Journal of Geochemical Exploration 142 (2014) 75–81

Contents lists available at ScienceDirect

Journal of Geochemical Exploration

journal homepage: www.elsevier.com/locate/jgeoexp

The fate of Cs-137 in forest soils of Russian Federation and Ukraine contaminated due to the Chernobyl accident

Alexey I. Shcheglov [a], Olga B. Tsvetnova [a], Alexey Klyashtorin [b,*]

[a] Moscow Lomonosov State University, Department of Soil Science, GSP-1, 1-12 Leninskie Gory, 119991 Moscow, Russian Federation
[b] Saskatchewan Research Council, 125-15 Innovation Boulevard, Saskatoon SK S7N 2X8, Canada

ARTICLE INFO

Article history:
Received 4 January 2013
Accepted 19 May 2013
Available online 26 May 2013

Keywords:
^{137}Cs
Chernobyl accident
Forest ecosystem
Forest litter
Migration

ABSTRACT

The paper is based on a 25-year monitoring study of the Chernobyl-born fallout fate in forest ecosystems of Russian Federation and Ukraine severely contaminated due to the Chernobyl accident (1986). It was found that the intensity of ^{137}Cs transport in the soil profile depends primarily on type of ecosystem and soil properties, with a particular role of forest litter structure and depth. In general, retarding capacity of forest litters and ^{137}Cs half-stay period (effective half-life) in the forest litters can be expressed by the following rank order: destructive, shallow forest litters (O1 only) < fermentative, incomplete profile forest litters (O1 and O2) < humus, full profile forest litters (O1, O2, O3). The retarding capacity of individual forest litter layers for ^{137}Cs is ranked as O1 < O2 < O3. In the first five years after the fallout, ^{137}Cs release from the forest litters to mineral layers and its further migration down the soil profile was not uniform and did not exhibit a front-like character, which is likely due to a combination of local intrasoil flows and mechanical soil mixing processes. Currently, spatial pattern of ^{137}Cs within the forest litters and 0–15 cm mineral profile looks more uniform. The influence of initial fallout properties is only manifested in the topmost (0–5 cm) mineral layer.
© 2013 Elsevier B.V. All rights reserved.

1. Introduction

The total area of Russian Federation (RF) contaminated by radioactive fallout due to the Chernobyl accident (1986) estimates to 47,170 km^2. In 83% of the contaminated area in the RF, ^{137}Cs deposition varied from 37 to185 kBq/m^2, while 11.6%, 4.5%, and 0.6% of the area received deposition 185–555 kBq/m^2, 155–1480 kBq/m^2, and over 1480 kBq/m^2, respectively. The most exposed territories in the RF included Tula, Kaluga and Bryansk Oblast[1] (Fig. 1). In Ukraine, the total contaminated area estimates to 37,450 km^2, of which 90.8% received ^{137}Cs deposition 37–185 kBq/m^2, while the remaining 5.0%, 2.1%, and 1.6% received deposition 185–555 kBq/m^2; 155–1480 kBq/m^2, and over 1480 kBq/m^2, respectively (Kryshev, 1991). The Chernobyl-born fallout was extremely variable by radionuclide composition and physical–chemical nature of the particles, and expressed a complex spatial and temporal pattern of the initial deposition.

In general, the Chernobyl born deposition in Russian Federation and Ukraine varied within 5–6 orders of magnitude: from n ∗ kBq/m^2 to n ∗ 100 MBq/m^2, with the highest levels attributed to the so called "nearby zone", within 5–6 km of the accidental unit of the Chernobyl NPP (ChNPP). The radionuclide composition in these areas closest to the ChNPP was in fact similar to the radionuclide composition in the damaged reactor at the moment of the accident. The composition of the fallout which accumulated in more distant territories ("remote zone") was relatively depleted of high-melting radionuclides (cerium, zirconium, niobium, etc) and enriched with volatile radionuclides, such as cesium and iodine (Egorov et al., 1994; Orlov et al., 1992).

The territory exposed to radioactive fallout included several soil-climatic zones, subzones, soil provinces, and ecosystems (Belova, 1997; Dobrovol'skii and Urusevskaya, 2006; Gagarina et al., 1995). For example, the most contaminated areas in Russian Federation were attributed to the Middle-Russian soil province comprising primarily of bog soddy-podzolic soils differing from each other by the particle-size composition and depth of podzolic horizon. Southern part of this region is covered by gray forest soils. Another eco-geographical region exposed to the Chernobyl-born fallout (the so-called Oka-Don soil province) is covered by podzolized chernozems (leached and typical), meadow chernozems, sandy podzolic soils, gray forest soils, and sporadic solonetzic soils. In Ukraine, major areas exposed to the Chernobyl-born fallout are attributed to the so-called North-Ukrainian soil province covered primarily by podzolized low-humus chernozems (leached and typical).

