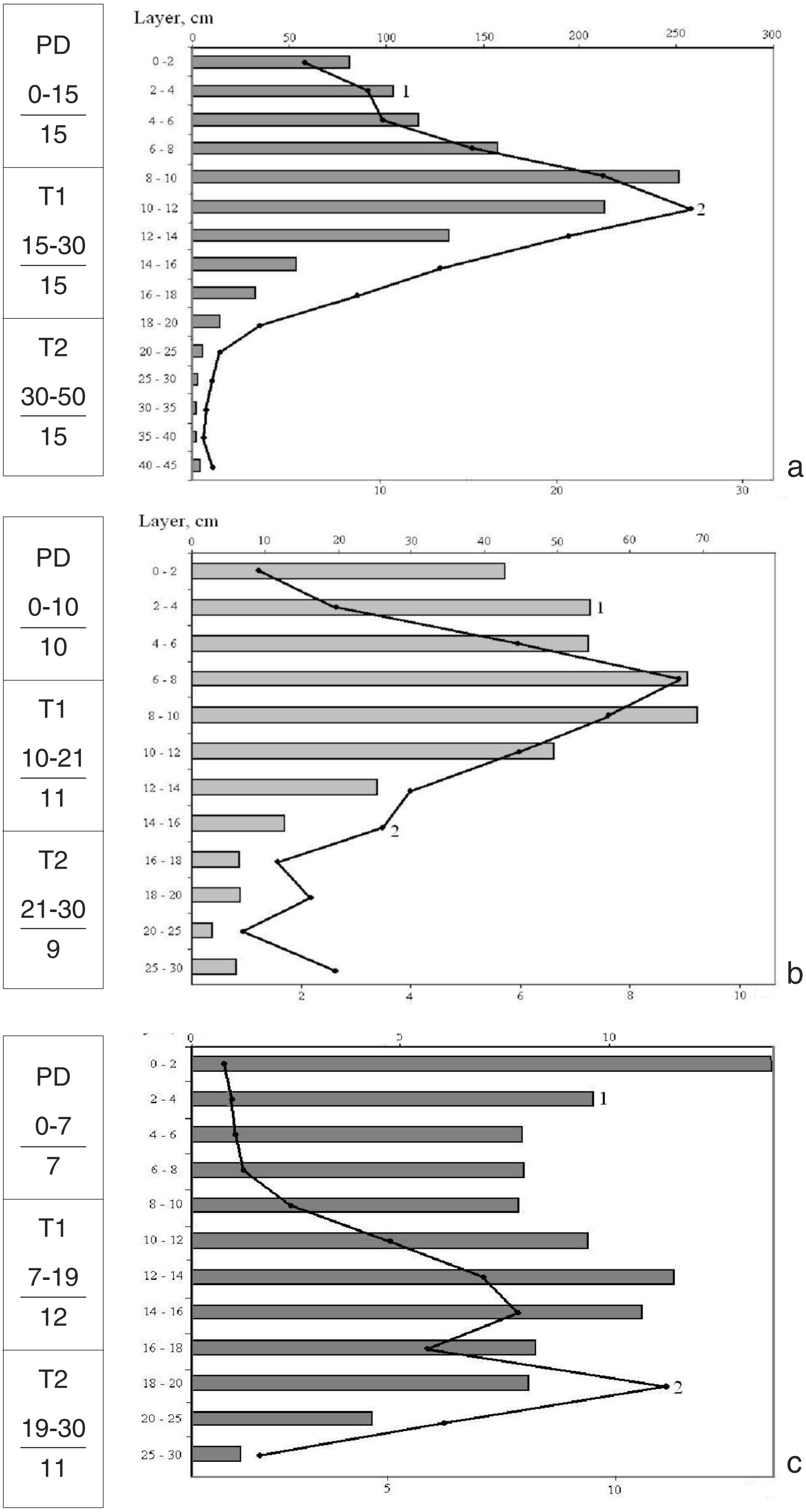

Figure 1. Distribution of total ^{137}Cs content in bog soils of (a) Topilovskii KSP, (b) Veprinskii KSP, and (c) Krasnogorskii KSP:(1) histogram, kBq/kg; (2) concentration, kBq/dm^3.

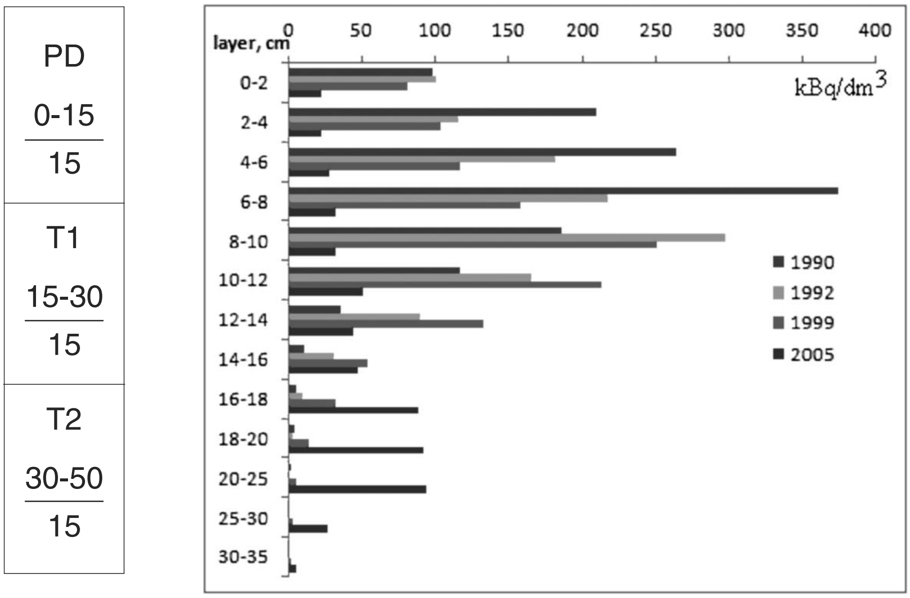

Figure 2. Dynamics of total [137]Cs distribution in the soil of Topilovskii KSP in different years.

a gley horizon. It was probably weak development of peaty horizons that provided for of the increased mobility of [137]Cs in the profile of this soil. Zubkova and Karpachevskii (2001) noted that adsorption properties of soil depend on the size of the soil matrix. If the area of its surface ranges from 40 to 150 m^2/g, as is the case with bog soils, it functions as a geochemical barrier that retards migration of substances in the soil. The soil matrix of bog soils is an assemblage of specific organic substances that form peat. The concentrations of individual peat components correlate with the degree of peat decomposition (Lishtvan and Korol, 1975). The area of the soil matrix surface in bog soils depends on the degree of peat decomposition and is different in genetic horizons. This situation is typical of geochemical barriers (Alekseenko and Alekseenko, 2003), which allows us to regard the soil profile as a system of microgeochemical barriers.

Thus, the processes of [137]Cs input, accumulation, and partial removal down the profile take place in every horizon of the soils studied. The parameters of [137]Cs migration in each horizon are determined by the physicochemical properties of this horizon. This is well illustrated by data on the dynamics of [137]Cs distribution in the profile of bog soil (Table). On average, a greater amount of [137]Cs is transferred from peat dust to the T1 horizon than from the T1 to T2 horizon.

Table 1. Total [137]Cs contents in raised-bog humus-peaty soil of Topilovskii KSP (proportion of total stock in the profile,%)

Horizon	1990	1992	1999	2005
Peat dust	94,9	89,9	77,8	33,21
T1	4,8	9,4	20,4	62,55
T2	0,3	0,7	1,9	4,23

The pattern of [137]Cs migration in humus-peaty soil changed significantly with time. Initially (1986–1990), [137]Cs actively migrated down the profile and its content reached a peak at a depth of 6–8 cm; in 1992 and 1999, this peak was detected at depths of 8–10 and 10–12 cm, respectively. In 2005 maximum it was marked on depth 16 - 25 cm (Fig. 2). As a result, the content of [137]Cs in peat dust gradually decreased and the radionuclide accumulated in the T1 horizon, with its partial transfer to the T2 horizon. The concentrations of unexchangeable forms of [137]Cs in the profile of humus-peaty soil signifi-