The most severe radioactive fallout in both Russia and Ukraine took place in a very special geographical region, the so-called Ukraine and Bryansk Polesie. This region is covered by coarse, sandy soddy-podzolic soils combined with a variety of peat-bog soils. The Polesie landscapes are very vulnerable to any environmental pollution, and in particular radioactive fallout, as they provide the most favorable conditions for long-lived radionuclide transport and accumulation in the ecosystem components.

* Corresponding author. Tel.: +1 306 371 5424; fax: +1 3069337299.
E-mail address: klyashtorin@src.sk.ca (A. Klyashtorin).
[1] Administrative units in Russian Federation.

0375-6742/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.gexplo.2013.05.004

Fig. 1. Map of the study area and key site locations in Russian Federation and Ukraine.

This study is based on the results of long term (25 years) monitoring of vast areas in the RF and Ukraine, and discusses the fate of ^{137}Cs in the "forest litter–mineral soil" system. A portion of data (1991–1995) was obtained within the framework of ECP-5 International Project "Radionuclide Migration in Natural and Semi-Natural Environments" (1991–1995) (Belli and Tikhomirov, 1996).

2. Objects and methods

The study aimed at investigation of spatial and temporal trends of ^{137}Cs fate in the soils depending on soil properties, environmental and ecological conditions, and physical–chemical speciation of the initial fallout. The monitoring network was established in 1986–1988 and covered the typical ecosystems and soil types in the contaminated areas of Russia and Ukraine (Fig. 1).

The field material was sampled from the key sites located in the typical landscapes at different distances from the ChNPP. In 1986–1999, soil sampling was performed annually, and in the following years (2000–2012), the soils were sampled every 3–5 years. At each plot, forest litter and mineral soil were taken separately. Three sub-layers of the forest litter were collected from the area of 20 × 20 cm (400 cm^2) using a special steel frame. Then soil column of 20 cm in depth was taken out from the litter-free soil and separated into the sections of 1, 2, 5, etc. cm using a cylindrical steel sampler (Shcheglov et al., 2001).

3. Results and discussion

Basic landscape-ecological and radiological characteristics of the key sites in 1986 are shown in Table 1, and basic physical–chemical parameters of the soils are presented in Tables 2, 3.

Soddy podzolic and podzolic soils in the study area (Bryansk and Ukraine Polesie) are acidic, unsaturated by bases, and well drained. They have low inventory of organic matter, low absorption capacity, and devoid of visible geochemical barriers for downward radionuclides migration. Various peat-bog soils of the area have a shallow peat underplayed by organic-mineral strata. Oppositely, dark-gray forest soils of Tula Oblast have mostly neutral reaction, high content of clay particles and organic matter, and are saturated by bases (Shcheglov et al., 2001). These soils possess the highest absorption capacity in the study area (especially for ^{137}Cs).

Our studies show that during the first months after the accident, virtually all ^{137}Cs deposition in the entire contaminated area was attributed to the leaf layer (O1) of the forest litter (Table 3).

Table 1
Ecological and radiological characteristics of the investigated key sites.

Key site location in relation to ChNPP	Soil	Landscape type	Phytocenosis	^{137}Cs deposition MBq/m^2
Tula Oblast, RF				
550 km NE	Dark-gray, heavy loam forest soil	Eluvial	Oak forest with grassy understory	0.37
Bryansk Oblast, RF				
220 km SSE	Soddy-podzolic sandy soil	Eluvial	Pine forest with moss understory	9.18
Kiev Oblast, 30-km ChNPP exclusion zone, Ukraine				
26–28 km S	Podzolic, iron-illuvial sandy soil	Eluvial	Mixed, pine-broad leaved forest	0.24
6.5 km SE	Secondary-podzolized, sandy soil	Transit-accumulative	Pine forest with grass-moss understory	2.90
6 km W	Weakly podzolic, low differentiated sandy soil	Eluvial	Mixed, pine-broad leaved forest	44.73

Download English Version:

https://daneshyari.com/en/article/4457405

Download Persian Version:

https://daneshyari.com/article/4457405

Daneshyari.com