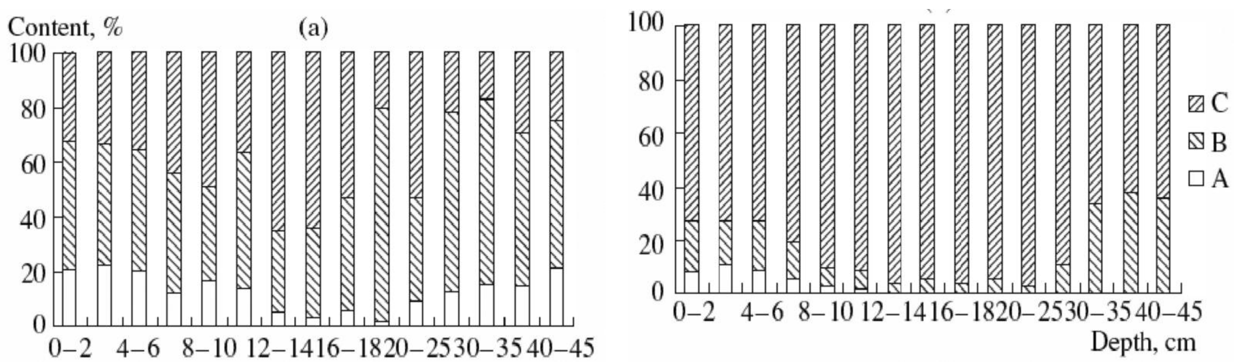

Figure 3. Relative contents of [137]Cs forms in the soil of Topilovskii KSP in (a) 1992 and (b) 1999. Forms of 137Cs : (A) water-soluble (H_2O), (B) exchangeable (1 N CH_3COONH_4), and (C) unexchangeable (6 N HCl).

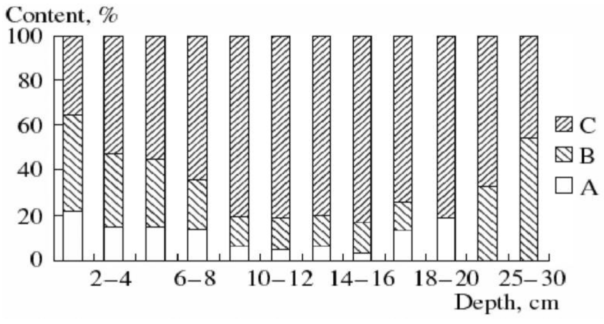

Figure 4. Relative contents of ^{137}Cs forms in the soil of Veprinskii KSP in 1999. Forms of 137Cs : (A) water-soluble (H_2O), (B) exchangeable (1 N CH_3COONH_4), and (C) unexchangeable (6 N HCl).

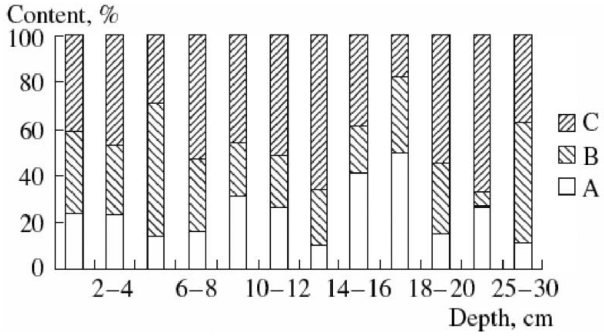

Figure 5. Relative contents of 137Cs forms in the soil of Krasnogorskii KSP in 1999.

cantly increased by 1999, compared with that in 1992 (Fig. 3). The cell walls of sphagnum mosses contain polygalacturones, specific high-molecular substances with a high ion-exchange capacity with respect to monovalent cations (Brehm, 1971). Apparently, ^{137}Cs is fixed by these substances in exchangeable or unexchangeable forms, as is the case with other elements of Group I of the periodic table. The concentrations of water-soluble and exchangeable forms of ^{137}Cs apparently depend on soil genesis, the depth of peaty horizons, and the water content in the soil profile. They increase in peaty-gley soil with a shallow peaty horizon (Figs 4, 5). As the absorbing complex of peaty soils is very specific, the division of radionuclide physicochemical forms into exchangeable and unexchangeable is largely arbitrary. These forms are in dynamic equilibrium, and its shift toward an increase or decrease in radionuclide mobility apparently depends on a number of factors.

Conclusions

1. The profile of bog soils represents the system of microgeochemical barriers, which determine the behavior of ^{137}Cs in transitional bogs.
2. The behavior of ^{137}Cs in peat dust and peaty horizons of bog soils differs, being determined by specific features of soil genesis and of watershed areas.
3. Bog soils transform ^{137}Cs into hardly movable compounds, transforming transitional bogs into critical ecosystems.

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